College Biology

Chapter Summaries, Learning Execises with Answers, and Key Terminology

A Supplement to *College Biology* (Volumes 1 - 3)

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Summaries, Exercises, Answers

Note on page numbering: Page numbers, which may have gaps, are the same as in the original textbook, making for easy reference.

CHAPTER SUMMARY

1.1 The Science of Biology

Biology is the science that studies living organisms and their interactions with one another and their environments. Science attempts to describe and understand the nature of the universe in whole or in part by rational means. Science has many fields; those fields related to the physical world and its phenomena are considered natural sciences.

Science can be basic or applied. The main goal of basic science is to expand knowledge without any expectation of short-term practical application of that knowledge. The primary goal of applied research, however, is to solve practical problems.

Two types of logical reasoning are used in science. Inductive reasoning uses particular results to produce general scientific principles. Deductive reasoning is a form of logical thinking that predicts results by applying general principles. The common thread throughout scientific research is the use of the scientific method, a step-based process that consists of making observations, defining a problem, posing hypotheses, testing these hypotheses, and drawing one or more conclusions. The testing uses proper controls. Scientists present their results in peer-reviewed scientific papers published in scientific journals. A scientific research paper consists of several well-defined sections: introduction, materials and methods, results, and, finally, a concluding discussion. Review papers summarize the research done in a particular field over a period of time.

1.2 Themes and Concepts of Biology

Biology is the science of life. All living organisms share several key properties such as order, sensitivity or response to stimuli, reproduction, growth and development, regulation, homeostasis, and energy processing. Living things are highly organized parts of a hierarchy that includes atoms, molecules, organelles, cells, tissues, organs, and organ systems. Organisms, in turn, are grouped as populations, communities, ecosystems, and the biosphere. The great diversity of life today evolved from less-diverse ancestral organisms over billions of years. A diagram called a phylogenetic tree can be used to show evolutionary relationships among organisms.

Biology is very broad and includes many branches and subdisciplines. Examples include molecular biology, microbiology, neurobiology, zoology, and botany, among others.

ART CONNECTION QUESTIONS

1. **Figure 1.6** In the example below, the scientific method is used to solve an everyday problem. Order the scientific method steps (numbered items) with the process of solving the everyday problem (lettered items). Based on the results of the experiment, is the hypothesis correct? If it is incorrect, propose some alternative hypotheses.

1. Observation
2. Question
3. Hypothesis (answer)
4. Prediction
5. Experiment
6. Result

a. There is something wrong with the electrical outlet.
b. If something is wrong with the outlet, my coffeemaker also won't work when plugged into it.
c. My toaster doesn't toast my bread.
d. I plug my coffee maker into the outlet.
e. My coffeemaker works.
f. Why doesn't my toaster work work?

2. **Figure 1.7** Decide if each of the following is an example of inductive or deductive reasoning.

1. All flying birds and insects have wings. Birds and insects flap their wings as they move through the air. Therefore, wings enable flight.
2. Insects generally survive mild winters better than harsh ones. Therefore, insect pests will become more problematic if global temperatures increase.
3. Chromosomes, the carriers of DNA, separate into daughter cells during cell division. Therefore, DNA is the genetic material.
4. Animals as diverse as humans, insects, and wolves all exhibit social behavior. Therefore, social behavior must have an evolutionary advantage.

3. **Figure 1.16** Which of the following statements is false?

a. Tissues exist within organs which exist within organ systems.
b. Communities exist within populations which exist within ecosystems.

c. Organelles exist within cells which exist within tissues.
d. Communities exist within ecosystems which exist in the biosphere.

REVIEW QUESTIONS

4. The first forms of life on Earth were _____.
a. plants
b. microorganisms
c. birds
d. dinosaurs

5. A suggested and testable explanation for an event is called a _____.
a. hypothesis
b. variable
c. theory
d. control

6. Which of the following sciences is not considered a natural science?
a. biology
b. astronomy
c. physics
d. computer science

7. The type of logical thinking that uses related observations to arrive at a general conclusion is called _____.
a. deductive reasoning
b. the scientific method
c. hypothesis-based science
d. inductive reasoning

8. The process of _____ helps to ensure that a scientist's research is original, significant, logical, and thorough.
a. publication
b. public speaking
c. peer review
d. the scientific method

9. A person notices that her houseplants that are regularly exposed to music seem to grow more quickly than those in rooms with no music. As a result, she determines that plants grow better when exposed to music. This example most closely resembles which type of reasoning?
a. inductive reasoning
b. deductive reasoning
c. neither, because no hypothesis was made
d. both inductive and deductive reasoning

10. The smallest unit of biological structure that meets the functional requirements of "living" is the _____.
a. organ
b. organelle
c. cell
d. macromolecule

11. Viruses are not considered living because they _____.
a. are not made of cells
b. lack cell nuclei
c. do not contain DNA or RNA
d. cannot reproduce

12. The presence of a membrane-enclosed nucleus is a characteristic of _____.
a. prokaryotic cells
b. eukaryotic cells
c. living organisms
d. bacteria

13. A group of individuals of the same species living in the same area is called a(n) _____.
a. family
b. community
c. population
d. ecosystem

14. Which of the following sequences represents the hierarchy of biological organization from the most inclusive to the least complex level?
a. organelle, tissue, biosphere, ecosystem, population
b. organism, organ, tissue, organelle, molecule
c. organism, community, biosphere, molecule, tissue, organ
d. biosphere, ecosystem, community, population, organism

15. Where in a phylogenetic tree would you expect to find the organism that had evolved most recently?
a. at the base
b. within the branches
c. at the nodes
d. at the branch tips

CRITICAL THINKING QUESTIONS

16. Although the scientific method is used by most of the sciences, it can also be applied to everyday situations. Think about a problem that you may have at home, at school, or with your car, and apply the scientific method to solve it.

17. Give an example of how applied science has had a direct effect on your daily life.

18. Name two topics that are likely to be studied by biologists, and two areas of scientific study that would fall outside the realm of biology.

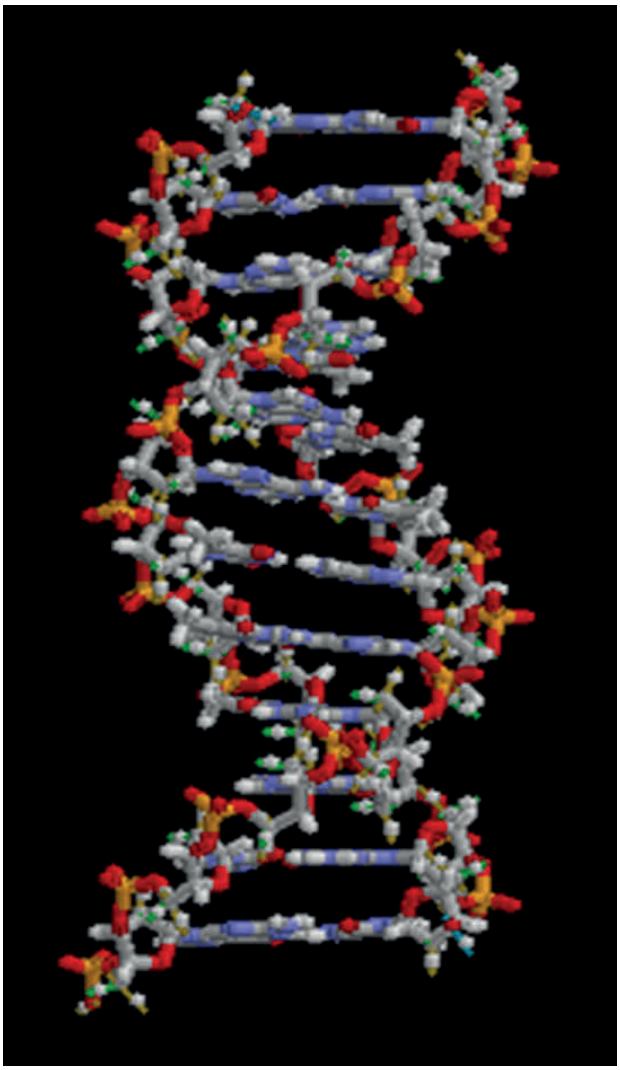
19. Thinking about the topic of cancer, write a basic science question and an applied science question that a researcher interested in this topic might ask

20. Select two items that biologists agree are necessary in order to consider an organism "alive." For each, give an example of a non-living object that otherwise fits the definition of "alive,"

21. Consider the levels of organization of the biological world, and place each of these items in order from smallest level of organization to most encompassing: skin cell, elephant, water molecule, planet Earth, tropical rainforest, hydrogen atom, wolf pack, liver.

22. You go for a long walk on a hot day. Give an example of a way in which homeostasis keeps your body healthy.

23. Using examples, explain how biology can be studied from a microscopic approach to a global approach.



CHAPTER SUMMARY

2.1 Atoms, Isotopes, Ions, and Molecules: The Building Blocks

Matter is anything that occupies space and has mass. It is made up of elements. All of the 92 elements that occur naturally have unique qualities that allow them to combine in various ways to create molecules, which in turn combine to form cells, tissues, organ systems, and organisms. Atoms, which consist of protons, neutrons, and electrons, are the smallest units of an element that retain all of the

properties of that element. Electrons can be transferred, shared, or cause charge disparities between atoms to create bonds, including ionic, covalent, and hydrogen bonds, as well as van der Waals interactions.

2.2 Water

Water has many properties that are critical to maintaining life. It is a polar molecule, allowing for the formation of hydrogen bonds. Hydrogen bonds allow ions and other polar molecules to dissolve in water. Therefore, water is an excellent solvent. The hydrogen bonds between water molecules cause the water to have a high heat capacity, meaning it takes a lot of added heat to raise its temperature. As the temperature rises, the hydrogen bonds between water continually break and form anew. This allows for the overall temperature to remain stable, although energy is added to the system. Water also exhibits a high heat of vaporization, which is key to how organisms cool themselves by the evaporation of sweat. Water's cohesive forces allow for the property of surface tension, whereas its adhesive properties are seen as water rises inside capillary tubes. The pH value is a measure of hydrogen ion concentration in a solution and is one of many chemical characteristics that is highly regulated in living organisms through homeostasis. Acids and bases can change pH values, but buffers tend to moderate the changes they cause. These properties of water are intimately connected to the biochemical and physical processes performed by living organisms, and life would be very different if these properties were altered, if it could exist at all.

2.3 Carbon

The unique properties of carbon make it a central part of biological molecules. Carbon binds to oxygen, hydrogen, and nitrogen covalently to form the many molecules important for cellular function. Carbon has four electrons in its outermost shell and can form four bonds. Carbon and hydrogen can form hydrocarbon chains or rings. Functional groups are groups of atoms that confer specific properties to hydrocarbon (or substituted hydrocarbon) chains or rings that define their overall chemical characteristics and function.

ART CONNECTION QUESTIONS

1. **Figure 2.3** How many neutrons do carbon-12 and carbon-13 have, respectively?

2. **Figure 2.7** An atom may give, take, or share electrons with another atom to achieve a full valence shell, the most stable electron configuration. Looking at this figure, how many electrons do elements in group 1 need to lose in order to achieve a stable electron configuration? How many electrons do elements in groups 14 and 17 need to gain to achieve a stable configuration?

3. **Figure 2.24** Which of the following statements is false?

a. Molecules with the formulas CH_3CH_2COOH and $C_3H_6O_2$ could be structural isomers.
b. Molecules must have a double bond to be *cis-trans* isomers.
c. To be enantiomers, a molecule must have at least three different atoms or groups connected to a central carbon.
d. To be enantiomers, a molecule must have at least four different atoms or groups connected to a central carbon.

REVIEW QUESTIONS

4. If xenon has an atomic number of 54 and a mass number of 108, how many neutrons does it have?

a. 54
b. 27
c. 100
d. 108

5. Atoms that vary in the number of neutrons found in their nuclei are called _____.

a. ions
b. neutrons
c. neutral atoms
d. isotopes

6. Potassium has an atomic number of 19. What is its electron configuration?

a. shells 1 and 2 are full, and shell 3 has nine electrons
b. shells 1, 2 and 3 are full and shell 4 has three electrons
c. shells 1, 2 and 3 are full and shell 4 has one electron
d. shells 1, 2 and 3 are full and no other electrons are present

7. Which type of bond represents a weak chemical bond?

a. hydrogen bond
b. atomic bond
c. covalent bond
d. nonpolar covalent bond

8. Which of the following statements is not true?

a. Water is polar.
b. Water stabilizes temperature.
c. Water is essential for life.
d. Water is the most abundant molecule in the Earth's atmosphere.

9. When acids are added to a solution, the pH should _____.

a. decrease
b. increase
c. stay the same
d. cannot tell without testing

10. A molecule that binds up excess hydrogen ions in a solution is called a(n) _____.

a. acid
b. isotope
c. base
d. donator

11. Which of the following statements is true?

a. Acids and bases cannot mix together.
b. Acids and bases will neutralize each other.
c. Acids, but not bases, can change the pH of a solution.
d. Acids donate hydroxide ions (OH^-); bases donate hydrogen ions (H^+).

12. Each carbon molecule can bond with as many as_____ other atom(s) or molecule(s).

a. one
b. two
c. six
d. four

13. Which of the following is not a functional group that can bond with carbon?

a. sodium
b. hydroxyl
c. phosphate
d. carbonyl

CRITICAL THINKING QUESTIONS

14. What makes ionic bonds different from covalent bonds?

15. Why are hydrogen bonds and van der Waals interactions necessary for cells?

16. Discuss how buffers help prevent drastic swings in pH.

17. Why can some insects walk on water?

18. What property of carbon makes it essential for organic life?

19. Compare and contrast saturated and unsaturated triglycerides.

CHAPTER SUMMARY

3.1 Synthesis of Biological Macromolecules

Proteins, carbohydrates, nucleic acids, and lipids are the four major classes of biological macromolecules—large molecules necessary for life that are built from smaller organic molecules. Macromolecules are made up of single units known as monomers that are joined by covalent bonds to form larger polymers. The polymer is more than the sum of its parts: it acquires new characteristics, and leads to an osmotic pressure that is much lower than that formed by its ingredients; this is an important advantage in the maintenance of cellular osmotic conditions. A monomer joins with another monomer with the release of a water molecule, leading to the formation of a covalent bond. These types of reactions are known as dehydration or condensation reactions. When polymers are broken down into smaller units (monomers), a molecule of water is used for each bond broken by these reactions; such reactions are known as hydrolysis reactions. Dehydration and hydrolysis reactions are similar for all macromolecules, but each monomer and polymer reaction is specific to its class. Dehydration reactions typically require an investment of energy for new bond formation, while hydrolysis reactions typically release energy by breaking bonds.

3.2 Carbohydrates

Carbohydrates are a group of macromolecules that are a vital energy source for the cell and provide structural support to plant cells, fungi, and all of the arthropods that include lobsters, crabs, shrimp, insects, and spiders. Carbohydrates are classified as monosaccharides, disaccharides, and polysaccharides depending on the number of monomers in the molecule. Monosaccharides are linked by glycosidic bonds that are formed as a result of dehydration reactions, forming disaccharides and polysaccharides with the elimination of a water molecule for each bond formed. Glucose, galactose, and fructose are common monosaccharides, whereas common disaccharides include lactose, maltose, and sucrose. Starch and glycogen, examples of polysaccharides, are the storage forms of glucose in plants and animals, respectively. The long polysaccharide chains may be branched or unbranched. Cellulose is an example of an unbranched polysaccharide, whereas amylopectin, a constituent of starch, is a highly branched molecule. Storage of glucose, in the form of polymers like starch of glycogen, makes it slightly less accessible for metabolism; however, this prevents it from leaking out of the cell or creating a high osmotic pressure that could cause excessive water uptake by the cell.

3.3 Lipids

Lipids are a class of macromolecules that are nonpolar and hydrophobic in nature. Major types include fats and oils, waxes, phospholipids, and steroids. Fats are a stored form of energy and are also known as triacylglycerols or triglycerides. Fats are made up of fatty acids and either glycerol or sphingosine. Fatty acids may be unsaturated or saturated, depending on the presence or absence of double bonds in the hydrocarbon chain. If only single bonds are present, they are known as saturated fatty acids. Unsaturated fatty acids may have one or more double bonds in the hydrocarbon chain. Phospholipids make up the matrix of membranes. They have a glycerol or sphingosine backbone to which two fatty acid chains and a phosphate-containing group are attached. Steroids are another class of lipids. Their basic structure has four fused carbon rings. Cholesterol is a type of steroid and is an important constituent of the plasma membrane, where it helps to maintain the fluid nature of the membrane. It is also the precursor of steroid hormones such as testosterone.

3.4 Proteins

Proteins are a class of macromolecules that perform a diverse range of functions for the cell. They help in metabolism by providing structural support and by acting as enzymes, carriers, or hormones. The building blocks of proteins (monomers) are amino acids. Each amino acid has a central carbon that is linked to an amino group, a carboxyl group, a hydrogen atom, and an R group or side chain. There are 20 commonly occurring amino acids, each of which differs in the R group. Each amino acid is linked to its neighbors by a peptide bond. A long chain of amino acids is known as a polypeptide.

Proteins are organized at four levels: primary, secondary, tertiary, and (optional) quaternary. The primary structure is the unique sequence of amino acids. The local folding of the polypeptide to form

structures such as the α helix and β-pleated sheet constitutes the secondary structure. The overall three-dimensional structure is the tertiary structure. When two or more polypeptides combine to form the complete protein structure, the configuration is known as the quaternary structure of a protein. Protein shape and function are intricately linked; any change in shape caused by changes in temperature or pH may lead to protein denaturation and a loss in function.

3.5 Nucleic Acids

Nucleic acids are molecules made up of nucleotides that direct cellular activities such as cell division and protein synthesis. Each nucleotide is made up of a pentose sugar, a nitrogenous base, and a phosphate group. There are two types of nucleic acids: DNA and RNA. DNA carries the genetic blueprint of the cell and is passed on from parents to offspring (in the form of chromosomes). It has a double-helical structure with the two strands running in opposite directions, connected by hydrogen bonds, and complementary to each other. RNA is single-stranded and is made of a pentose sugar (ribose), a nitrogenous base, and a phosphate group. RNA is involved in protein synthesis and its regulation. Messenger RNA (mRNA) is copied from the DNA, is exported from the nucleus to the cytoplasm, and contains information for the construction of proteins. Ribosomal RNA (rRNA) is a part of the ribosomes at the site of protein synthesis, whereas transfer RNA (tRNA) carries the amino acid to the site of protein synthesis. microRNA regulates the use of mRNA for protein synthesis.

ART CONNECTION QUESTIONS

1. **Figure 3.5** What kind of sugars are these, aldose or ketose?

2. **Figure 3.23** Which categories of amino acid would you expect to find on the surface of a soluble protein, and which would you expect to find in the interior? What distribution of amino acids would you expect to find in a protein embedded in a lipid bilayer?

3. **Figure 3.33** A mutation occurs, and cytosine is replaced with adenine. What impact do you think this will have on the DNA structure?

REVIEW QUESTIONS

4. Dehydration synthesis leads to formation of

a. monomers
b. polymers
c. water and polymers
d. none of the above

5. During the breakdown of polymers, which of the following reactions takes place?

a. hydrolysis
b. dehydration
c. condensation
d. covalent bond

6. An example of a monosaccharide is _____.

a. fructose
b. glucose
c. galactose
d. all of the above

7. Cellulose and starch are examples of:

a. monosaccharides
b. disaccharides
c. lipids
d. polysaccharides

8. Plant cell walls contain which of the following in abundance?

a. starch
b. cellulose
c. glycogen
d. lactose

9. Lactose is a disaccharide formed by the formation of a _____ bond between glucose and _____.

a. glycosidic; lactose
b. glycosidic; galactose
c. hydrogen; sucrose
d. hydrogen; fructose

10. Saturated fats have all of the following characteristics except:

a. they are solid at room temperature
b. they have single bonds within the carbon chain
c. they are usually obtained from animal sources
d. they tend to dissolve in water easily

11. Phospholipids are important components of _____.

a. the plasma membrane of animal cells
b. the ring structure of steroids
c. the waxy covering on leaves
d. the double bond in hydrocarbon chains

12. The monomers that make up proteins are called _____.

a. nucleotides
b. disaccharides
c. amino acids
d. chaperones

13. The α helix and the β-pleated sheet are part of which protein structure?

a. primary
b. secondary
c. tertiary
d. quaternary

14. A nucleotide of DNA may contain _____.

a. ribose, uracil, and a phosphate group
b. deoxyribose, uracil, and a phosphate group
c. deoxyribose, thymine, and a phosphate group
d. ribose, thymine, and a phosphate group

15. The building blocks of nucleic acids are _____.

a. sugars
b. nitrogenous bases
c. peptides
d. nucleotides

CRITICAL THINKING QUESTIONS

16. Why are biological macromolecules considered organic?

17. What role do electrons play in dehydration synthesis and hydrolysis?

18. Describe the similarities and differences between glycogen and starch.

19. Why is it impossible for humans to digest food that contains cellulose?

20. Explain at least three functions that lipids serve in plants and/or animals.

21. Why have trans fats been banned from some restaurants? How are they created?

22. Explain what happens if even one amino acid is substituted for another in a polypeptide chain. Provide a specific example.

23. Describe the differences in the four protein structures.

24. What are the structural differences between RNA and DNA?

25. What are the four types of RNA and how do they function?

CHAPTER SUMMARY

4.1 Studying Cells

A cell is the smallest unit of life. Most cells are so tiny that they cannot be seen with the naked eye. Therefore, scientists use microscopes to study cells. Electron microscopes provide higher magnification, higher resolution, and more detail than light microscopes. The unified cell theory states that all organisms are composed of one or more cells, the cell is the basic unit of life, and new cells arise from existing cells.

4.2 Prokaryotic Cells

Prokaryotes are predominantly single-celled organisms of the domains Bacteria and Archaea. All prokaryotes have plasma membranes, cytoplasm, ribosomes, and DNA that is not membrane-bound. Most have peptidoglycan cell walls and many have polysaccharide capsules. Prokaryotic cells range in diameter from 0.1 to 5.0 μm.

As a cell increases in size, its surface area-to-volume ratio decreases. If the cell grows too large, the plasma membrane will not have sufficient surface area to support the rate of diffusion required for the increased volume.

4.3 Eukaryotic Cells

Like a prokaryotic cell, a eukaryotic cell has a plasma membrane, cytoplasm, and ribosomes, but a eukaryotic cell is typically larger than a prokaryotic cell, has a true nucleus (meaning its DNA is surrounded by a membrane), and has other membrane-bound organelles that allow for compartmentalization of functions. The plasma membrane is a phospholipid bilayer embedded with proteins. The nucleus's nucleolus is the site of ribosome assembly. Ribosomes are either found in the cytoplasm or attached to the cytoplasmic side of the plasma membrane or endoplasmic reticulum. They perform protein synthesis. Mitochondria participate in cellular respiration; they are responsible for the majority of ATP produced in the cell. Peroxisomes hydrolyze fatty acids, amino acids, and some toxins. Vesicles and vacuoles are storage and transport compartments. In plant cells, vacuoles also help break down macromolecules.

Animal cells also have a centrosome and lysosomes. The centrosome has two bodies perpendicular to each other, the centrioles, and has an unknown purpose in cell division. Lysosomes are the digestive organelles of animal cells.

Plant cells and plant-like cells each have a cell wall, chloroplasts, and a central vacuole. The plant cell wall, whose primary component is cellulose, protects the cell, provides structural support, and gives shape to the cell. Photosynthesis takes place in chloroplasts. The central vacuole can expand without having to produce more cytoplasm.

4.4 The Endomembrane System and Proteins

The endomembrane system includes the nuclear envelope, lysosomes, vesicles, the ER, and Golgi apparatus, as well as the plasma membrane. These cellular components work together to modify, package, tag, and transport proteins and lipids that form the membranes.

The RER modifies proteins and synthesizes phospholipids used in cell membranes. The SER synthesizes carbohydrates, lipids, and steroid hormones; engages in the detoxification of medications and poisons; and stores calcium ions. Sorting, tagging, packaging, and distribution of lipids and proteins take place in the Golgi apparatus. Lysosomes are created by the budding of the membranes of the RER and Golgi. Lysosomes digest macromolecules, recycle worn-out organelles, and destroy pathogens.

4.5 The Cytoskeleton

The cytoskeleton has three different types of protein elements. From narrowest to widest, they are the microfilaments (actin filaments), intermediate filaments, and microtubules. Microfilaments are often associated with myosin. They provide rigidity and shape to the cell and facilitate cellular movements. Intermediate filaments bear tension and anchor the nucleus and other organelles in place. Microtubules help the cell resist compression, serve as tracks for motor proteins that move vesicles through the cell,

and pull replicated chromosomes to opposite ends of a dividing cell. They are also the structural element of centrioles, flagella, and cilia.

4.6 Connections between Cells and Cellular Activities

Animal cells communicate via their extracellular matrices and are connected to each other via tight junctions, desmosomes, and gap junctions. Plant cells are connected and communicate with each other via plasmodesmata.

When protein receptors on the surface of the plasma membrane of an animal cell bind to a substance in the extracellular matrix, a chain of reactions begins that changes activities taking place within the cell. Plasmodesmata are channels between adjacent plant cells, while gap junctions are channels between adjacent animal cells. However, their structures are quite different. A tight junction is a watertight seal between two adjacent cells, while a desmosome acts like a spot weld.

ART CONNECTION QUESTIONS

1. **Figure 4.7** Prokaryotic cells are much smaller than eukaryotic cells. What advantages might small cell size confer on a cell? What advantages might large cell size have?

2. **Figure 4.8** If the nucleolus were not able to carry out its function, what other cellular organelles would be affected?

3. **Figure 4.18** If a peripheral membrane protein were synthesized in the lumen (inside) of the ER, would it end up on the inside or outside of the plasma membrane?

REVIEW QUESTIONS

4. When viewing a specimen through a light microscope, scientists use _____ to distinguish the individual components of cells.

a. a beam of electrons
b. radioactive isotopes
c. special stains
d. high temperatures

5. The _____ is the basic unit of life.

a. organism
b. cell
c. tissue
d. organ

6. Prokaryotes depend on _____ to obtain some materials and to get rid of wastes.

a. ribosomes
b. flagella
c. cell division
d. diffusion

7. Bacteria that lack fimbrae are less likely to _____.

a. adhere to cell surfaces
b. swim through bodily fluids
c. synthesize proteins
d. retain the ability to divide

8. Which of the following is surrounded by two phospholipid bilayers?

a. the ribosomes
b. the vesicles
c. the cytoplasm
d. the nucleoplasm

9. Peroxisomes got their name because hydrogen peroxide is:

a. used in their detoxification reactions
b. produced during their oxidation reactions
c. incorporated into their membranes
d. a cofactor for the organelles' enzymes

10. In plant cells, the function of the lysosomes is carried out by _____.

a. vacuoles
b. peroxisomes
c. ribosomes
d. nuclei

11. Which of the following is found both in eukaryotic and prokaryotic cells?

a. nucleus
b. mitochondrion
c. vacuole
d. ribosomes

12. Which of the following is not a component of the endomembrane system?

a. mitochondrion
b. Golgi apparatus
c. endoplasmic reticulum
d. lysosome

13. The process by which a cell engulfs a foreign particle is known as:

a. endosymbiosis
b. phagocytosis
c. hydrolysis
d. membrane synthesis

14. Which of the following is most likely to have the greatest concentration of smooth endoplasmic reticulum?

a. a cell that secretes enzymes

b. a cell that destroys pathogens
c. a cell that makes steroid hormones
d. a cell that engages in photosynthesis

15. Which of the following sequences correctly lists in order the steps involved in the incorporation of a proteinaceous molecule within a cell?

a. synthesis of the protein on the ribosome; modification in the Golgi apparatus; packaging in the endoplasmic reticulum; tagging in the vesicle
b. synthesis of the protein on the lysosome; tagging in the Golgi; packaging in the vesicle; distribution in the endoplasmic reticulum
c. synthesis of the protein on the ribosome; modification in the endoplasmic reticulum; tagging in the Golgi; distribution via the vesicle
d. synthesis of the protein on the lysosome; packaging in the vesicle; distribution via the Golgi; tagging in the endoplasmic reticulum

16. Which of the following have the ability to disassemble and reform quickly?

a. microfilaments and intermediate filaments
b. microfilaments and microtubules
c. intermediate filaments and microtubules
d. only intermediate filaments

17. Which of the following do not play a role in intracellular movement?

a. microfilaments and intermediate filaments
b. microfilaments and microtubules
c. intermediate filaments and microtubules
d. only intermediate filaments

18. Which of the following are found only in plant cells?

a. gap junctions
b. desmosomes
c. plasmodesmata
d. tight junctions

19. The key components of desmosomes are cadherins and _____.

a. actin
b. microfilaments
c. intermediate filaments
d. microtubules

CRITICAL THINKING QUESTIONS

20. In your everyday life, you have probably noticed that certain instruments are ideal for certain situations. For example, you would use a spoon rather than a fork to eat soup because a spoon is shaped for scooping, while soup would slip between the tines of a fork. The use of ideal instruments also applies in science. In what situation(s) would the use of a light microscope be ideal, and why?

21. In what situation(s) would the use of a scanning electron microscope be ideal, and why?

22. In what situation(s) would a transmission electron microscope be ideal, and why?

23. What are the advantages and disadvantages of each of these types of microscopes?

24. Antibiotics are medicines that are used to fight bacterial infections. These medicines kill prokaryotic cells without harming human cells. What part or parts of the bacterial cell do you think antibiotics target? Why?

25. Explain why not all microbes are harmful.

26. You already know that ribosomes are abundant in red blood cells. In what other cells of the body would you find them in great abundance? Why?

27. What are the structural and functional similarities and differences between mitochondria and chloroplasts?

28. In the context of cell biology, what do we mean by form follows function? What are at least two examples of this concept?

29. In your opinion, is the nuclear membrane part of the endomembrane system? Why or why not? Defend your answer.

30. What are the similarities and differences between the structures of centrioles and flagella?

31. How do cilia and flagella differ?

32. How does the structure of a plasmodesma differ from that of a gap junction?

33. Explain how the extracellular matrix functions.

CHAPTER SUMMARY

5.1 Components and Structure

The modern understanding of the plasma membrane is referred to as the fluid mosaic model. The plasma membrane is composed of a bilayer of phospholipids, with their hydrophobic, fatty acid tails in contact with each other. The landscape of the membrane is studded with proteins, some of which span the membrane. Some of these proteins serve to transport materials into or out of the cell. Carbohydrates are attached to some of the proteins and lipids on the outward-facing surface of the membrane, forming complexes that function to identify the cell to other cells. The fluid nature of the membrane is due to temperature, the configuration of the fatty acid tails (some kinked by double bonds), the presence of cholesterol embedded in the membrane, and the mosaic nature of the proteins and protein-carbohydrate combinations, which are not firmly fixed in place. Plasma membranes enclose and define the borders of cells, but rather than being a static bag, they are dynamic and constantly in flux.

5.2 Passive Transport

The passive forms of transport, diffusion and osmosis, move materials of small molecular weight across membranes. Substances diffuse from areas of high concentration to areas of lower concentration, and this process continues until the substance is evenly distributed in a system. In solutions containing more than one substance, each type of molecule diffuses according to its own concentration gradient, independent of the diffusion of other substances. Many factors can affect the rate of diffusion, including concentration gradient, size of the particles that are diffusing, temperature of the system, and so on.

In living systems, diffusion of substances into and out of cells is mediated by the plasma membrane. Some materials diffuse readily through the membrane, but others are hindered, and their passage is made possible by specialized proteins, such as channels and transporters. The chemistry of living things occurs in aqueous solutions, and balancing the concentrations of those solutions is an ongoing problem. In living systems, diffusion of some substances would be slow or difficult without membrane proteins that facilitate transport.

5.3 Active Transport

The combined gradient that affects an ion includes its concentration gradient and its electrical gradient. A positive ion, for example, might tend to diffuse into a new area, down its concentration gradient, but if it is diffusing into an area of net positive charge, its diffusion will be hampered by its electrical gradient. When dealing with ions in aqueous solutions, a combination of the electrochemical and concentration gradients, rather than just the concentration gradient alone, must be considered. Living cells need certain substances that exist inside the cell in concentrations greater than they exist in the extracellular space. Moving substances up their electrochemical gradients requires energy from the cell. Active transport uses energy stored in ATP to fuel this transport. Active transport of small molecular-sized materials uses integral proteins in the cell membrane to move the materials: These proteins are analogous to pumps. Some pumps, which carry out primary active transport, couple directly with ATP to drive their action. In co-transport (or secondary active transport), energy from primary transport can be used to move another substance into the cell and up its concentration gradient.

5.4 Bulk Transport

Active transport methods require the direct use of ATP to fuel the transport. Large particles, such as macromolecules, parts of cells, or whole cells, can be engulfed by other cells in a process called phagocytosis. In phagocytosis, a portion of the membrane invaginates and flows around the particle, eventually pinching off and leaving the particle entirely enclosed by an envelope of plasma membrane. Vesicle contents are broken down by the cell, with the particles either used as food or dispatched. Pinocytosis is a similar process on a smaller scale. The plasma membrane invaginates and pinches off, producing a small envelope of fluid from outside the cell. Pinocytosis imports substances that the cell needs from the extracellular fluid. The cell expels waste in a similar but reverse manner: it pushes a membranous vacuole to the plasma membrane, allowing the vacuole to fuse with the membrane and incorporate itself into the membrane structure, releasing its contents to the exterior.

ART CONNECTION QUESTIONS

1. **Figure 5.12** A doctor injects a patient with what the doctor thinks is an isotonic saline solution. The patient dies, and an autopsy reveals that many red blood cells have been destroyed. Do you think the solution the doctor injected was really isotonic?

2. **Figure 5.16** Injection of a potassium solution into a person's blood is lethal; this is used in capital punishment and euthanasia. Why do you think a potassium solution injection is lethal?

3. **Figure 5.19** If the pH outside the cell decreases, would you expect the amount of amino acids transported into the cell to increase or decrease?

REVIEW QUESTIONS

4. Which plasma membrane component can be either found on its surface or embedded in the membrane structure?

a. protein
b. cholesterol
c. carbohydrate
d. phospholipid

5. Which characteristic of a phospholipid contributes to the fluidity of the membrane?

a. its head
b. cholesterol
c. a saturated fatty acid tail
d. double bonds in the fatty acid tail

6. What is the primary function of carbohydrates attached to the exterior of cell membranes?

a. identification of the cell
b. flexibility of the membrane
c. strengthening the membrane
d. channels through membrane

7. Water moves via osmosis _____.

a. throughout the cytoplasm
b. from an area with a high concentration of other solutes to a lower one
c. from an area with a high concentration of water to one of lower concentration
d. from an area with a low concentration of water to one of higher concentration

8. The principal force driving movement in diffusion is the _____.

a. temperature
b. particle size
c. concentration gradient
d. membrane surface area

9. What problem is faced by organisms that live in fresh water?

a. Their bodies tend to take in too much water.
b. They have no way of controlling their tonicity.
c. Only salt water poses problems for animals that live in it.
d. Their bodies tend to lose too much water to their environment.

10. Active transport must function continuously because _____.

a. plasma membranes wear out
b. not all membranes are amphiphilic
c. facilitated transport opposes active transport
d. diffusion is constantly moving solutes in opposite directions

11. How does the sodium-potassium pump make the interior of the cell negatively charged?

a. by expelling anions
b. by pulling in anions
c. by expelling more cations than are taken in
d. by taking in and expelling an equal number of cations

12. What is the combination of an electrical gradient and a concentration gradient called?

a. potential gradient
b. electrical potential
c. concentration potential
d. electrochemical gradient

13. What happens to the membrane of a vesicle after exocytosis?

a. It leaves the cell.
b. It is disassembled by the cell.
c. It fuses with and becomes part of the plasma membrane.
d. It is used again in another exocytosis event.

14. Which transport mechanism can bring whole cells into a cell?

a. pinocytosis
b. phagocytosis
c. facilitated transport
d. primary active transport

15. In what important way does receptor-mediated endocytosis differ from phagocytosis?

a. It transports only small amounts of fluid.
b. It does not involve the pinching off of membrane.
c. It brings in only a specifically targeted substance.
d. It brings substances into the cell, while phagocytosis removes substances.

CRITICAL THINKING QUESTIONS

16. Why is it advantageous for the cell membrane to be fluid in nature?

17. Why do phospholipids tend to spontaneously orient themselves into something resembling a membrane?

18. Discuss why the following affect the rate of diffusion: molecular size, temperature, solution density, and the distance that must be traveled.

19. Why does water move through a membrane?

20. Both of the regular intravenous solutions administered in medicine, normal saline and lactated Ringer's solution, are isotonic. Why is this important?

21. Where does the cell get energy for active transport processes?

22. How does the sodium-potassium pump contribute to the net negative charge of the interior of the cell?

23. Why is it important that there are different types of proteins in plasma membranes for the transport of materials into and out of a cell?

24. Why do ions have a difficult time getting through plasma membranes despite their small size?

CHAPTER SUMMARY

6.1 Energy and Metabolism

Cells perform the functions of life through various chemical reactions. A cell's metabolism refers to the chemical reactions that take place within it. There are metabolic reactions that involve the breaking down of complex chemicals into simpler ones, such as the breakdown of large macromolecules. This process is referred to as catabolism, and such reactions are associated with a release of energy. On the other end of the spectrum, anabolism refers to metabolic processes that build complex molecules out of simpler ones, such as the synthesis of macromolecules. Anabolic processes require energy. Glucose synthesis and glucose breakdown are examples of anabolic and catabolic pathways, respectively.

6.2 Potential, Kinetic, Free, and Activation Energy

Energy comes in many different forms. Objects in motion do physical work, and kinetic energy is the energy of objects in motion. Objects that are not in motion may have the potential to do work, and thus, have potential energy. Molecules also have potential energy because the breaking of molecular bonds has the potential to release energy. Living cells depend on the harvesting of potential energy from molecular bonds to perform work. Free energy is a measure of energy that is available to do work. The free energy of a system changes during energy transfers such as chemical reactions, and this change is referred to as ΔG.

The ΔG of a reaction can be negative or positive, meaning that the reaction releases energy or consumes energy, respectively. A reaction with a negative ΔG that gives off energy is called an exergonic reaction. One with a positive ΔG that requires energy input is called an endergonic reaction. Exergonic reactions are said to be spontaneous, because their products have less energy than their reactants. The products of endergonic reactions have a higher energy state than the reactants, and so these are nonspontaneous reactions. However, all reactions (including spontaneous $-\Delta G$ reactions) require an initial input of energy in order to reach the transition state, at which they'll proceed. This initial input of energy is called the activation energy.

6.3 The Laws of Thermodynamics

In studying energy, scientists use the term "system" to refer to the matter and its environment involved in energy transfers. Everything outside of the system is called the surroundings. Single cells are biological systems. Systems can be thought of as having a certain amount of order. It takes energy to make a system more ordered. The more ordered a system is, the lower its entropy. Entropy is a measure of the disorder of a system. As a system becomes more disordered, the lower its energy and the higher its entropy become.

A series of laws, called the laws of thermodynamics, describe the properties and processes of energy transfer. The first law states that the total amount of energy in the universe is constant. This means that energy can't be created or destroyed, only transferred or transformed. The second law of thermodynamics states that every energy transfer involves some loss of energy in an unusable form, such as heat energy, resulting in a more disordered system. In other words, no energy transfer is completely efficient and tends toward disorder.

6.4 ATP: Adenosine Triphosphate

ATP is the primary energy-supplying molecule for living cells. ATP is made up of a nucleotide, a five-carbon sugar, and three phosphate groups. The bonds that connect the phosphates (phosphoanhydride bonds) have high-energy content. The energy released from the hydrolysis of ATP into ADP + P_i is used to perform cellular work. Cells use ATP to perform work by coupling the exergonic reaction of ATP hydrolysis with endergonic reactions. ATP donates its phosphate group to another molecule via a process known as phosphorylation. The phosphorylated molecule is at a higher-energy state and is less stable than its unphosphorylated form, and this added energy from the addition of the phosphate allows the molecule to undergo its endergonic reaction.

6.5 Enzymes

Enzymes are chemical catalysts that accelerate chemical reactions at physiological temperatures by lowering their activation energy. Enzymes are usually proteins consisting of one or more polypeptide chains. Enzymes have an active site that provides a unique chemical environment, made up of certain amino acid R groups (residues). This unique environment is perfectly suited to convert particular chemical reactants for that enzyme, called substrates, into unstable intermediates called transition states. Enzymes and substrates are thought to bind with an induced fit, which means that enzymes undergo slight conformational adjustments upon substrate contact, leading to full, optimal binding. Enzymes bind to substrates and catalyze reactions in four different ways: bringing substrates together in an optimal orientation, compromising the bond structures of substrates so that bonds can be more easily broken, providing optimal environmental conditions for a reaction to occur, or participating directly in their chemical reaction by forming transient covalent bonds with the substrates.

Enzyme action must be regulated so that in a given cell at a given time, the desired reactions are being catalyzed and the undesired reactions are not. Enzymes are regulated by cellular conditions, such as temperature and pH. They are also regulated through their location within a cell, sometimes being compartmentalized so that they can only catalyze reactions under certain circumstances. Inhibition and activation of enzymes via other molecules are other important ways that enzymes are regulated. Inhibitors can act competitively, noncompetitively, or allosterically; noncompetitive inhibitors are usually allosteric. Activators can also enhance the function of enzymes allosterically. The most common method by which cells regulate the enzymes in metabolic pathways is through feedback inhibition. During feedback inhibition, the products of a metabolic pathway serve as inhibitors (usually allosteric) of one or more of the enzymes (usually the first committed enzyme of the pathway) involved in the pathway that produces them.

ART CONNECTION QUESTIONS

1. **Figure 6.8** Look at each of the processes shown, and decide if it is endergonic or exergonic. In each case, does enthalpy increase or decrease, and does entropy increase or decrease?

2. **Figure 6.10** If no activation energy were required to break down sucrose (table sugar), would you be able to store it in a sugar bowl?

3. **Figure 6.14** The hydrolysis of one ATP molecule releases 7.3 kcal/mol of energy ($\Delta G = -7.3$ kcal/mol of energy). If it takes 2.1 kcal/mol of energy to move one Na^+ across the membrane ($\Delta G = +2.1$ kcal/mol of energy), how many sodium ions could be moved by the hydrolysis of one ATP molecule?

REVIEW QUESTIONS

4. Energy is stored long-term in the bonds of _____ and used short-term to perform work from a(n) _____ molecule.

a. ATP : glucose
b. an anabolic molecule : catabolic molecule
c. glucose : ATP
d. a catabolic molecule : anabolic molecule

5. DNA replication involves unwinding two strands of parent DNA, copying each strand to synthesize complementary strands, and releasing the parent and daughter DNA. Which of the following accurately describes this process?

a. This is an anabolic process
b. This is a catabolic process
c. This is both anabolic and catabolic
d. This is a metabolic process but is neither anabolic nor catabolic

6. Consider a pendulum swinging. Which type(s) of energy is/are associated with the pendulum in the following instances: i. the moment at which it completes one cycle, just before it begins to fall back towards the other end, ii. the moment that it is in the middle between the two ends, iii. just before it reaches the end of one cycle (just before instant i.).

a. i. potential and kinetic, ii. potential and kinetic, iii. kinetic
b. i. potential, ii. potential and kinetic, iii. potential and kinetic
c. i. potential, ii. kinetic, iii. potential and kinetic
d. i. potential and kinetic, ii. kinetic iii. kinetic

7. Which of the following comparisons or contrasts between endergonic and exergonic reactions is false?

a. Endergonic reactions have a positive ΔG and exergonic reactions have a negative ΔG
b. Endergonic reactions consume energy and exergonic reactions release energy

c. Both endergonic and exergonic reactions require a small amount of energy to overcome an activation barrier
d. Endergonic reactions take place slowly and exergonic reactions take place quickly

8. Which of the following is the best way to judge the relative activation energies between two given chemical reactions?
a. Compare the ΔG values between the two reactions
b. Compare their reaction rates
c. Compare their ideal environmental conditions
d. Compare the spontaneity between the two reactions

9. Which of the following is not an example of an energy transformation?
a. Turning on a light switch
b. Solar panels at work
c. Formation of static electricity
d. None of the above

10. Label each of the following systems as high or low entropy: i. the instant that a perfume bottle is sprayed compared with 30 seconds later, ii. an old 1950s car compared with a brand new car, and iii. a living cell compared with a dead cell.
a. i. low, ii. high, iii. low
b. i. low, ii. high, iii. high
c. i. high, ii. low, iii. high
d. i. high, ii. low, iii. Low

11. The energy released by the hydrolysis of ATP is
a. primarily stored between the alpha and beta phosphates
b. equal to −57 kcal/mol
c. harnessed as heat energy by the cell to perform work
d. providing energy to coupled reactions

12. Which of the following molecules is likely to have the most potential energy?
a. sucrose
b. ATP
c. glucose
d. ADP

13. Which of the following is not true about enzymes:
a. They increase ΔG of reactions
b. They are usually made of amino acids
c. They lower the activation energy of chemical reactions
d. Each one is specific to the particular substrate(s) to which it binds

14. An allosteric inhibitor does which of the following?
a. Binds to an enzyme away from the active site and changes the conformation of the active site, increasing its affinity for substrate binding
b. Binds to the active site and blocks it from binding substrate
c. Binds to an enzyme away from the active site and changes the conformation of the active site, decreasing its affinity for the substrate
d. Binds directly to the active site and mimics the substrate

15. Which of the following analogies best describe the induced-fit model of enzyme-substrate binding?
a. A hug between two people
b. A key fitting into a lock
c. A square peg fitting through the square hole and a round peg fitting through the round hole of a children's toy
d. The fitting together of two jigsaw puzzle pieces.

CRITICAL THINKING QUESTIONS

16. Does physical exercise involve anabolic and/or catabolic processes? Give evidence for your answer.

17. Name two different cellular functions that require energy that parallel human energy-requiring functions.

18. Explain in your own words the difference between a spontaneous reaction and one that occurs instantaneously, and what causes this difference.

19. Describe the position of the transition state on a vertical energy scale, from low to high, relative to the position of the reactants and products, for both endergonic and exergonic reactions.

20. Imagine an elaborate ant farm with tunnels and passageways through the sand where ants live in a large community. Now imagine that an earthquake shook the ground and demolished the ant farm. In which of these two scenarios, before or after the earthquake, was the ant farm system in a state of higher or lower entropy?

21. Energy transfers take place constantly in everyday activities. Think of two scenarios: cooking on a stove and driving. Explain how the second law of thermodynamics applies to these two scenarios.

22. Do you think that the E_A for ATP hydrolysis is relatively low or high? Explain your reasoning.

23. With regard to enzymes, why are vitamins necessary for good health? Give examples.

24. Explain in your own words how enzyme feedback inhibition benefits a cell.

CHAPTER SUMMARY

7.1 Energy in Living Systems

ATP functions as the energy currency for cells. It allows the cell to store energy briefly and transport it within the cell to support endergonic chemical reactions. The structure of ATP is that of an RNA nucleotide with three phosphates attached. As ATP is used for energy, a phosphate group or two are detached, and either ADP or AMP is produced. Energy derived from glucose catabolism is used to convert ADP into ATP. When ATP is used in a reaction, the third phosphate is temporarily attached to a substrate in a process called phosphorylation. The two processes of ATP regeneration that are used in conjunction with glucose catabolism are substrate-level phosphorylation and oxidative phosphorylation through the process of chemiosmosis.

7.2 Glycolysis

Glycolysis is the first pathway used in the breakdown of glucose to extract energy. It was probably one of the earliest metabolic pathways to evolve and is used by nearly all of the organisms on earth. Glycolysis consists of two parts: The first part prepares the six-carbon ring of glucose for cleavage into two three-carbon sugars. ATP is invested in the process during this half to energize the separation. The second half of glycolysis extracts ATP and high-energy electrons from hydrogen atoms and attaches them to NAD^+. Two ATP molecules are invested in the first half and four ATP molecules are formed by substrate phosphorylation during the second half. This produces a net gain of two ATP and two NADH molecules for the cell.

7.3 Oxidation of Pyruvate and the Citric Acid Cycle

In the presence of oxygen, pyruvate is transformed into an acetyl group attached to a carrier molecule of coenzyme A. The resulting acetyl CoA can enter several pathways, but most often, the acetyl group is delivered to the citric acid cycle for further catabolism. During the conversion of pyruvate into the acetyl group, a molecule of carbon dioxide and two high-energy electrons are removed. The carbon dioxide accounts for two (conversion of two pyruvate molecules) of the six carbons of the original glucose molecule. The electrons are picked up by NAD^+, and the NADH carries the electrons to a later pathway for ATP production. At this point, the glucose molecule that originally entered cellular respiration has been completely oxidized. Chemical potential energy stored within the glucose molecule has been transferred to electron carriers or has been used to synthesize a few ATPs.

The citric acid cycle is a series of redox and decarboxylation reactions that remove high-energy electrons and carbon dioxide. The electrons temporarily stored in molecules of NADH and $FADH_2$ are used to generate ATP in a subsequent pathway. One molecule of either GTP or ATP is produced by substrate-level phosphorylation on each turn of the cycle. There is no comparison of the cyclic pathway with a linear one.

7.4 Oxidative Phosphorylation

The electron transport chain is the portion of aerobic respiration that uses free oxygen as the final electron acceptor of the electrons removed from the intermediate compounds in glucose catabolism. The electron transport chain is composed of four large, multiprotein complexes embedded in the inner mitochondrial membrane and two small diffusible electron carriers shuttling electrons between them. The electrons are passed through a series of redox reactions, with a small amount of free energy used at three points to transport hydrogen ions across a membrane. This process contributes to the gradient used in chemiosmosis. The electrons passing through the electron transport chain gradually lose energy, High-energy electrons donated to the chain by either NADH or $FADH_2$ complete the chain, as low-energy electrons reduce oxygen molecules and form water. The level of free energy of the electrons drops from about 60 kcal/mol in NADH or 45 kcal/mol in $FADH_2$ to about 0 kcal/mol in water. The end products of the electron transport chain are water and ATP. A number of intermediate compounds of the citric acid cycle can be diverted into the anabolism of other biochemical molecules, such as nonessential amino acids, sugars, and lipids. These same molecules can serve as energy sources for the glucose pathways.

7.5 Metabolism without Oxygen

If NADH cannot be oxidized through aerobic respiration, another electron acceptor is used. Most organisms will use some form of fermentation to accomplish the regeneration of NAD^+, ensuring the

continuation of glycolysis. The regeneration of NAD^+ in fermentation is not accompanied by ATP production; therefore, the potential of NADH to produce ATP using an electron transport chain is not utilized.

7.6 Connections of Carbohydrate, Protein, and Lipid Metabolic Pathways

The breakdown and synthesis of carbohydrates, proteins, and lipids connect with the pathways of glucose catabolism. The simple sugars are galactose, fructose, glycogen, and pentose. These are catabolized during glycolysis. The amino acids from proteins connect with glucose catabolism through pyruvate, acetyl CoA, and components of the citric acid cycle. Cholesterol synthesis starts with acetyl groups, and the components of triglycerides come from glycerol-3-phosphate from glycolysis and acetyl groups produced in the mitochondria from pyruvate.

7.7 Regulation of Cellular Respiration

Cellular respiration is controlled by a variety of means. The entry of glucose into a cell is controlled by the transport proteins that aid glucose passage through the cell membrane. Most of the control of the respiration processes is accomplished through the control of specific enzymes in the pathways. This is a type of negative feedback, turning the enzymes off. The enzymes respond most often to the levels of the available nucleosides ATP, ADP, AMP, NAD^+, and FAD. Other intermediates of the pathway also affect certain enzymes in the systems.

ART CONNECTION QUESTIONS

1. **Figure 7.11** Dinitrophenol (DNP) is an uncoupler that makes the inner mitochondrial membrane leaky to protons. It was used until 1938 as a weight-loss drug. What effect would you expect DNP to have on the change in pH across the inner mitochondrial membrane? Why do you think this might be an effective weight-loss drug?

2. **Figure 7.12** Cyanide inhibits cytochrome c oxidase, a component of the electron transport chain. If cyanide poisoning occurs, would you expect the pH of the intermembrane space to increase or decrease? What effect would cyanide have on ATP synthesis?

3. **Figure 7.14** Tremetol, a metabolic poison found in the white snake root plant, prevents the metabolism of lactate. When cows eat this plant, it is concentrated in the milk they produce. Humans who consume the milk become ill. Symptoms of this disease, which include vomiting, abdominal pain, and tremors, become worse after exercise. Why do you think this is the case?

REVIEW QUESTIONS

4. The energy currency used by cells is _____.

a. ATP
b. ADP
c. AMP
d. adenosine

5. A reducing chemical reaction _____.

a. reduces the compound to a simpler form
b. adds an electron to the substrate
c. removes a hydrogen atom from the substrate
d. is a catabolic reaction

6. During the second half of glycolysis, what occurs?

a. ATP is used up.
b. Fructose is split in two.
c. ATP is made.
d. Glucose becomes fructose.

7. What is removed from pyruvate during its conversion into an acetyl group?

a. oxygen
b. ATP
c. B vitamin
d. carbon dioxide

8. What do the electrons added to NAD^+ do?

a. They become part of a fermentation pathway.
b. They go to another pathway for ATP production.
c. They energize the entry of the acetyl group into the citric acid cycle.
d. They are converted to NADP.

9. GTP or ATP is produced during the conversion of _____.

a. isocitrate into α-ketoglutarate
b. succinyl CoA into succinate
c. fumarate into malate
d. malate into oxaloacetate

10. How many NADH molecules are produced on each turn of the citric acid cycle?

a. one
b. two
c. three
d. four

11. What compound receives electrons from NADH?
a. FMN
b. ubiquinone
c. cytochrome c_1
d. oxygen

12. Chemiosmosis involves _____.
a. the movement of electrons across the cell membrane
b. the movement of hydrogen atoms across a mitochondrial membrane
c. the movement of hydrogen ions across a mitochondrial membrane
d. the movement of glucose through the cell membrane

13. Which of the following fermentation methods can occur in animal skeletal muscles?
a. lactic acid fermentation
b. alcohol fermentation
c. mixed acid fermentation
d. propionic fermentation

14. A major connection for sugars in glycolysis is _____.
a. glucose-6-phosphate
b. fructose-1,6-bisphosphate
c. dihydroxyacetone phosphate
d. phosphoenolpyruvate

15. Beta-oxidation is _____.
a. the breakdown of sugars
b. the assembly of sugars
c. the breakdown of fatty acids
d. the removal of amino groups from amino acids

16. The effect of high levels of ADP is to _____.
a. increase the activity of the enzyme
b. decrease the activity of the enzyme
c. have no effect on the activity of the enzyme
d. slow down the pathway

17. The control of which enzyme exerts the most control on glycolysis?
a. hexokinase
b. phosphofructokinase
c. glucose-6-phosphatase
d. aldolase

CRITICAL THINKING QUESTIONS

18. Why is it beneficial for cells to use ATP rather than energy directly from the bonds of carbohydrates? What are the greatest drawbacks to harnessing energy directly from the bonds of several different compounds?

19. Nearly all organisms on earth carry out some form of glycolysis. How does that fact support or not support the assertion that glycolysis is one of the oldest metabolic pathways?

20. Red blood cells do not perform aerobic respiration, but they do perform glycolysis. Why do all cells need an energy source, and what would happen if glycolysis were blocked in a red blood cell?

21. What is the primary difference between a circular pathway and a linear pathway?

22. How do the roles of ubiquinone and cytochrome c differ from the other components of the electron transport chain?

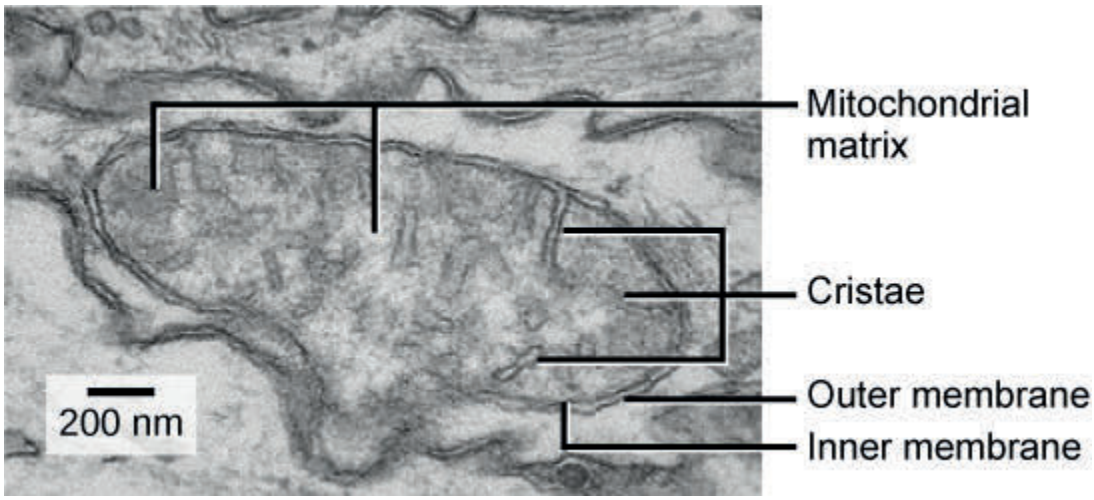
23. What accounts for the different number of ATP molecules that are formed through cellular respiration?

24. What is the primary difference between fermentation and anaerobic respiration?

25. Would you describe metabolic pathways as inherently wasteful or inherently economical, and why?

26. How does citrate from the citric acid cycle affect glycolysis?

27. Why might negative feedback mechanisms be more common than positive feedback mechanisms in living cells?



CHAPTER SUMMARY

8.1 Overview of Photosynthesis

The process of photosynthesis transformed life on Earth. By harnessing energy from the sun, photosynthesis evolved to allow living things access to enormous amounts of energy. Because of photosynthesis, living things gained access to sufficient energy that allowed them to build new structures and achieve the biodiversity evident today.

Only certain organisms, called photoautotrophs, can perform photosynthesis; they require the presence of chlorophyll, a specialized pigment that absorbs certain portions of the visible spectrum and can capture energy from sunlight. Photosynthesis uses carbon dioxide and water to assemble carbohydrate molecules and release oxygen as a waste product into the atmosphere. Eukaryotic autotrophs, such as plants and algae, have organelles called chloroplasts in which photosynthesis takes place, and starch accumulates. In prokaryotes, such as cyanobacteria, the process is less localized and occurs within folded membranes, extensions of the plasma membrane, and in the cytoplasm.

8.2 The Light-Dependent Reactions of Photosynthesis

The pigments of the first part of photosynthesis, the light-dependent reactions, absorb energy from sunlight. A photon strikes the antenna pigments of photosystem II to initiate photosynthesis. The energy travels to the reaction center that contains chlorophyll *a* to the electron transport chain, which pumps hydrogen ions into the thylakoid interior. This action builds up a high concentration of ions. The ions flow through ATP synthase via chemiosmosis to form molecules of ATP, which are used for the formation of sugar molecules in the second stage of photosynthesis. Photosystem I absorbs a second photon, which results in the formation of an NADPH molecule, another energy and reducing power carrier for the light-independent reactions.

8.3 Using Light Energy to Make Organic Molecules

Using the energy carriers formed in the first steps of photosynthesis, the light-independent reactions, or the Calvin cycle, take in CO_2 from the environment. An enzyme, RuBisCO, catalyzes a reaction with CO_2 and another molecule, RuBP. After three cycles, a three-carbon molecule of G3P leaves the cycle to become part of a carbohydrate molecule. The remaining G3P molecules stay in the cycle to be regenerated into RuBP, which is then ready to react with more CO_2. Photosynthesis forms an energy cycle with the process of cellular respiration. Plants need both photosynthesis and respiration for their ability to function in both the light and dark, and to be able to interconvert essential metabolites. Therefore, plants contain both chloroplasts and mitochondria.

ART CONNECTION QUESTIONS

1. **Figure 8.6** On a hot, dry day, plants close their stomata to conserve water. What impact will this have on photosynthesis?

2. **Figure 8.16** What is the source of electrons for the chloroplast electron transport chain?

a. Water
b. Oxygen
c. Carbon dioxide
d. NADPH

3. **Figure 8.18** Which of the following statements is true?

a. In photosynthesis, oxygen, carbon dioxide, ATP, and NADPH are reactants. G3P and water are products.
b. In photosynthesis, chlorophyll, water, and carbon dioxide are reactants. G3P and oxygen are products.
c. In photosynthesis, water, carbon dioxide, ATP, and NADPH are reactants. RuBP and oxygen are products.
d. In photosynthesis, water and carbon dioxide are reactants. G3P and oxygen are products.

REVIEW QUESTIONS

4. Which of the following components is *not* used by both plants and cyanobacteria to carry out photosynthesis?

a. chloroplasts
b. chlorophyll
c. carbon dioxide
d. water

5. What two main products result from photosynthesis?

a. oxygen and carbon dioxide
b. chlorophyll and oxygen
c. sugars/carbohydrates and oxygen
d. sugars/carbohydrates and carbon dioxide

6. In which compartment of the plant cell do the light-independent reactions of photosynthesis take place?

a. thylakoid
b. stroma
c. outer membrane
d. mesophyll

7. Which statement about thylakoids in eukaryotes is *not* correct?

a. Thylakoids are assembled into stacks.
b. Thylakoids exist as a maze of folded membranes.
c. The space surrounding thylakoids is called stroma.
d. Thylakoids contain chlorophyll.

8. Which of the following structures is *not* a component of a photosystem?

a. ATP synthase
b. antenna molecule
c. reaction center
d. primary electron acceptor

9. How many photons does it take to fully reduce one molecule of $NADP^+$ to NADPH?

a. 1
b. 2
c. 4
d. 8

10. Which complex is *not* involved in the establishment of conditions for ATP synthesis?

a. photosystem I
b. ATP synthase
c. photosystem II
d. cytochrome complex

11. From which component of the light-dependent reactions does NADPH form most directly?

a. photosystem II
b. photosystem I
c. cytochrome complex
d. ATP synthase

12. Which molecule must enter the Calvin cycle continually for the light-independent reactions to take place?

a. RuBisCO
b. RuBP
c. 3-PGA
d. CO_2

13. Which order of molecular conversions is correct for the Calvin cycle?

a. $RuBP + G3P \rightarrow 3\text{-}PGA \rightarrow sugar$

b. $RuBisCO \rightarrow CO_2 \rightarrow RuBP \rightarrow G3P$

c. $RuBP + CO_2 \rightarrow [RuBisCO]\ 3\text{-}PGA \rightarrow G3P$

d. $CO_2 \rightarrow 3\text{-}PGA \rightarrow RuBP \rightarrow G3P$

14. Where in eukaryotic cells does the Calvin cycle take place?

a. thylakoid membrane
b. thylakoid lumen
c. chloroplast stroma
d. granum

15. Which statement correctly describes carbon fixation?

a. the conversion of CO_2 into an organic compound
b. the use of RuBisCO to form 3-PGA
c. the production of carbohydrate molecules from G3P
d. the formation of RuBP from G3P molecules
e. the use of ATP and NADPH to reduce CO_2

CRITICAL THINKING QUESTIONS

16. What is the overall outcome of the light reactions in photosynthesis?

17. Why are carnivores, such as lions, dependent on photosynthesis to survive?

18. Why are energy carriers thought of as either "full" or "empty"?

19. Describe the pathway of electron transfer from photosystem II to photosystem I in light-dependent reactions.

20. What are the roles of ATP and NADPH in photosynthesis?

21. Why is the third stage of the Calvin cycle called the regeneration stage?

22. Which part of the light-independent reactions would be affected if a cell could not produce the enzyme RuBisCO?

23. Why does it take three turns of the Calvin cycle to produce G3P, the initial product of photosynthesis?

CHAPTER SUMMARY

9.1 Signaling Molecules and Cellular Receptors

Cells communicate by both inter- and intracellular signaling. Signaling cells secrete ligands that bind to target cells and initiate a chain of events within the target cell. The four categories of signaling in multicellular organisms are paracrine signaling, endocrine signaling, autocrine signaling, and direct signaling across gap junctions. Paracrine signaling takes place over short distances. Endocrine signals are carried long distances through the bloodstream by hormones, and autocrine signals are received by the same cell that sent the signal or other nearby cells of the same kind. Gap junctions allow small molecules, including signaling molecules, to flow between neighboring cells.

Internal receptors are found in the cell cytoplasm. Here, they bind ligand molecules that cross the plasma membrane; these receptor-ligand complexes move to the nucleus and interact directly with cellular DNA. Cell-surface receptors transmit a signal from outside the cell to the cytoplasm. Ion channel-linked receptors, when bound to their ligands, form a pore through the plasma membrane through which certain ions can pass. G-protein-linked receptors interact with a G-protein on the cytoplasmic side of the plasma membrane, promoting the exchange of bound GDP for GTP and interacting with other enzymes or ion channels to transmit a signal. Enzyme-linked receptors transmit a signal from outside the cell to an intracellular domain of a membrane-bound enzyme. Ligand binding causes activation of the enzyme. Small hydrophobic ligands (like steroids) are able to penetrate the plasma membrane and bind to internal receptors. Water-soluble hydrophilic ligands are unable to pass through the membrane; instead, they bind to cell-surface receptors, which transmit the signal to the inside of the cell.

9.2 Propagation of the Signal

Ligand binding to the receptor allows for signal transduction through the cell. The chain of events that conveys the signal through the cell is called a signaling pathway or cascade. Signaling pathways are often very complex because of the interplay between different proteins. A major component of cell signaling cascades is the phosphorylation of molecules by enzymes known as kinases. Phosphorylation adds a phosphate group to serine, threonine, and tyrosine residues in a protein, changing their shapes, and activating or inactivating the protein. Small molecules like nucleotides can also be phosphorylated. Second messengers are small, non-protein molecules that are used to transmit a signal within a cell. Some examples of second messengers are calcium ions (Ca^{2+}), cyclic AMP (cAMP), diacylglycerol (DAG), and inositol triphosphate (IP_3).

9.3 Response to the Signal

The initiation of a signaling pathway is a response to external stimuli. This response can take many different forms, including protein synthesis, a change in the cell's metabolism, cell growth, or even cell death. Many pathways influence the cell by initiating gene expression, and the methods utilized are quite numerous. Some pathways activate enzymes that interact with DNA transcription factors. Others modify proteins and induce them to change their location in the cell. Depending on the status of the organism, cells can respond by storing energy as glycogen or fat, or making it available in the form of glucose. A signal transduction pathway allows muscle cells to respond to immediate requirements for energy in the form of glucose. Cell growth is almost always stimulated by external signals called growth factors. Uncontrolled cell growth leads to cancer, and mutations in the genes encoding protein components of signaling pathways are often found in tumor cells. Programmed cell death, or apoptosis, is important for removing damaged or unnecessary cells. The use of cellular signaling to organize the dismantling of a cell ensures that harmful molecules from the cytoplasm are not released into the spaces between cells, as they are in uncontrolled death, necrosis. Apoptosis also ensures the efficient recycling of the components of the dead cell. Termination of the cellular signaling cascade is very important so that the response to a signal is appropriate in both timing and intensity. Degradation of signaling molecules and dephosphorylation of phosphorylated intermediates of the pathway by phosphatases are two ways to terminate signals within the cell.

9.4 Signaling in Single-Celled Organisms

Yeasts and multicellular organisms have similar signaling mechanisms. Yeasts use cell-surface receptors and signaling cascades to communicate information on mating with other yeast cells. The signaling molecule secreted by yeasts is called mating factor.

Bacterial signaling is called quorum sensing. Bacteria secrete signaling molecules called autoinducers that are either small, hydrophobic molecules or peptide-based signals. The hydrophobic autoinducers, such as AHL, bind transcription factors and directly affect gene expression. The peptide-based molecules bind kinases and initiate signaling cascades in the cells.

ART CONNECTION QUESTIONS

1. **Figure 9.8** HER2 is a receptor tyrosine kinase. In 30 percent of human breast cancers, HER2 is permanently activated, resulting in unregulated cell division. Lapatinib, a drug used to treat breast cancer, inhibits HER2 receptor tyrosine kinase autophosphorylation (the process by which the receptor adds phosphates onto itself), thus reducing tumor growth by 50 percent. Besides autophosphorylation, which of the following steps would be inhibited by Lapatinib?

a. Signaling molecule binding, dimerization, and the downstream cellular response.
b. Dimerization, and the downstream cellular response.
c. The downstream cellular response.
d. Phosphatase activity, dimerization, and the downsteam cellular response.

2. **Figure 9.10** In certain cancers, the GTPase activity of the RAS G-protein is inhibited. This means that the RAS protein can no longer hydrolyze GTP into GDP. What effect would this have on downstream cellular events?

3. **Figure 9.17** Which of the following statements about quorum sensing is false?

a. Autoinducer must bind to receptor to turn on transcription of genes responsible for the production of more autoinducer.
b. The receptor stays in the bacterial cell, but the autoinducer diffuses out.

c. Autoinducer can only act on a different cell: it cannot act on the cell in which it is made.
d. Autoinducer turns on genes that enable the bacteria to form a biofilm.

4. **Figure 9.18** What advantage might biofilm production confer on the *S. aureus* inside the catheter?

REVIEW QUESTIONS

5. What property prevents the ligands of cell-surface receptors from entering the cell?

a. The molecules bind to the extracellular domain.
b. The molecules are hydrophilic and cannot penetrate the hydrophobic interior of the plasma membrane.
c. The molecules are attached to transport proteins that deliver them through the bloodstream to target cells.
d. The ligands are able to penetrate the membrane and directly influence gene expression upon receptor binding.

6. The secretion of hormones by the pituitary gland is an example of _____.

a. autocrine signaling
b. paracrine signaling
c. endocrine signaling
d. direct signaling across gap junctions

7. Why are ion channels necessary to transport ions into or out of a cell?

a. Ions are too large to diffuse through the membrane.
b. Ions are charged particles and cannot diffuse through the hydrophobic interior of the membrane.
c. Ions do not need ion channels to move through the membrane.
d. Ions bind to carrier proteins in the bloodstream, which must be removed before transport into the cell.

8. Endocrine signals are transmitted more slowly than paracrine signals because _____.

a. the ligands are transported through the bloodstream and travel greater distances
b. the target and signaling cells are close together
c. the ligands are degraded rapidly
d. the ligands don't bind to carrier proteins during transport

9. Where do DAG and IP_3 originate?

a. They are formed by phosphorylation of cAMP.
b. They are ligands expressed by signaling cells.
c. They are hormones that diffuse through the plasma membrane to stimulate protein production.
d. They are the cleavage products of the inositol phospholipid, PIP_2.

10. What property enables the residues of the amino acids serine, threonine, and tyrosine to be phosphorylated?

a. They are polar.
b. They are non-polar.
c. They contain a hydroxyl group.
d. They occur more frequently in the amino acid sequence of signaling proteins.

11. What is the function of a phosphatase?

a. A phosphatase removes phosphorylated amino acids from proteins.
b. A phosphatase removes the phosphate group from phosphorylated amino acid residues in a protein.
c. A phosphatase phosphorylates serine, threonine, and tyrosine residues.
d. A phosphatase degrades second messengers in the cell.

12. How does NF-κB induce gene expression?

a. A small, hydrophobic ligand binds to NF-κB, activating it.
b. Phosphorylation of the inhibitor Iκ-B dissociates the complex between it and NF-κB, and allows NF-κB to enter the nucleus and stimulate transcription.
c. NF-κB is phosphorylated and is then free to enter the nucleus and bind DNA.
d. NF-κB is a kinase that phosphorylates a transcription factor that binds DNA and promotes protein production.

13. Apoptosis can occur in a cell when the cell is _____.

a. damaged
b. no longer needed
c. infected by a virus
d. all of the above

14. What is the effect of an inhibitor binding an enzyme?

a. The enzyme is degraded.
b. The enzyme is activated.
c. The enzyme is inactivated.
d. The complex is transported out of the cell.

15. Which type of molecule acts as a signaling molecule in yeasts?

a. steroid

b. autoinducer
c. mating factor
d. second messenger

16. Quorum sensing is triggered to begin when _____.

a. treatment with antibiotics occurs
b. bacteria release growth hormones
c. bacterial protein expression is switched on
d. a sufficient number of bacteria are present

CRITICAL THINKING QUESTIONS

17. What is the difference between intracellular signaling and intercellular signaling?

18. How are the effects of paracrine signaling limited to an area near the signaling cells?

19. What are the differences between internal receptors and cell-surface receptors?

20. Cells grown in the laboratory are mixed with a dye molecule that is unable to pass through the plasma membrane. If a ligand is added to the cells, observations show that the dye enters the cells. What type of receptor did the ligand bind to on the cell surface?

21. The same second messengers are used in many different cells, but the response to second messengers is different in each cell. How is this possible?

22. What would happen if the intracellular domain of a cell-surface receptor was switched with the domain from another receptor?

23. What is a possible result of a mutation in a kinase that controls a pathway that stimulates cell growth?

24. How does the extracellular matrix control the growth of cells?

25. What characteristics make yeasts a good model for learning about signaling in humans?

26. Why is signaling in multicellular organisms more complicated than signaling in single-celled organisms?

CHAPTER SUMMARY

10.1 Cell Division

Prokaryotes have a single circular chromosome composed of double-stranded DNA, whereas eukaryotes have multiple, linear chromosomes composed of chromatin surrounded by a nuclear membrane. The 46 chromosomes of human somatic cells are composed of 22 pairs of autosomes (matched pairs) and a pair of sex chromosomes, which may or may not be matched. This is the 2*n* or diploid state. Human gametes have 23 chromosomes or one complete set of chromosomes; a set of chromosomes is complete with either one of the sex chromosomes. This is the *n* or haploid state. Genes are segments of DNA that code for a specific protein. An organism's traits are determined by the genes inherited from each parent. Duplicated chromosomes are composed of two sister chromatids. Chromosomes are compacted using a variety of mechanisms during certain stages of the cell cycle. Several classes of protein are involved in the organization and packing of the chromosomal DNA into a highly condensed structure. The condensing complex compacts chromosomes, and the resulting condensed structure is necessary for chromosomal segregation during mitosis.

10.2 The Cell Cycle

The cell cycle is an orderly sequence of events. Cells on the path to cell division proceed through a series of precisely timed and carefully regulated stages. In eukaryotes, the cell cycle consists of a long preparatory period, called interphase. Interphase is divided into G_1, S, and G_2 phases. The mitotic phase begins with karyokinesis (mitosis), which consists of five stages: prophase, prometaphase, metaphase, anaphase, and telophase. The final stage of the mitotic phase is cytokinesis, during which the cytoplasmic components of the daughter cells are separated either by an actin ring (animal cells) or by cell plate formation (plant cells).

10.3 Control of the Cell Cycle

Each step of the cell cycle is monitored by internal controls called checkpoints. There are three major checkpoints in the cell cycle: one near the end of G_1, a second at the G_2/M transition, and the third during metaphase. Positive regulator molecules allow the cell cycle to advance to the next stage. Negative regulator molecules monitor cellular conditions and can halt the cycle until specific requirements are met.

10.4 Cancer and the Cell Cycle

Cancer is the result of unchecked cell division caused by a breakdown of the mechanisms that regulate the cell cycle. The loss of control begins with a change in the DNA sequence of a gene that codes for one of the regulatory molecules. Faulty instructions lead to a protein that does not function as it should. Any disruption of the monitoring system can allow other mistakes to be passed on to the daughter cells. Each successive cell division will give rise to daughter cells with even more accumulated damage. Eventually, all checkpoints become nonfunctional, and rapidly reproducing cells crowd out normal cells, resulting in a tumor or leukemia (blood cancer).

10.5 Prokaryotic Cell Division

In both prokaryotic and eukaryotic cell division, the genomic DNA is replicated and then each copy is allocated into a daughter cell. In addition, the cytoplasmic contents are divided evenly and distributed to the new cells. However, there are many differences between prokaryotic and eukaryotic cell division. Bacteria have a single, circular DNA chromosome but no nucleus. Therefore, mitosis is not necessary in bacterial cell division. Bacterial cytokinesis is directed by a ring composed of a protein called FtsZ. Ingrowth of membrane and cell wall material from the periphery of the cells results in the formation of a septum that eventually constructs the separate cell walls of the daughter cells.

ART CONNECTION QUESTIONS

1. **Figure 10.6** Which of the following is the correct order of events in mitosis?

a. Sister chromatids line up at the metaphase plate. The kinetochore becomes attached to the mitotic spindle. The nucleus reforms and the cell divides. Cohesin proteins break down and the sister chromatids separate.

b. The kinetochore becomes attached to the mitotic spindle. Cohesin proteins break down and the sister chromatids separate. Sister chromatids line up at the metaphase plate. The nucleus reforms and the cell divides.
c. The kinetochore becomes attached to the cohesin proteins. Sister chromatids line up at the metaphase plate. The kinetochore breaks down and the sister chromatids separate. The nucleus reforms and the cell divides.
d. The kinetochore becomes attached to the mitotic spindle. Sister chromatids line up at the metaphase plate. Cohesin proteins break down and the sister chromatids separate. The nucleus reforms and the cell divides.

2. **Figure 10.13** Rb and other proteins that negatively regulate the cell cycle are sometimes called tumor suppressors. Why do you think the name tumor suppressor might be an appropriate for these proteins?

3. **Figure 10.14** Human papillomavirus can cause cervical cancer. The virus encodes E6, a protein that binds p53. Based on this fact and what you know about p53, what effect do you think E6 binding has on p53 activity?

a. E6 activates p53
b. E6 inactivates p53
c. E6 mutates p53
d. E6 binding marks p53 for degradation

REVIEW QUESTIONS

4. A diploid cell has_____ the number of chromosomes as a haploid cell.

a. one-fourth
b. half
c. twice
d. four times

5. An organism's traits are determined by the specific combination of inherited _____.

a. cells.
b. genes.
c. proteins.
d. chromatids.

6. The first level of DNA organization in a eukaryotic cell is maintained by which molecule?

a. cohesin
b. condensin
c. chromatin
d. histone

7. Identical copies of chromatin held together by cohesin at the centromere are called _____.

a. histones.
b. nucleosomes.
c. chromatin.
d. sister chromatids.

8. Chromosomes are duplicated during what stage of the cell cycle?

a. G_1 phase
b. S phase
c. prophase
d. prometaphase

9. Which of the following events does not occur during some stages of interphase?

a. DNA duplication
b. organelle duplication
c. increase in cell size
d. separation of sister chromatids

10. The mitotic spindles arise from which cell structure?

a. centromere
b. centrosome
c. kinetochore
d. cleavage furrow

11. Attachment of the mitotic spindle fibers to the kinetochores is a characteristic of which stage of mitosis?

a. prophase
b. prometaphase
c. metaphase
d. anaphase

12. Unpacking of chromosomes and the formation of a new nuclear envelope is a characteristic of which stage of mitosis?

a. prometaphase
b. metaphase
c. anaphase
d. telophase

13. Separation of the sister chromatids is a characteristic of which stage of mitosis?

a. prometaphase
b. metaphase
c. anaphase
d. telophase

14. The chromosomes become visible under a light microscope during which stage of mitosis?

a. prophase
b. prometaphase
c. metaphase
d. anaphase

15. The fusing of Golgi vesicles at the metaphase plate of dividing plant cells forms what structure?

a. cell plate
b. actin ring
c. cleavage furrow

d. mitotic spindle

16. At which of the cell cycle checkpoints do external forces have the greatest influence?

a. G_1 checkpoint
b. G_2 checkpoint
c. M checkpoint
d. G_0 checkpoint

17. What is the main prerequisite for clearance at the G_2 checkpoint?

a. cell has reached a sufficient size
b. an adequate stockpile of nucleotides
c. accurate and complete DNA replication
d. proper attachment of mitotic spindle fibers to kinetochores

18. If the M checkpoint is not cleared, what stage of mitosis will be blocked?

a. prophase
b. prometaphase
c. metaphase
d. anaphase

19. Which protein is a positive regulator that phosphorylates other proteins when activated?

a. p53
b. retinoblastoma protein (Rb)
c. cyclin
d. cyclin-dependent kinase (Cdk)

20. Many of the negative regulator proteins of the cell cycle were discovered in what type of cells?

a. gametes
b. cells in G_0
c. cancer cells
d. stem cells

21. Which negative regulatory molecule can trigger cell suicide (apoptosis) if vital cell cycle events do not occur?

a. p53
b. p21
c. retinoblastoma protein (Rb)
d. cyclin-dependent kinase (Cdk)

22. _____ are changes to the order of nucleotides in a segment of DNA that codes for a protein.

a. Proto-oncogenes
b. Tumor suppressor genes
c. Gene mutations
d. Negative regulators

23. A gene that codes for a positive cell cycle regulator is called a(n) _____.

a. kinase inhibitor.
b. tumor suppressor gene.
c. proto-oncogene.
d. oncogene.

24. A mutated gene that codes for an altered version of Cdk that is active in the absence of cyclin is a(n) _____.

a. kinase inhibitor.
b. tumor suppressor gene.
c. proto-oncogene.
d. oncogene.

25. Which molecule is a Cdk inhibitor that is controlled by p53?

a. cyclin
b. anti-kinase
c. Rb
d. p21

26. Which eukaryotic cell cycle event is missing in binary fission?

a. cell growth
b. DNA duplication
c. karyokinesis
d. cytokinesis

27. FtsZ proteins direct the formation of a _____ that will eventually form the new cell walls of the daughter cells.

a. contractile ring
b. cell plate
c. cytoskeleton
d. septum

CRITICAL THINKING QUESTIONS

28. Compare and contrast a human somatic cell to a human gamete.

29. What is the relationship between a genome, chromosomes, and genes?

30. Eukaryotic chromosomes are thousands of times longer than a typical cell. Explain how chromosomes can fit inside a eukaryotic nucleus.

31. Briefly describe the events that occur in each phase of interphase.

32. Chemotherapy drugs such as vincristine and colchicine disrupt mitosis by binding to tubulin (the subunit of microtubules) and interfering with microtubule assembly and disassembly. Exactly what mitotic structure is targeted by these drugs and what effect would that have on cell division?

33. Describe the similarities and differences between the cytokinesis mechanisms found in animal cells versus those in plant cells.

34. List some reasons why a cell that has just completed cytokinesis might enter the G_0 phase instead of the G_1 phase.

35. What cell cycle events will be affected in a cell that produces mutated (non-functional) cohesin protein?

36. Describe the general conditions that must be met at each of the three main cell cycle checkpoints.

37. Explain the roles of the positive cell cycle regulators compared to the negative regulators.

38. What steps are necessary for Cdk to become fully active?

39. Rb is a negative regulator that blocks the cell cycle at the G_1 checkpoint until the cell achieves a requisite size. What molecular mechanism does Rb employ to halt the cell cycle?

40. Outline the steps that lead to a cell becoming cancerous.

41. Explain the difference between a proto-oncogene and a tumor suppressor gene.

42. List the regulatory mechanisms that might be lost in a cell producing faulty p53.

43. p53 can trigger apoptosis if certain cell cycle events fail. How does this regulatory outcome benefit a multicellular organism?

44. Name the common components of eukaryotic cell division and binary fission.

45. Describe how the duplicated bacterial chromosomes are distributed into new daughter cells without the direction of the mitotic spindle.

CHAPTER SUMMARY

11.1 The Process of Meiosis

Sexual reproduction requires that diploid organisms produce haploid cells that can fuse during fertilization to form diploid offspring. As with mitosis, DNA replication occurs prior to meiosis during

the S-phase of the cell cycle. Meiosis is a series of events that arrange and separate chromosomes and chromatids into daughter cells. During the interphases of meiosis, each chromosome is duplicated. In meiosis, there are two rounds of nuclear division resulting in four nuclei and usually four daughter cells, each with half the number of chromosomes as the parent cell. The first separates homologs, and the second—like mitosis—separates chromatids into individual chromosomes. During meiosis, variation in the daughter nuclei is introduced because of crossover in prophase I and random alignment of tetrads at metaphase I. The cells that are produced by meiosis are genetically unique.

Meiosis and mitosis share similarities, but have distinct outcomes. Mitotic divisions are single nuclear divisions that produce daughter nuclei that are genetically identical and have the same number of chromosome sets as the original cell. Meiotic divisions include two nuclear divisions that produce four daughter nuclei that are genetically different and have one chromosome set instead of the two sets of chromosomes in the parent cell. The main differences between the processes occur in the first division of meiosis, in which homologous chromosomes are paired and exchange non-sister chromatid segments. The homologous chromosomes separate into different nuclei during meiosis I, causing a reduction of ploidy level in the first division. The second division of meiosis is more similar to a mitotic division, except that the daughter cells do not contain identical genomes because of crossover.

11.2 Sexual Reproduction

Nearly all eukaryotes undergo sexual reproduction. The variation introduced into the reproductive cells by meiosis appears to be one of the advantages of sexual reproduction that has made it so successful. Meiosis and fertilization alternate in sexual life cycles. The process of meiosis produces unique reproductive cells called gametes, which have half the number of chromosomes as the parent cell. Fertilization, the fusion of haploid gametes from two individuals, restores the diploid condition. Thus, sexually reproducing organisms alternate between haploid and diploid stages. However, the ways in which reproductive cells are produced and the timing between meiosis and fertilization vary greatly. There are three main categories of life cycles: diploid-dominant, demonstrated by most animals; haploid-dominant, demonstrated by all fungi and some algae; and the alternation of generations, demonstrated by plants and some algae.

ART CONNECTION QUESTIONS

1. **Figure 11.9** If a mutation occurs so that a fungus is no longer able to produce a minus mating type, will it still be able to reproduce?

REVIEW QUESTIONS

2. Meiosis produces _____ daughter cells.

a. two haploid
b. two diploid
c. four haploid
d. four diploid

3. What structure is most important in forming the tetrads?

a. centromere
b. synaptonemal complex
c. chiasma
d. kinetochore

4. At which stage of meiosis are sister chromatids separated from each other?

a. prophase I
b. prophase II
c. anaphase I
d. anaphase II

5. At metaphase I, homologous chromosomes are connected only at what structures?

a. chiasmata
b. recombination nodules
c. microtubules
d. kinetochores

6. Which of the following is *not* true in regard to crossover?

a. Spindle microtubules guide the transfer of DNA across the synaptonemal complex.
b. Non-sister chromatids exchange genetic material.
c. Chiasmata are formed.
d. Recombination nodules mark the crossover point.

7. What phase of mitotic interphase is missing from meiotic interkinesis?

a. G_0 phase
b. G_1 phase
c. S phase
d. G_2 phase

8. The part of meiosis that is similar to mitosis is _____.

a. meiosis I
b. anaphase I

c. meiosis II
d. interkinesis

9. If a muscle cell of a typical organism has 32 chromosomes, how many chromosomes will be in a gamete of that same organism?

a. 8
b. 16
c. 32
d. 64

10. What is a likely evolutionary advantage of sexual reproduction over asexual reproduction?

a. Sexual reproduction involves fewer steps.
b. There is a lower chance of using up the resources in a given environment.
c. Sexual reproduction results in variation in the offspring.
d. Sexual reproduction is more cost-effective.

11. Which type of life cycle has both a haploid and diploid multicellular stage?

a. asexual
b. diploid-dominant
c. haploid-dominant
d. alternation of generations

12. Fungi typically display which type of life cycle?

a. diploid-dominant
b. haploid-dominant
c. alternation of generations
d. asexual

13. A diploid, multicellular life-cycle stage that gives rise to haploid cells by meiosis is called a _____.

a. sporophyte
b. gametophyte
c. spore
d. gamete

CRITICAL THINKING QUESTIONS

14. Describe the process that results in the formation of a tetrad.

15. Explain how the random alignment of homologous chromosomes during metaphase I contributes to the variation in gametes produced by meiosis.

16. What is the function of the fused kinetochore found on sister chromatids in prometaphase I?

17. In a comparison of the stages of meiosis to the stages of mitosis, which stages are unique to meiosis and which stages have the same events in both meiosis and mitosis?

18. List and briefly describe the three processes that lead to variation in offspring with the same parents.

19. Compare the three main types of life cycles in multicellular organisms and give an example of an organism that employs each.

CHAPTER SUMMARY

12.1 Mendel's Experiments and the Laws of Probability

Working with garden pea plants, Mendel found that crosses between parents that differed by one trait produced F_1 offspring that all expressed the traits of one parent. Observable traits are referred to as dominant, and non-expressed traits are described as recessive. When the offspring in Mendel's experiment were self-crossed, the F_2 offspring exhibited the dominant trait or the recessive trait in a 3:1 ratio, confirming that the recessive trait had been transmitted faithfully from the original P_0 parent. Reciprocal crosses generated identical F_1 and F_2 offspring ratios. By examining sample sizes, Mendel showed that his crosses behaved reproducibly according to the laws of probability, and that the traits were inherited as independent events.

Two rules in probability can be used to find the expected proportions of offspring of different traits from different crosses. To find the probability of two or more independent events occurring together, apply the product rule and multiply the probabilities of the individual events. The use of the word "and" suggests the appropriate application of the product rule. To find the probability of two or more events occurring in combination, apply the sum rule and add their individual probabilities together. The use of the word "or" suggests the appropriate application of the sum rule.

12.2 Characteristics and Traits

When true-breeding or homozygous individuals that differ for a certain trait are crossed, all of the offspring will be heterozygotes for that trait. If the traits are inherited as dominant and recessive, the F_1

offspring will all exhibit the same phenotype as the parent homozygous for the dominant trait. If these heterozygous offspring are self-crossed, the resulting F_2 offspring will be equally likely to inherit gametes carrying the dominant or recessive trait, giving rise to offspring of which one quarter are homozygous dominant, half are heterozygous, and one quarter are homozygous recessive. Because homozygous dominant and heterozygous individuals are phenotypically identical, the observed traits in the F_2 offspring will exhibit a ratio of three dominant to one recessive.

Alleles do not always behave in dominant and recessive patterns. Incomplete dominance describes situations in which the heterozygote exhibits a phenotype that is intermediate between the homozygous phenotypes. Codominance describes the simultaneous expression of both of the alleles in the heterozygote. Although diploid organisms can only have two alleles for any given gene, it is common for more than two alleles of a gene to exist in a population. In humans, as in many animals and some plants, females have two X chromosomes and males have one X and one Y chromosome. Genes that are present on the X but not the Y chromosome are said to be X-linked, such that males only inherit one allele for the gene, and females inherit two. Finally, some alleles can be lethal. Recessive lethal alleles are only lethal in homozygotes, but dominant lethal alleles are fatal in heterozygotes as well.

12.3 Laws of Inheritance

Mendel postulated that genes (characteristics) are inherited as pairs of alleles (traits) that behave in a dominant and recessive pattern. Alleles segregate into gametes such that each gamete is equally likely to receive either one of the two alleles present in a diploid individual. In addition, genes are assorted into gametes independently of one another. That is, alleles are generally not more likely to segregate into a gamete with a particular allele of another gene. A dihybrid cross demonstrates independent assortment when the genes in question are on different chromosomes or distant from each other on the same chromosome. For crosses involving more than two genes, use the forked line or probability methods to predict offspring genotypes and phenotypes rather than a Punnett square.

Although chromosomes sort independently into gametes during meiosis, Mendel’s law of independent assortment refers to genes, not chromosomes, and a single chromosome may carry more than 1,000 genes. When genes are located in close proximity on the same chromosome, their alleles tend to be inherited together. This results in offspring ratios that violate Mendel's law of independent assortment. However, recombination serves to exchange genetic material on homologous chromosomes such that maternal and paternal alleles may be recombined on the same chromosome. This is why alleles on a given chromosome are not always inherited together. Recombination is a random event occurring anywhere on a chromosome. Therefore, genes that are far apart on the same chromosome are likely to still assort independently because of recombination events that occurred in the intervening chromosomal space.

Whether or not they are sorting independently, genes may interact at the level of gene products such that the expression of an allele for one gene masks or modifies the expression of an allele for a different gene. This is called epistasis.

ART CONNECTION QUESTIONS

1. **Figure 12.5** In pea plants, round peas (*R*) are dominant to wrinkled peas (*r*). You do a test cross between a pea plant with wrinkled peas (genotype *rr*) and a plant of unknown genotype that has round peas. You end up with three plants, all which have round peas. From this data, can you tell if the round pea parent plant is homozygous dominant or heterozygous? If the round pea parent plant is heterozygous, what is the probability that a random sample of 3 progeny peas will all be round?

2. **Figure 12.6** What are the genotypes of the individuals labeled 1, 2 and 3?

3. **Figure 12.12** What ratio of offspring would result from a cross between a white-eyed male and a female that is heterozygous for red eye color?

4. **Figure 12.16** In pea plants, purple flowers (P) are dominant to white flowers (p) and yellow peas (Y) are dominant to green peas (y). What are the possible genotypes and phenotypes for a cross between PpYY and ppYy pea plants? How many squares do you need to do a Punnett square analysis of this cross?

REVIEW QUESTIONS

5. Mendel performed hybridizations by transferring pollen from the _____ of the male plant to the female ova.

a. anther
b. pistil
c. stigma
d. seed

6. Which is one of the seven characteristics that Mendel observed in pea plants?

a. flower size
b. seed texture
c. leaf shape
d. stem color

7. Imagine you are performing a cross involving seed color in garden pea plants. What F_1 offspring would you expect if you cross true-breeding parents with green seeds and yellow seeds? Yellow seed color is dominant over green.

a. 100 percent yellow-green seeds
b. 100 percent yellow seeds
c. 50 percent yellow, 50 percent green seeds
d. 25 percent green, 75 percent yellow seeds

8. Consider a cross to investigate the pea pod texture trait, involving constricted or inflated pods. Mendel found that the traits behave according to a dominant/recessive pattern in which inflated pods were dominant. If you performed this cross and obtained 650 inflated-pod plants in the F_2 generation, approximately how many constricted-pod plants would you expect to have?

a. 600
b. 165
c. 217
d. 468

9. The observable traits expressed by an organism are described as its _____.

a. phenotype
b. genotype
c. alleles
d. zygote

10. A recessive trait will be observed in individuals that are _____ for that trait.

a. heterozygous
b. homozygous or heterozygous
c. homozygous
d. diploid

11. If black and white true-breeding mice are mated and the result is all gray offspring, what inheritance pattern would this be indicative of?

a. dominance
b. codominance
c. multiple alleles
d. incomplete dominance

12. The ABO blood groups in humans are expressed as the I^A, I^B, and i alleles. The I^A allele encodes the A blood group antigen, I^B encodes B, and i encodes O. Both A and B are dominant to O. If a heterozygous blood type A parent (I^Ai) and a heterozygous blood type B parent (I^Bi) mate, one quarter of their offspring will have AB blood type (I^AI^B) in which both antigens are expressed equally. Therefore, ABO blood groups are an example of:

a. multiple alleles and incomplete dominance
b. codominance and incomplete dominance
c. incomplete dominance only
d. multiple alleles and codominance

13. In a mating between two individuals that are heterozygous for a recessive lethal allele that is expressed *in utero*, what genotypic ratio (homozygous dominant:heterozygous:homozygous recessive) would you expect to observe in the offspring?

a. 1:2:1
b. 3:1:1
c. 1:2:0
d. 0:2:1

14. Assuming no gene linkage, in a dihybrid cross of *AABB* x *aabb* with *AaBb* F_1 heterozygotes, what is the ratio of the F_1 gametes (*AB*, *aB*, *Ab*, *ab*) that will give rise to the F_2 offspring?

a. 1:1:1:1
b. 1:3:3:1
c. 1:2:2:1
d. 4:3:2:1

15. The forked line and probability methods make use of what probability rule?

a. test cross
b. product rule
c. monohybrid rule
d. sum rule

16. How many different offspring genotypes are expected in a trihybrid cross between parents heterozygous for all three traits when the traits behave in a dominant and recessive pattern? How many phenotypes?

a. 64 genotypes; 16 phenotypes
b. 16 genotypes; 64 phenotypes
c. 8 genotypes; 27 phenotypes
d. 27 genotypes; 8 phenotypes

CRITICAL THINKING QUESTIONS

17. Describe one of the reasons why the garden pea was an excellent choice of model system for studying inheritance.

18. How would you perform a reciprocal cross for the characteristic of stem height in the garden pea?

19. The gene for flower position in pea plants exists as axial or terminal alleles. Given that axial is dominant to terminal, list all of the possible F_1 and F_2 genotypes and phenotypes from a cross involving parents that are homozygous for each trait. Express genotypes with conventional genetic abbreviations.

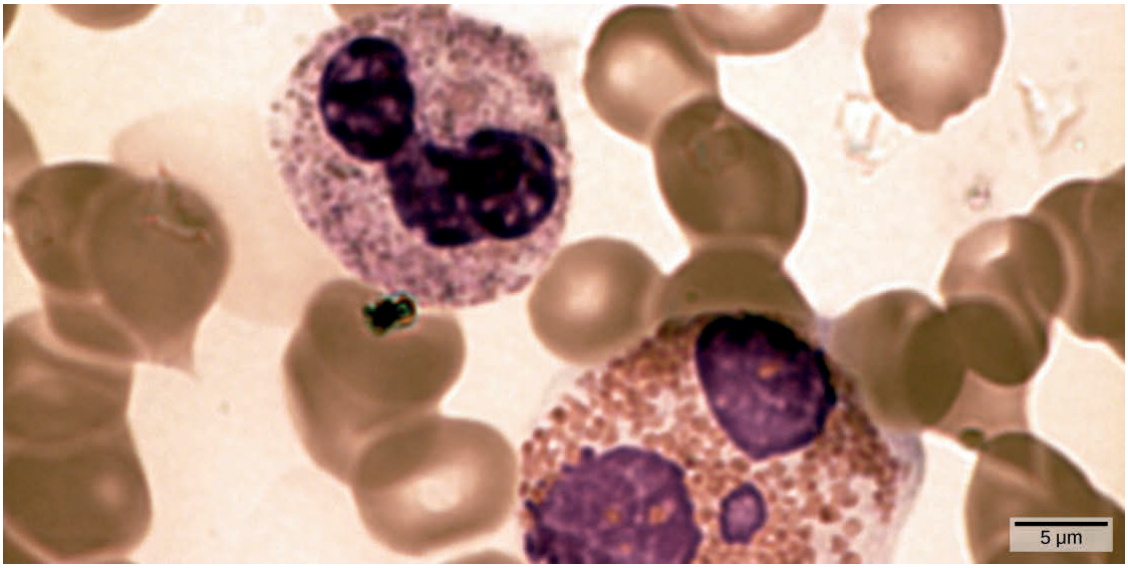
20. Use a Punnett square to predict the offspring in a cross between a dwarf pea plant (homozygous recessive) and a tall pea plant (heterozygous). What is the phenotypic ratio of the offspring?

21. Can a human male be a carrier of red-green color blindness?

22. Use the probability method to calculate the genotypes and genotypic proportions of a cross between *AABBCc* and *Aabbcc* parents.

23. Explain epistatis in terms of its Greek-language roots “standing upon.”

24. In Section 12.3, “Laws of Inheritance,” an example of epistasis was given for the summer squash. Cross white *WwYy* heterozygotes to prove the phenotypic ratio of 12 white:3 yellow:1 green that was given in the text.



CHAPTER SUMMARY

13.1 Chromosomal Theory and Genetic Linkage

The Chromosomal Theory of inheritance, proposed by Sutton and Boveri, states that chromosomes are the vehicles of genetic heredity. Neither Mendelian genetics nor gene linkage is perfectly accurate; instead, chromosome behavior involves segregation, independent assortment, and occasionally, linkage. Sturtevant devised a method to assess recombination frequency and infer the relative positions and distances of linked genes on a chromosome on the basis of the average number of crossovers in the intervening region between the genes. Sturtevant correctly presumed that genes are arranged in serial

order on chromosomes and that recombination between homologs can occur anywhere on a chromosome with equal likelihood. Whereas linkage causes alleles on the same chromosome to be inherited together, homologous recombination biases alleles toward an inheritance pattern of independent assortment.

13.2 Chromosomal Basis of Inherited Disorders

The number, size, shape, and banding pattern of chromosomes make them easily identifiable in a karyogram and allows for the assessment of many chromosomal abnormalities. Disorders in chromosome number, or aneuploidies, are typically lethal to the embryo, although a few trisomic genotypes are viable. Because of X inactivation, aberrations in sex chromosomes typically have milder phenotypic effects. Aneuploidies also include instances in which segments of a chromosome are duplicated or deleted. Chromosome structures may also be rearranged, for example by inversion or translocation. Both of these aberrations can result in problematic phenotypic effects. Because they force chromosomes to assume unnatural topologies during meiosis, inversions and translocations are often associated with reduced fertility because of the likelihood of nondisjunction.

ART CONNECTION QUESTIONS

1. **Figure 13.3** In a test cross for two characteristics such as the one shown here, can the predicted frequency of recombinant offspring be 60 percent? Why or why not?

2. **Figure 13.4** Which of the following statements is true?

a. Recombination of the body color and red/cinnabar eye alleles will occur more frequently than recombination of the alleles for wing length and aristae length.
b. Recombination of the body color and aristae length alleles will occur more frequently than recombination of red/brown eye alleles and the aristae length alleles.
c. Recombination of the gray/black body color and long/short aristae alleles will not occur.
d. Recombination of the red/brown eye and long/short aristae alleles will occur more frequently than recombination of the alleles for wing length and body color.

3. **Figure 13.6** Which of the following statements about nondisjunction is true?

a. Nondisjunction only results in gametes with n+1 or n–1 chromosomes.
b. Nondisjunction occurring during meiosis II results in 50 percent normal gametes.
c. Nondisjunction during meiosis I results in 50 percent normal gametes.
d. Nondisjunction always results in four different kinds of gametes.

REVIEW QUESTIONS

4. X-linked recessive traits in humans (or in *Drosophila*) are observed _____.

a. in more males than females
b. in more females than males
c. in males and females equally
d. in different distributions depending on the trait

5. The first suggestion that chromosomes may physically exchange segments came from the microscopic identification of _____.

a. synapsis
b. sister chromatids
c. chiasmata
d. alleles

6. Which recombination frequency corresponds to independent assortment and the absence of linkage?

a. 0
b. 0.25
c. 0.50
d. 0.75

7. Which recombination frequency corresponds to perfect linkage and violates the law of independent assortment?

a. 0
b. 0.25
c. 0.50
d. 0.75

8. Which of the following codes describes position 12 on the long arm of chromosome 13?

a. 13p12
b. 13q12
c. 12p13
d. 12q13

9. In agriculture, polyploid crops (like coffee, strawberries, or bananas) tend to produce _____.

a. more uniformity
b. more variety
c. larger yields
d. smaller yields

10. Assume a pericentric inversion occurred in one of two homologs prior to meiosis. The other homolog remains normal. During meiosis, what structure—if any—would these homologs assume in order to pair accurately along their lengths?

a. V formation
b. cruciform
c. loop
d. pairing would not be possible

11. The genotype XXY corresponds to
a. Klinefelter syndrome
b. Turner syndrome
c. Triplo-X
d. Jacob syndrome

12. Abnormalities in the number of X chromosomes tends to have milder phenotypic effects than the same abnormalities in autosomes because of _____.
a. deletions
b. nonhomologous recombination
c. synapsis
d. X inactivation

13. By definition, a pericentric inversion includes the _____.
a. centromere
b. chiasma
c. telomere
d. synapse

CRITICAL THINKING QUESTIONS

14. Explain how the Chromosomal Theory of Inheritance helped to advance our understanding of genetics.

15. Using diagrams, illustrate how nondisjunction can result in an aneuploid zygote.

CHAPTER SUMMARY

14.1 Historical Basis of Modern Understanding

DNA was first isolated from white blood cells by Friedrich Miescher, who called it nuclein because it was isolated from nuclei. Frederick Griffith's experiments with strains of *Streptococcus pneumoniae* provided the first hint that DNA may be the transforming principle. Avery, MacLeod, and McCarty proved that DNA is required for the transformation of bacteria. Later experiments by Hershey and Chase using bacteriophage T2 proved that DNA is the genetic material. Chargaff found that the ratio of A = T and C = G, and that the percentage content of A, T, G, and C is different for different species.

14.2 DNA Structure and Sequencing

The currently accepted model of the double-helix structure of DNA was proposed by Watson and Crick. Some of the salient features are that the two strands that make up the double helix are complementary and anti-parallel in nature. Deoxyribose sugars and phosphates form the backbone of the structure, and the nitrogenous bases are stacked inside. The diameter of the double helix, 2 nm, is uniform throughout. A purine always pairs with a pyrimidine; A pairs with T, and G pairs with C. One turn of the helix has ten base pairs. During cell division, each daughter cell receives a copy of the DNA by a process known as DNA replication. Prokaryotes are much simpler than eukaryotes in many of their features. Most prokaryotes contain a single, circular chromosome. In general, eukaryotic chromosomes contain a linear DNA molecule packaged into nucleosomes, and have two distinct regions that can be distinguished by staining, reflecting different states of packaging and compaction.

14.3 Basics of DNA Replication

The model for DNA replication suggests that the two strands of the double helix separate during replication, and each strand serves as a template from which the new complementary strand is copied. In conservative replication, the parental DNA is conserved, and the daughter DNA is newly synthesized. The semi-conservative method suggests that each of the two parental DNA strands acts as template for new DNA to be synthesized; after replication, each double-stranded DNA includes one parental or “old” strand and one “new” strand. The dispersive mode suggested that the two copies of the DNA would have segments of parental DNA and newly synthesized DNA.

14.4 DNA Replication in Prokaryotes

Replication in prokaryotes starts from a sequence found on the chromosome called the origin of replication—the point at which the DNA opens up. Helicase opens up the DNA double helix, resulting in the formation of the replication fork. Single-strand binding proteins bind to the single-stranded DNA near the replication fork to keep the fork open. Primase synthesizes an RNA primer to initiate synthesis by DNA polymerase, which can add nucleotides only in the 5' to 3' direction. One strand is synthesized continuously in the direction of the replication fork; this is called the leading strand. The other strand is synthesized in a direction away from the replication fork, in short stretches of DNA known as Okazaki fragments. This strand is known as the lagging strand. Once replication is completed, the RNA primers are replaced by DNA nucleotides and the DNA is sealed with DNA ligase, which creates phosphodiester bonds between the 3'-OH of one end and the 5' phosphate of the other strand.

14.5 DNA Replication in Eukaryotes

Replication in eukaryotes starts at multiple origins of replication. The mechanism is quite similar to prokaryotes. A primer is required to initiate synthesis, which is then extended by DNA polymerase as it adds nucleotides one by one to the growing chain. The leading strand is synthesized continuously, whereas the lagging strand is synthesized in short stretches called Okazaki fragments. The RNA primers are replaced with DNA nucleotides; the DNA remains one continuous strand by linking the DNA fragments with DNA ligase. The ends of the chromosomes pose a problem as polymerase is unable to extend them without a primer. Telomerase, an enzyme with an inbuilt RNA template, extends the ends by copying the RNA template and extending one end of the chromosome. DNA polymerase can then extend the DNA using the primer. In this way, the ends of the chromosomes are protected.

14.6 DNA Repair

DNA polymerase can make mistakes while adding nucleotides. It edits the DNA by proofreading every newly added base. Incorrect bases are removed and replaced by the correct base, and then a new base is added. Most mistakes are corrected during replication, although when this does not happen, the mismatch repair mechanism is employed. Mismatch repair enzymes recognize the wrongly incorporated base and excise it from the DNA, replacing it with the correct base. In yet another type of repair, nucleotide excision repair, the incorrect base is removed along with a few bases on the 5' and 3' end, and these are replaced by copying the template with the help of DNA polymerase. The ends of the newly synthesized fragment are attached to the rest of the DNA using DNA ligase, which creates a phosphodiester bond.

Most mistakes are corrected, and if they are not, they may result in a mutation defined as a permanent change in the DNA sequence. Mutations can be of many types, such as substitution, deletion, insertion, and translocation. Mutations in repair genes may lead to serious consequences such as cancer. Mutations can be induced or may occur spontaneously.

ART CONNECTION QUESTIONS

1. **Figure 14.10** In eukaryotic cells, DNA and RNA synthesis occur in a separate compartment from protein synthesis. In prokaryotic cells, both processes occur together. What advantages might there be to separating the processes? What advantages might there be to having them occur together?

2. **Figure 14.14** You isolate a cell strain in which the joining together of Okazaki fragments is impaired and suspect that a mutation has occurred in an enzyme found at the replication fork. Which enzyme is most likely to be mutated?

3. **Figure 14.21** A frameshift mutation that results in the insertion of three nucleotides is often less deleterious than a mutation that results in the insertion of one nucleotide. Why?

REVIEW QUESTIONS

4. If DNA of a particular species was analyzed and it was found that it contains 27 percent A, what would be the percentage of C?

a. 27 percent
b. 30 percent
c. 23 percent
d. 54 percent

5. The experiments by Hershey and Chase helped confirm that DNA was the hereditary material on the basis of the finding that:

a. radioactive phage were found in the pellet
b. radioactive cells were found in the supernatant
c. radioactive sulfur was found inside the cell
d. radioactive phosphorus was found in the cell

6. DNA double helix does not have which of the following?

a. antiparallel configuration
b. complementary base pairing
c. major and minor grooves
d. uracil

7. In eukaryotes, what is the DNA wrapped around?

a. single-stranded binding proteins
b. sliding clamp
c. polymerase
d. histones

8. Meselson and Stahl's experiments proved that DNA replicates by which mode?

a. conservative
b. semi-conservative
c. dispersive
d. none of the above

9. If the sequence of the 5'-3' strand is AATGCTAC, then the complementary sequence has the following sequence:

a. 3'-AATGCTAC-5'
b. 3'-CATCGTAA-5'
c. 3'-TTACGATG-5'
d. 3'-GTAGCATT-5'

10. Which of the following components is not involved during the formation of the replication fork?

a. single-strand binding proteins
b. helicase
c. origin of replication
d. ligase

11. Which of the following does the enzyme primase synthesize?

a. DNA primer
b. RNA primer
c. Okazaki fragments
d. phosphodiester linkage

12. In which direction does DNA replication take place?

a. 5'-3'
b. 3'-5'
c. 5'
d. 3'

13. The ends of the linear chromosomes are maintained by

a. helicase
b. primase
c. DNA pol
d. telomerase

14. During proofreading, which of the following enzymes reads the DNA?

a. primase
b. topoisomerase
c. DNA pol
d. helicase

15. The initial mechanism for repairing nucleotide errors in DNA is _____.

a. mismatch repair
b. DNA polymerase proofreading
c. nucleotide excision repair
d. thymine dimers

CRITICAL THINKING QUESTIONS

16. Explain Griffith's transformation experiments. What did he conclude from them?

17. Why were radioactive sulfur and phosphorous used to label bacteriophage in Hershey and Chase's experiments?

18. Provide a brief summary of the Sanger sequencing method.

19. Describe the structure and complementary base pairing of DNA.

20. How did the scientific community learn that DNA replication takes place in a semi-conservative fashion?

21. DNA replication is bidirectional and discontinuous; explain your understanding of those concepts.

22. What are Okazaki fragments and how they are formed?

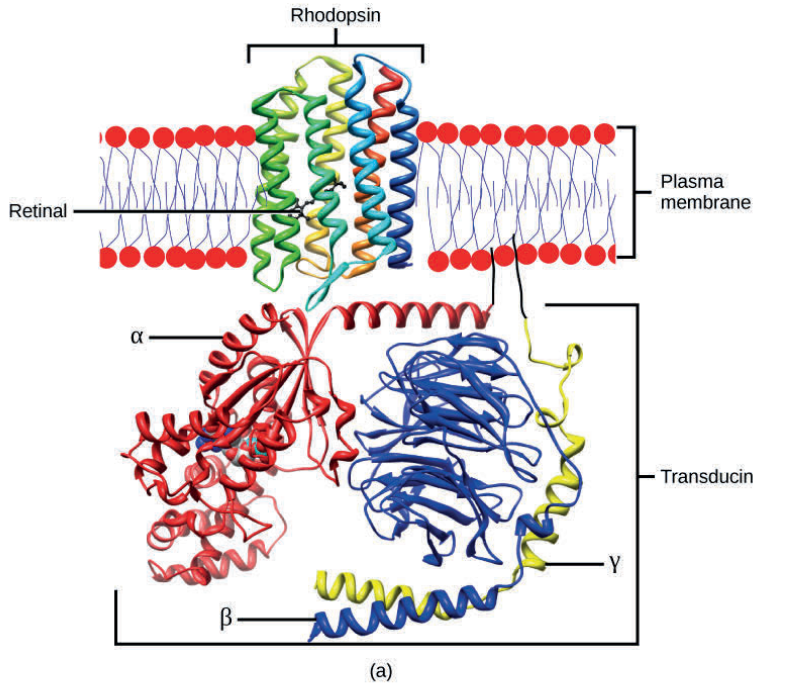
23. If the rate of replication in a particular prokaryote is 900 nucleotides per second, how long would it take 1.2 million base pair genomes to make two copies?

24. Explain the events taking place at the replication fork. If the gene for helicase is mutated, what part of replication will be affected?

25. What is the role of a primer in DNA replication? What would happen if you forgot to add a primer in a tube containing the reaction mix for a DNA sequencing reaction?

26. How do the linear chromosomes in eukaryotes ensure that its ends are replicated completely?

27. What is the consequence of mutation of a mismatch repair enzyme? How will this affect the function of a gene?



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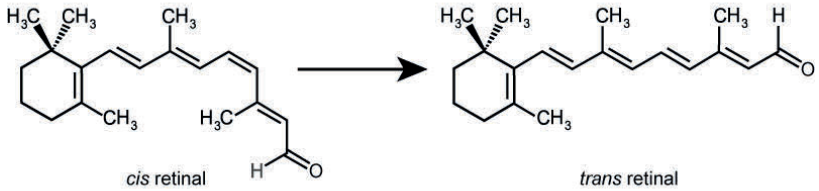

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CHAPTER SUMMARY

15.1 The Genetic Code

The genetic code refers to the DNA alphabet (A, T, C, G), the RNA alphabet (A, U, C, G), and the polypeptide alphabet (20 amino acids). The Central Dogma describes the flow of genetic information in the cell from genes to mRNA to proteins. Genes are used to make mRNA by the process of transcription; mRNA is used to synthesize proteins by the process of translation. The genetic code is

degenerate because 64 triplet codons in mRNA specify only 20 amino acids and three nonsense codons. Almost every species on the planet uses the same genetic code.

15.2 Prokaryotic Transcription

In prokaryotes, mRNA synthesis is initiated at a promoter sequence on the DNA template comprising two consensus sequences that recruit RNA polymerase. The prokaryotic polymerase consists of a core enzyme of four protein subunits and a σ protein that assists only with initiation. Elongation synthesizes mRNA in the 5' to 3' direction at a rate of 40 nucleotides per second. Termination liberates the mRNA and occurs either by rho protein interaction or by the formation of an mRNA hairpin.

15.3 Eukaryotic Transcription

Transcription in eukaryotes involves one of three types of polymerases, depending on the gene being transcribed. RNA polymerase II transcribes all of the protein-coding genes, whereas RNA polymerase I transcribes rRNA genes, and RNA polymerase III transcribes rRNA, tRNA, and small nuclear RNA genes. The initiation of transcription in eukaryotes involves the binding of several transcription factors to complex promoter sequences that are usually located upstream of the gene being copied. The mRNA is synthesized in the 5' to 3' direction, and the FACT complex moves and reassembles nucleosomes as the polymerase passes by. Whereas RNA polymerases I and III terminate transcription by protein- or RNA hairpin-dependent methods, RNA polymerase II transcribes for 1,000 or more nucleotides beyond the gene template and cleaves the excess during pre-mRNA processing.

15.4 RNA Processing in Eukaryotes

Eukaryotic pre-mRNAs are modified with a 5' methylguanosine cap and a poly-A tail. These structures protect the mature mRNA from degradation and help export it from the nucleus. Pre-mRNAs also undergo splicing, in which introns are removed and exons are reconnected with single-nucleotide accuracy. Only finished mRNAs that have undergone 5' capping, 3' polyadenylation, and intron splicing are exported from the nucleus to the cytoplasm. Pre-rRNAs and pre-tRNAs may be processed by intramolecular cleavage, splicing, methylation, and chemical conversion of nucleotides. Rarely, RNA editing is also performed to insert missing bases after an mRNA has been synthesized.

15.5 Ribosomes and Protein Synthesis

The players in translation include the mRNA template, ribosomes, tRNAs, and various enzymatic factors. The small ribosomal subunit forms on the mRNA template either at the Shine-Dalgarno sequence (prokaryotes) or the 5' cap (eukaryotes). Translation begins at the initiating AUG on the mRNA, specifying methionine. The formation of peptide bonds occurs between sequential amino acids specified by the mRNA template according to the genetic code. Charged tRNAs enter the ribosomal A site, and their amino acid bonds with the amino acid at the P site. The entire mRNA is translated in three-nucleotide “steps” of the ribosome. When a nonsense codon is encountered, a release factor binds and dissociates the components and frees the new protein. Folding of the protein occurs during and after translation.

ART CONNECTION QUESTIONS

1. **Figure 15.11** A scientist splices a eukaryotic promoter in front of a bacterial gene and inserts the gene in a bacterial chromosome. Would you expect the bacteria to transcribe the gene?

2. **Figure 15.13** Errors in splicing are implicated in cancers and other human diseases. What kinds of mutations might lead to splicing errors? Think of different possible outcomes if splicing errors occur.

3. **Figure 15.16** Many antibiotics inhibit bacterial protein synthesis. For example, tetracycline blocks the A site on the bacterial ribosome, and chloramphenicol blocks peptidyl transfer. What specific effect would you expect each of these antibiotics to have on protein synthesis?

Tetracycline would directly affect:

a. tRNA binding to the ribosome
b. ribosome assembly
c. growth of the protein chain

Chloramphenicol would directly affect

a. tRNA binding to the ribosome
b. ribosome assembly
c. growth of the protein chain

REVIEW QUESTIONS

4. The AUC and AUA codons in mRNA both specify isoleucine. What feature of the genetic code explains this?

a. complementarity
b. nonsense codons
c. universality
d. degeneracy

5. How many nucleotides are in 12 mRNA codons?

a. 12
b. 24
c. 36
d. 48

6. Which subunit of the *E. coli* polymerase confers specificity to transcription?

a. α
b. β
c. β'
d. σ

7. The -10 and -35 regions of prokaryotic promoters are called consensus sequences because _____.

a. they are identical in all bacterial species
b. they are similar in all bacterial species
c. they exist in all organisms
d. they have the same function in all organisms

8. Which feature of promoters can be found in both prokaryotes and eukaryotes?

a. GC box
b. TATA box
c. octamer box
d. -10 and -35 sequences

9. What transcripts will be most affected by low levels of α-amanitin?

a. 18S and 28S rRNAs
b. pre-mRNAs
c. 5S rRNAs and tRNAs
d. other small nuclear RNAs

10. Which pre-mRNA processing step is important for initiating translation?

a. poly-A tail
b. RNA editing
c. splicing
d. 7-methylguanosine cap

11. What processing step enhances the stability of pre-tRNAs and pre-rRNAs?

a. methylation
b. nucleotide modification
c. cleavage
d. splicing

12. The RNA components of ribosomes are synthesized in the _____.

a. cytoplasm
b. nucleus
c. nucleolus
d. endoplasmic reticulum

13. In any given species, there are at least how many types of aminoacyl tRNA synthetases?

a. 20
b. 40
c. 100
d. 200

CRITICAL THINKING QUESTIONS

14. Imagine if there were 200 commonly occurring amino acids instead of 20. Given what you know about the genetic code, what would be the shortest possible codon length? Explain.

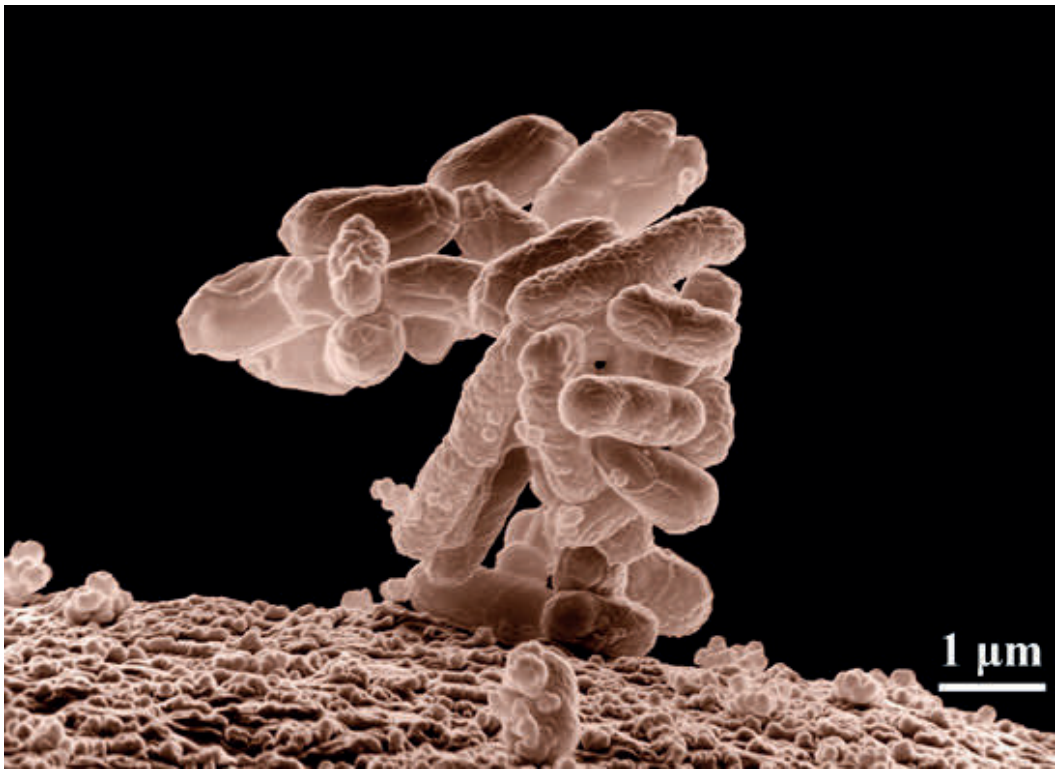
15. Discuss how degeneracy of the genetic code makes cells more robust to mutations.

16. If mRNA is complementary to the DNA template strand and the DNA template strand is complementary to the DNA nontemplate strand, then why are base sequences of mRNA and the DNA nontemplate strand not identical? Could they ever be?

17. In your own words, describe the difference between rho-dependent and rho-independent termination of transcription in prokaryotes.

18. Transcribe and translate the following DNA sequence (nontemplate strand): 5'-ATGGCCGGTTATTAAGCA-3'

19. Explain how single nucleotide changes can have vastly different effects on protein function.



CHAPTER SUMMARY

16.1 Regulation of Gene Expression

While all somatic cells within an organism contain the same DNA, not all cells within that organism express the same proteins. Prokaryotic organisms express the entire DNA they encode in every cell, but not necessarily all at the same time. Proteins are expressed only when they are needed. Eukaryotic organisms express a subset of the DNA that is encoded in any given cell. In each cell type, the type and amount of protein is regulated by controlling gene expression. To express a protein, the DNA is first transcribed into RNA, which is then translated into proteins. In prokaryotic cells, these processes occur almost simultaneously. In eukaryotic cells, transcription occurs in the nucleus and is separate from the translation that occurs in the cytoplasm. Gene expression in prokaryotes is regulated only at the transcriptional level, whereas in eukaryotic cells, gene expression is regulated at the epigenetic, transcriptional, post-transcriptional, translational, and post-translational levels.

16.2 Prokaryotic Gene Regulation

The regulation of gene expression in prokaryotic cells occurs at the transcriptional level. There are three ways to control the transcription of an operon: repressive control, activator control, and inducible control. Repressive control, typified by the *trp* operon, uses proteins bound to the operator sequence to physically prevent the binding of RNA polymerase and the activation of transcription. Therefore, if tryptophan is not needed, the repressor is bound to the operator and transcription remains off. Activator control, typified by the action of CAP, increases the binding ability of RNA polymerase to the promoter when CAP is bound. In this case, low levels of glucose result in the binding of cAMP to CAP. CAP

then binds the promoter, which allows RNA polymerase to bind to the promoter better. In the last example—the *lac* operon—two conditions must be met to initiate transcription. Glucose must not be present, and lactose must be available for the *lac* operon to be transcribed. If glucose is absent, CAP binds to the operator. If lactose is present, the repressor protein does not bind to its operator. Only when both conditions are met will RNA polymerase bind to the promoter to induce transcription.

16.3 Eukaryotic Epigenetic Gene Regulation

In eukaryotic cells, the first stage of gene expression control occurs at the epigenetic level. Epigenetic mechanisms control access to the chromosomal region to allow genes to be turned on or off. These mechanisms control how DNA is packed into the nucleus by regulating how tightly the DNA is wound around histone proteins. The addition or removal of chemical modifications (or flags) to histone proteins or DNA signals to the cell to open or close a chromosomal region. Therefore, eukaryotic cells can control whether a gene is expressed by controlling accessibility to transcription factors and the binding of RNA polymerase to initiate transcription.

16.4 Eukaryotic Transcription Gene Regulation

To start transcription, general transcription factors, such as TFIID, TFIIH, and others, must first bind to the TATA box and recruit RNA polymerase to that location. The binding of additional regulatory transcription factors to *cis*-acting elements will either increase or prevent transcription. In addition to promoter sequences, enhancer regions help augment transcription. Enhancers can be upstream, downstream, within a gene itself, or on other chromosomes. Transcription factors bind to enhancer regions to increase or prevent transcription.

16.5 Eukaryotic Post-transcriptional Gene Regulation

Post-transcriptional control can occur at any stage after transcription, including RNA splicing, nuclear shuttling, and RNA stability. Once RNA is transcribed, it must be processed to create a mature RNA that is ready to be translated. This involves the removal of introns that do not code for protein. Spliceosomes bind to the signals that mark the exon/intron border to remove the introns and ligate the exons together. Once this occurs, the RNA is mature and can be translated. RNA is created and spliced in the nucleus, but needs to be transported to the cytoplasm to be translated. RNA is transported to the cytoplasm through the nuclear pore complex. Once the RNA is in the cytoplasm, the length of time it resides there before being degraded, called RNA stability, can also be altered to control the overall amount of protein that is synthesized. The RNA stability can be increased, leading to longer residency time in the cytoplasm, or decreased, leading to shortened time and less protein synthesis. RNA stability is controlled by RNA-binding proteins (RPBs) and microRNAs (miRNAs). These RPBs and miRNAs bind to the 5' UTR or the 3' UTR of the RNA to increase or decrease RNA stability. Depending on the RBP, the stability can be increased or decreased significantly; however, miRNAs always decrease stability and promote decay.

16.6 Eukaryotic Translational and Post-translational Gene Regulation

Changing the status of the RNA or the protein itself can affect the amount of protein, the function of the protein, or how long it is found in the cell. To translate the protein, a protein initiator complex must assemble on the RNA. Modifications (such as phosphorylation) of proteins in this complex can prevent proper translation from occurring. Once a protein has been synthesized, it can be modified (phosphorylated, acetylated, methylated, or ubiquitinated). These post-translational modifications can greatly impact the stability, degradation, or function of the protein.

16.7 Cancer and Gene Regulation

Cancer can be described as a disease of altered gene expression. Changes at every level of eukaryotic gene expression can be detected in some form of cancer at some point in time. In order to understand how changes to gene expression can cause cancer, it is critical to understand how each stage of gene regulation works in normal cells. By understanding the mechanisms of control in normal, non-diseased cells, it will be easier for scientists to understand what goes wrong in disease states including complex ones like cancer.

ART CONNECTION QUESTIONS

1. **Figure 16.5** In *E. coli*, the *trp* operon is on by default, while the *lac* operon is off. Why do you think that this is the case?

2. **Figure 16.7** In females, one of the two X chromosomes is inactivated during embryonic development because of epigenetic changes to the chromatin. What impact do you think these changes would have on nucleosome packing?

3. **Figure 16.13** An increase in phosphorylation levels of eIF-2 has been observed in patients with neurodegenerative diseases such as Alzheimer's, Parkinson's, and Huntington's. What impact do you think this might have on protein synthesis?

REVIEW QUESTIONS

4. Control of gene expression in eukaryotic cells occurs at which level(s)?

a. only the transcriptional level
b. epigenetic and transcriptional levels
c. epigenetic, transcriptional, and translational levels
d. epigenetic, transcriptional, post-transcriptional, translational, and post-translational levels

5. Post-translational control refers to:

a. regulation of gene expression after transcription
b. regulation of gene expression after translation
c. control of epigenetic activation
d. period between transcription and translation

6. If glucose is absent, but so is lactose, the *lac* operon will be _____.

a. activated
b. repressed
c. activated, but only partially
d. mutated

7. Prokaryotic cells lack a nucleus. Therefore, the genes in prokaryotic cells are:

a. all expressed, all of the time
b. transcribed and translated almost simultaneously
c. transcriptionally controlled because translation begins before transcription ends
d. b and c are both true

8. What are epigenetic modifications?

a. the addition of reversible changes to histone proteins and DNA
b. the removal of nucleosomes from the DNA
c. the addition of more nucleosomes to the DNA
d. mutation of the DNA sequence

9. Which of the following are true of epigenetic changes?

a. allow DNA to be transcribed
b. move histones to open or close a chromosomal region
c. are temporary
d. all of the above

10. The binding of _____ is required for transcription to start.

a. a protein
b. DNA polymerase
c. RNA polymerase
d. a transcription factor

11. What will result from the binding of a transcription factor to an enhancer region?

a. decreased transcription of an adjacent gene
b. increased transcription of a distant gene
c. alteration of the translation of an adjacent gene
d. initiation of the recruitment of RNA polymerase

12. Which of the following are involved in post-transcriptional control?

a. control of RNA splicing
b. control of RNA shuttling
c. control of RNA stability
d. all of the above

13. Binding of an RNA binding protein will _____ the stability of the RNA molecule.

a. increase
b. decrease
c. neither increase nor decrease
d. either increase or decrease

14. Post-translational modifications of proteins can affect which of the following?

a. protein function
b. transcriptional regulation
c. chromatin modification
d. all of the above

15. Cancer causing genes are called _____.

a. transformation genes
b. tumor suppressor genes
c. oncogenes
d. mutated genes

16. Targeted therapies are used in patients with a set gene expression pattern. A targeted therapy that prevents the activation of the estrogen receptor in breast cancer would be beneficial to which type of patient?

a. patients who express the EGFR receptor in normal cells
b. patients with a mutation that inactivates the estrogen receptor

c. patients with lots of the estrogen receptor expressed in their tumor

d. patients that have no estrogen receptor expressed in their tumor

CRITICAL THINKING QUESTIONS

17. Name two differences between prokaryotic and eukaryotic cells and how these differences benefit multicellular organisms.

18. Describe how controlling gene expression will alter the overall protein levels in the cell.

19. Describe how transcription in prokaryotic cells can be altered by external stimulation such as excess lactose in the environment.

20. What is the difference between a repressible and an inducible operon?

21. In cancer cells, alteration to epigenetic modifications turns off genes that are normally expressed. Hypothetically, how could you reverse this process to turn these genes back on?

22. A mutation within the promoter region can alter transcription of a gene. Describe how this can happen.

23. What could happen if a cell had too much of an activating transcription factor present?

24. Describe how RBPs can prevent miRNAs from degrading an RNA molecule.

25. How can external stimuli alter post-transcriptional control of gene expression?

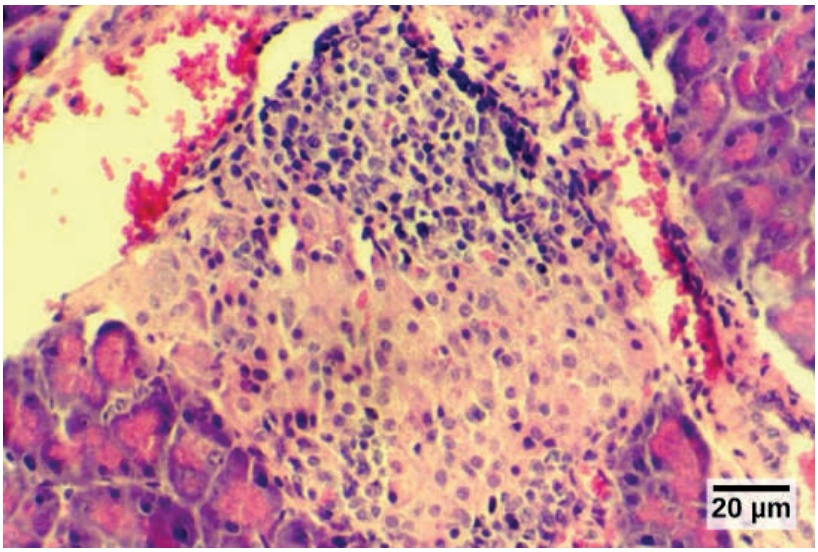
26. Protein modification can alter gene expression in many ways. Describe how phosphorylation of proteins can alter gene expression.

27. Alternative forms of a protein can be beneficial or harmful to a cell. What do you think would happen if too much of an alternative protein bound to the 3' UTR of an RNA and caused it to degrade?

28. Changes in epigenetic modifications alter the accessibility and transcription of DNA. Describe how environmental stimuli, such as ultraviolet light exposure, could modify gene expression.

29. New drugs are being developed that decrease DNA methylation and prevent the removal of acetyl groups from histone proteins. Explain how these drugs could affect gene expression to help kill tumor cells.

30. How can understanding the gene expression pattern in a cancer cell tell you something about that specific form of cancer?



CHAPTER SUMMARY

17.1 Biotechnology

Nucleic acids can be isolated from cells for the purposes of further analysis by breaking open the cells and enzymatically destroying all other major macromolecules. Fragmented or whole chromosomes can be separated on the basis of size by gel electrophoresis. Short stretches of DNA or RNA can be amplified by PCR. Southern and northern blotting can be used to detect the presence of specific short sequences in a DNA or RNA sample. The term “cloning” may refer to cloning small DNA fragments (molecular cloning), cloning cell populations (cellular cloning), or cloning entire organisms (reproductive cloning). Genetic testing is performed to identify disease-causing genes, and gene therapy is used to cure an inheritable disease.

Transgenic organisms possess DNA from a different species, usually generated by molecular cloning techniques. Vaccines, antibiotics, and hormones are examples of products obtained by recombinant DNA technology. Transgenic plants are usually created to improve characteristics of crop plants.

17.2 Mapping Genomes

Genome mapping is similar to solving a big, complicated puzzle with pieces of information coming from laboratories all over the world. Genetic maps provide an outline for the location of genes within a genome, and they estimate the distance between genes and genetic markers on the basis of recombination frequencies during meiosis. Physical maps provide detailed information about the physical distance between the genes. The most detailed information is available through sequence mapping. Information from all mapping and sequencing sources is combined to study an entire genome.

17.3 Whole-Genome Sequencing

Whole-genome sequencing is the latest available resource to treat genetic diseases. Some doctors are using whole-genome sequencing to save lives. Genomics has many industrial applications including biofuel development, agriculture, pharmaceuticals, and pollution control. The basic principle of all modern-day sequencing strategies involves the chain termination method of sequencing.

Although the human genome sequences provide key insights to medical professionals, researchers use whole-genome sequences of model organisms to better understand the genome of the species. Automation and the decreased cost of whole-genome sequencing may lead to personalized medicine in the future.

17.4 Applying Genomics

Imagination is the only barrier to the applicability of genomics. Genomics is being applied to most fields of biology; it is being used for personalized medicine, prediction of disease risks at an individual level, the study of drug interactions before the conduct of clinical trials, and the study of microorganisms in the environment as opposed to the laboratory. It is also being applied to developments such as the generation of new biofuels, genealogical assessment using mitochondria, advances in forensic science, and improvements in agriculture.

17.5 Genomics and Proteomics

Proteomics is the study of the entire set of proteins expressed by a given type of cell under certain environmental conditions. In a multicellular organism, different cell types will have different proteomes, and these will vary with changes in the environment. Unlike a genome, a proteome is dynamic and in constant flux, which makes it both more complicated and more useful than the knowledge of genomes alone.

Proteomics approaches rely on protein analysis; these techniques are constantly being upgraded. Proteomics has been used to study different types of cancer. Different biomarkers and protein signatures are being used to analyze each type of cancer. The future goal is to have a personalized treatment plan for each individual.

ART CONNECTION QUESTIONS

1. **Figure 17.6** You are working in a molecular biology lab and, unbeknownst to you, your lab partner left the foreign genomic DNA that you are planning to clone on the lab bench overnight instead of storing it in the freezer. As a result, it was degraded by nucleases, but still used in the experiment. The plasmid, on the other hand, is fine. What results would you expect from your molecular cloning experiment?

a. There will be no colonies on the bacterial plate.
b. There will be blue colonies only.
c. There will be blue and white colonies.
d. The will be white colonies only.

2. **Figure 17.8** Do you think Dolly was a Finn-Dorset or a Scottish Blackface sheep?

3. **Figure 17.15** In 2011, the United States Preventative Services Task Force recommended against using the PSA test to screen healthy men for prostate cancer. Their recommendation is based on evidence that screening does not reduce the risk of death from prostate cancer. Prostate cancer often develops very slowly and does not cause problems, while the cancer treatment can have severe side effects. The *PCA3* test is considered to be more accurate, but screening may still result in men who would not have been harmed by the cancer itself suffering side effects from treatment. What do you think? Should all healthy men be screened for prostate cancer using the *PCA3* or PSA test? Should people in general be screened to find out if they have a genetic risk for cancer or other diseases?

REVIEW QUESTIONS

4. GMOs are created by _____.

a. generating genomic DNA fragments with restriction endonucleases
b. introducing recombinant DNA into an organism by any means
c. overexpressing proteins in *E. coli.*
d. all of the above

5. Gene therapy can be used to introduce foreign DNA into cells _____.

a. for molecular cloning
b. by PCR
c. of tissues to cure inheritable disease
d. all of the above

6. Insulin produced by molecular cloning:

a. is of pig origin
b. is a recombinant protein
c. is made by the human pancreas
d. is recombinant DNA

7. Bt toxin is considered to be _____.

a. a gene for modifying insect DNA
b. an organic insecticide produced by bacteria
c. useful for humans to fight against insects

d. a recombinant protein

8. The Flavr Savr Tomato:
a. is a variety of vine-ripened tomato in the supermarket
b. was created to have better flavor and shelf-life
c. does not undergo soft rot
d. all of the above

9. ESTs are _____.
a. generated after a cDNA library is made
b. unique sequences in the genome
c. useful for mapping using sequence information
d. all of the above

10. Linkage analysis _____.
a. is used to create a physical map
b. is based on the natural recombination process
c. requires radiation hybrid mapping
d. involves breaking and re-joining of DNA artificially

11. Genetic recombination occurs by which process?
a. independent assortment
b. crossing over
c. chromosome segregation
d. sister chromatids

12. Individual genetic maps in a given species are:
a. genetically similar
b. genetically identical
c. genetically dissimilar
d. not useful in species analysis

13. Information obtained by microscopic analysis of stained chromosomes is used in:
a. radiation hybrid mapping
b. sequence mapping
c. RFLP mapping
d. cytogenetic mapping

14. The chain termination method of sequencing:
a. uses labeled ddNTPs
b. uses only dideoxynucleotides
c. uses only deoxynucleotides
d. uses labeled dNTPs

15. Whole-genome sequencing can be used for advances in:
a. the medical field
b. agriculture
c. biofuels
d. all of the above

16. Sequencing an individual person's genome
a. is currently possible
b. could lead to legal issues regarding discrimination and privacy
c. could help make informed choices about medical treatment
d. all of the above

17. What is the most challenging issue facing genome sequencing?
a. the inability to develop fast and accurate sequencing techniques
b. the ethics of using information from genomes at the individual level
c. the availability and stability of DNA
d. all of the above

18. Genomics can be used in agriculture to:
a. generate new hybrid strains
b. improve disease resistance
c. improve yield
d. all of the above

19. Genomics can be used on a personal level to:
a. decrease transplant rejection
b. Predict genetic diseases that a person may have inherited
c. Determine the risks of genetic diseases for an individual's children
d. All the above

20. What is a biomarker?
a. the color coding of different genes
b. a protein that is uniquely produced in a diseased state
c. a molecule in the genome or proteome
d. a marker that is genetically inherited

21. A protein signature is:
a. the path followed by a protein after it is synthesized in the nucleus
b. the path followed by a protein in the cytoplasm
c. a protein expressed on the cell surface
d. a unique set of proteins present in a diseased state

CRITICAL THINKING QUESTIONS

22. Describe the process of Southern blotting.

23. A researcher wants to study cancer cells from a patient with breast cancer. Is cloning the cancer cells an option?

24. How would a scientist introduce a gene for herbicide resistance into a plant?

25. If you had a chance to get your genome sequenced, what are some questions you might be able to have answered about yourself?

26. Why is so much effort being poured into genome mapping applications?

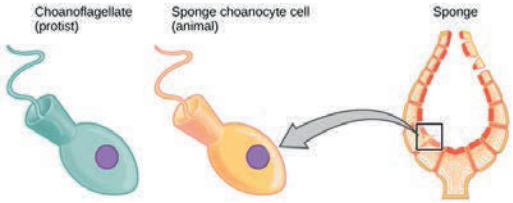
27. How could a genetic map of the human genome help find a cure for cancer?

28. Explain why metagenomics is probably the most revolutionary application of genomics.

29. How can genomics be used to predict disease risk and treatment options?

30. How has proteomics been used in cancer detection and treatment?

31. What is personalized medicine?



CHAPTER SUMMARY

18.1 Understanding Evolution

Evolution is the process of adaptation through mutation which allows more desirable characteristics to be passed to the next generation. Over time, organisms evolve more characteristics that are beneficial to their survival. For living organisms to adapt and change to environmental pressures, genetic variation must be present. With genetic variation, individuals have differences in form and function that allow some to survive certain conditions better than others. These organisms pass their favorable traits to their offspring. Eventually, environments change, and what was once a desirable, advantageous trait may become an undesirable trait and organisms may further evolve. Evolution may be convergent with similar traits evolving in multiple species or divergent with diverse traits evolving in multiple species that came from a common ancestor. Evidence of evolution can be observed by means of DNA code and the fossil record, and also by the existence of homologous and vestigial structures.

18.2 Formation of New Species

Speciation occurs along two main pathways: geographic separation (allopatric speciation) and through mechanisms that occur within a shared habitat (sympatric speciation). Both pathways isolate a population reproductively in some form. Mechanisms of reproductive isolation act as barriers between closely related species, enabling them to diverge and exist as genetically independent species. Prezygotic barriers block reproduction prior to formation of a zygote, whereas postzygotic barriers block reproduction after fertilization occurs. For a new species to develop, something must cause a breach in the reproductive barriers. Sympatric speciation can occur through errors in meiosis that form gametes with extra chromosomes (polyploidy). Autopolyploidy occurs within a single species, whereas allopolyploidy occurs between closely related species.

18.3 Reconnection and Rates of Speciation

Speciation is not a precise division: overlap between closely related species can occur in areas called hybrid zones. Organisms reproduce with other similar organisms. The fitness of these hybrid offspring can affect the evolutionary path of the two species. Scientists propose two models for the rate of speciation: one model illustrates how a species can change slowly over time; the other model demonstrates how change can occur quickly from a parent generation to a new species. Both models continue to follow the patterns of natural selection.

ART CONNECTION QUESTIONS

1. **Figure 18.14** Which is most likely to survive, offspring with $2n+1$ chromosomes or offspring with $2n-1$ chromosomes?

2. **Figure 18.22** If two species eat a different diet but one of the food sources is eliminated and both species are forced to eat the same foods, what change in the hybrid zone is most likely to occur?

3. **Figure 18.23** Which of the following statements is false?

a. Punctuated equilibrium is most likely to occur in a small population that experiences a rapid change in its environment.
b. Punctuated equilibrium is most likely to occur in a large population that lives in a stable climate.
c. Gradual speciation is most likely to occur in species that live in a stable climate.

d. Gradual speciation and punctuated equilibrium both result in the evolution of new species.

REVIEW QUESTIONS

4. Which scientific concept did Charles Darwin and Alfred Wallace independently discover?

a. mutation
b. natural selection
c. overbreeding
d. sexual reproduction

5. Which of the following situations will lead to natural selection?

a. The seeds of two plants land near each other and one grows larger than the other.
b. Two types of fish eat the same kind of food, and one is better able to gather food than the other.
c. Male lions compete for the right to mate with females, with only one possible winner.
d. all of the above

6. Which description is an example of a phenotype?

a. A certain duck has a blue beak.
b. A mutation occurred to a flower.
c. Most cheetahs live solitary lives.
d. both a and c

7. Which situation is most likely an example of convergent evolution?

a. Squid and humans have eyes similar in structure.
b. Worms and snakes both move without legs.
c. Some bats and birds have wings that allow them to fly
d. all of the above

8. Which situation would most likely lead to allopatric speciation?

a. flood causes the formation of a new lake.
b. A storm causes several large trees to fall down.
c. A mutation causes a new trait to develop.
d. An injury causes an organism to seek out a new food source.

9. What is the main difference between dispersal and vicariance?

a. One leads to allopatric speciation, whereas the other leads to sympatric speciation.
b. One involves the movement of the organism, and the other involves a change in the environment.
c. One depends on a genetic mutation occurring, and the other does not.
d. One involves closely related organisms, and the other involves only individuals of the same species.

10. Which variable increases the likelihood of allopatric speciation taking place more quickly?

a. lower rate of mutation
b. longer distance between divided groups
c. increased instances of hybrid formation
d. equivalent numbers of individuals in each population

11. What is the main difference between autopolyploid and allopolyploid?

a. the number of chromosomes
b. the functionality of the chromosomes
c. the source of the extra chromosomes
d. the number of mutations in the extra chromosomes

12. Which reproductive combination produces hybrids?

a. when individuals of the same species in different geographical areas reproduce
b. when any two individuals sharing the same habitat reproduce
c. when members of closely related species reproduce
d. when offspring of the same parents reproduce

13. Which condition is the basis for a species to be reproductively isolated from other members?

a. It does not share its habitat with related species.
b. It does not exist out of a single habitat.
c. It does not exchange genetic information with other species.
d. It does not undergo evolutionary changes for a significant period of time.

14. Which situation is *not* an example of a prezygotic barrier?

a. Two species of turtles breed at different times of the year.
b. Two species of flowers attract different pollinators.
c. Two species of birds display different mating dances.
d. Two species of insects produce infertile offspring.

15. Which term is used to describe the continued divergence of species based on the low fitness of hybrid offspring?

a. reinforcement
b. fusion

c. stability
d. punctuated equilibrium

16. Which components of speciation would be least likely to be a part of punctuated equilibrium?

a. a division of populations
b. a change in environmental conditions
c. ongoing gene flow among all individuals
d. a large number of mutations taking place at once

CRITICAL THINKING QUESTIONS

17. If a person scatters a handful of garden pea plant seeds in one area, how would natural selection work in this situation?

18. Why do scientists consider vestigial structures evidence for evolution?

19. How does the scientific meaning of "theory" differ from the common vernacular meaning?

20. Explain why the statement that a monkey is more evolved than a mouse is incorrect.

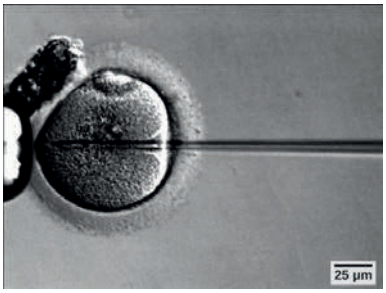
21. Why do island chains provide ideal conditions for adaptive radiation to occur?

22. Two species of fish had recently undergone sympatric speciation. The males of each species had a different coloring through which the females could identify and choose a partner from her own species. After some time, pollution made the lake so cloudy that it was hard for females to distinguish colors. What might take place in this situation?

23. Why can polyploidy individuals lead to speciation fairly quickly?

24. What do both rate of speciation models have in common?

25. Describe a situation where hybrid reproduction would cause two species to fuse into one.



CHAPTER SUMMARY

19.1 Population Evolution

The modern synthesis of evolutionary theory grew out of the cohesion of Darwin's, Wallace's, and Mendel's thoughts on evolution and heredity, along with the more modern study of population genetics. It describes the evolution of populations and species, from small-scale changes among individuals to large-scale changes over paleontological time periods. To understand how organisms evolve, scientists can track populations' allele frequencies over time. If they differ from generation to generation, scientists can conclude that the population is not in Hardy-Weinberg equilibrium, and is thus evolving.

19.2 Population Genetics

Both genetic and environmental factors can cause phenotypic variation in a population. Different alleles can confer different phenotypes, and different environments can also cause individuals to look or act differently. Only those differences encoded in an individual's genes, however, can be passed to its offspring and, thus, be a target of natural selection. Natural selection works by selecting for alleles that confer beneficial traits or behaviors, while selecting against those for deleterious qualities. Genetic drift stems from the chance occurrence that some individuals in the germ line have more offspring than others. When individuals leave or join the population, allele frequencies can change as a result of gene flow. Mutations to an individual's DNA may introduce new variation into a population. Allele frequencies can also be altered when individuals do not randomly mate with others in the group.

19.3 Adaptive Evolution

Because natural selection acts to increase the frequency of beneficial alleles and traits while decreasing the frequency of deleterious qualities, it is adaptive evolution. Natural selection acts at the level of the individual, selecting for those that have a higher overall fitness compared to the rest of the population. If the fit phenotypes are those that are similar, natural selection will result in stabilizing selection, and an overall decrease in the population's variation. Directional selection works to shift a population's variance toward a new, fit phenotype, as environmental conditions change. In contrast, diversifying selection results in increased genetic variance by selecting for two or more distinct phenotypes.

Other types of selection include frequency-dependent selection, in which individuals with either common (positive frequency-dependent selection) or rare (negative frequency-dependent selection) are selected for. Finally, sexual selection results from the fact that one sex has more variance in the reproductive success than the other. As a result, males and females experience different selective pressures, which can often lead to the evolution of phenotypic differences, or sexual dimorphisms, between the two.

ART CONNECTION QUESTIONS

1. **Figure 19.2** In plants, violet flower color (V) is dominant over white (v). If p=.8 and q = 0.2 in a population of 500 plants, how many individuals would you expect to be homozygous dominant (VV), heterozygous (Vv), and homozygous recessive (vv)? How many plants would you expect to have violet flowers, and how many would have white flowers?

2. **Figure 19.4** Do you think genetic drift would happen more quickly on an island or on the mainland?

3. **Figure 19.8** In recent years, factories have become cleaner, and less soot is released into the environment. What impact do you think this has had on the distribution of moth color in the population?

REVIEW QUESTIONS

4. What is the difference between micro- and macroevolution?

a. Microevolution describes the evolution of small organisms, such as insects, while macroevolution describes the evolution of large organisms, like people and elephants.
b. Microevolution describes the evolution of microscopic entities, such as molecules and proteins, while macroevolution describes the evolution of whole organisms.
c. Microevolution describes the evolution of organisms in populations, while macroevolution describes the evolution of species over long periods of time.
d. Microevolution describes the evolution of organisms over their lifetimes, while macroevolution describes the evolution of organisms over multiple generations.

5. Population genetics is the study of:

a. how selective forces change the allele frequencies in a population over time
b. the genetic basis of population-wide traits
c. whether traits have a genetic basis
d. the degree of inbreeding in a population

6. Which of the following populations is not in Hardy-Weinberg equilibrium?

a. a population with 12 homozygous recessive individuals (yy), 8 homozygous dominant individuals (YY), and 4 heterozygous individuals (Yy)
b. a population in which the allele frequencies do not change over time
c. $p^2 + 2pq + q^2 = 1$
d. a population undergoing natural selection

7. One of the original Amish colonies rose from a ship of colonists that came from Europe. The ship's captain, who had polydactyly, a rare dominant trait, was one of the original colonists. Today, we see a much higher frequency of polydactyly in the Amish population. This is an example of:

a. natural selection
b. genetic drift
c. founder effect
d. b and c

8. When male lions reach sexual maturity, they leave their group in search of a new pride. This can alter the allele frequencies of the population through which of the following mechanisms?

a. natural selection
b. genetic drift
c. gene flow
d. random mating

9. Which of the following evolutionary forces can introduce new genetic variation into a population?

a. natural selection and genetic drift
b. mutation and gene flow
c. natural selection and nonrandom mating
d. mutation and genetic drift

10. What is assortative mating?

a. when individuals mate with those who are similar to themselves
b. when individuals mate with those who are dissimilar to themselves
c. when individuals mate with those who are the most fit in the population
d. when individuals mate with those who are least fit in the population

11. When closely related individuals mate with each other, or inbreed, the offspring are often not as fit as the offspring of two unrelated individuals. Why?

a. Close relatives are genetically incompatible.
b. The DNA of close relatives reacts negatively in the offspring.
c. Inbreeding can bring together rare, deleterious mutations that lead to harmful phenotypes.
d. Inbreeding causes normally silent alleles to be expressed.

12. What is a cline?

a. the slope of a mountain where a population lives
b. the degree to which a mutation helps an individual survive
c. the number of individuals in the population
d. gradual geographic variation across an ecological gradient

13. Which type of selection results in greater genetic variance in a population?

a. stabilizing selection
b. directional selection
c. diversifying selection
d. positive frequency-dependent selection

14. When males and females of a population look or act differently, it is referred to as _____.

a. sexual dimorphism
b. sexual selection
c. diversifying selection
d. a cline

15. The good genes hypothesis is a theory that explains what?

a. why more fit individuals are more likely to have more offspring

b. why alleles that confer beneficial traits or behaviors are selected for by natural selection
c. why some deleterious mutations are maintained in the population
d. why individuals of one sex develop impressive ornamental traits

CRITICAL THINKING QUESTIONS

16. Solve for the genetic structure of a population with 12 homozygous recessive individuals (yy), 8 homozygous dominant individuals (YY), and 4 heterozygous individuals (Yy).

17. Explain the Hardy-Weinberg principle of equilibrium theory.

18. Imagine you are trying to test whether a population of flowers is undergoing evolution. You suspect there is selection pressure on the color of the flower: bees seem to cluster around the red flowers more often than the blue flowers. In a separate experiment, you discover blue flower color is dominant to red flower color. In a field, you count 600 blue flowers and 200 red flowers. What would you expect the genetic structure of the flowers to be?

19. Describe a situation in which a population would undergo the bottleneck effect and explain what impact that would have on the population's gene pool.

20. Describe natural selection and give an example of natural selection at work in a population.

21. Explain what a cline is and provide examples.

22. Give an example of a trait that may have evolved as a result of the handicap principle and explain your reasoning.

23. List the ways in which evolution can affect population variation and describe how they influence allele frequencies.

CHAPTER SUMMARY

20.1 Organizing Life on Earth

Scientists continually gain new information that helps understand the evolutionary history of life on Earth. Each group of organisms went through its own evolutionary journey, called its phylogeny. Each organism shares relatedness with others, and based on morphologic and genetic evidence, scientists attempt to map the evolutionary pathways of all life on Earth. Historically, organisms were organized into a taxonomic classification system. However, today many scientists build phylogenetic trees to illustrate evolutionary relationships.

20.2 Determining Evolutionary Relationships

To build phylogenetic trees, scientists must collect accurate information that allows them to make evolutionary connections between organisms. Using morphologic and molecular data, scientists work to identify homologous characteristics and genes. Similarities between organisms can stem either from shared evolutionary history (homologies) or from separate evolutionary paths (analogies). Newer technologies can be used to help distinguish homologies from analogies. After homologous information is identified, scientists use cladistics to organize these events as a means to determine an evolutionary timeline. Scientists apply the concept of maximum parsimony, which states that the order of events probably occurred in the most obvious and simple way with the least amount of steps. For evolutionary events, this would be the path with the least number of major divergences that correlate with the evidence.

20.3 Perspectives on the Phylogenetic Tree

The phylogenetic tree, first used by Darwin, is the classic “tree of life” model describing phylogenetic relationships among species, and the most common model used today. New ideas about HGT and genome fusion have caused some to suggest revising the model to resemble webs or rings.

ART CONNECTION QUESTIONS

1. **Figure 20.6** At what levels are cats and dogs considered to be part of the same group?

2. **Figure 20.10** Which animals in this figure belong to a clade that includes animals with hair? Which evolved first, hair or the amniotic egg?

3. **Figure 20.11** What is the largest clade in this diagram?

REVIEW QUESTIONS

4. What is used to determine phylogeny?

a. mutations
b. DNA
c. evolutionary history
d. organisms on earth

5. What do scientists in the field of systematics accomplish?

a. discover new fossil sites
b. organize and classify organisms
c. name new species
d. communicate among field biologists

6. Which statement about the taxonomic classification system is correct?

a. There are more domains than kingdoms.
b. Kingdoms are the top category of classification.
c. Classes are divisions of orders.
d. Subspecies are the most specific category of classification.

7. On a phylogenetic tree, which term refers to lineages that diverged from the same place?

a. sister taxa
b. basal taxa
c. rooted taxa
d. dichotomous taxa

8. Which statement about analogies is correct?

a. They occur only as errors.
b. They are synonymous with homologous traits.
c. They are derived by similar environmental constraints.
d. They are a form of mutation.

9. What do scientists use to apply cladistics?

a. homologous traits
b. homoplasies
c. analogous traits
d. monophyletic groups

10. What is true about organisms that are a part of the same clade?

a. They all share the same basic characteristics.
b. They evolved from a shared ancestor.
c. They usually fall into the same classification taxa.
d. They have identical phylogenies.

11. Why do scientists apply the concept of maximum parsimony?

a. to decipher accurate phylogenies
b. to eliminate analogous traits
c. to identify mutations in DNA codes
d. to locate homoplasies

12. The transfer of genes by a mechanism not involving asexual reproduction is called:

a. meiosis
b. web of life
c. horizontal gene transfer
d. gene fusion

13. Particles that transfer genetic material from one species to another, especially in marine prokaryotes:

a. horizontal gene transfer
b. lateral gene transfer
c. genome fusion device
d. gene transfer agents

14. What does the trunk of the classic phylogenetic tree represent?

a. single common ancestor
b. pool of ancestral organisms
c. new species
d. old species

15. Which phylogenetic model proposes that all three domains of life evolved from a pool of primitive prokaryotes?

a. tree of life
b. web of life
c. ring of life
d. network model

CRITICAL THINKING QUESTIONS

16. How does a phylogenetic tree relate to the passing of time?

17. Some organisms that appear very closely related on a phylogenetic tree may not actually be closely related. Why is this?

18. List the different levels of the taxonomic classification system.

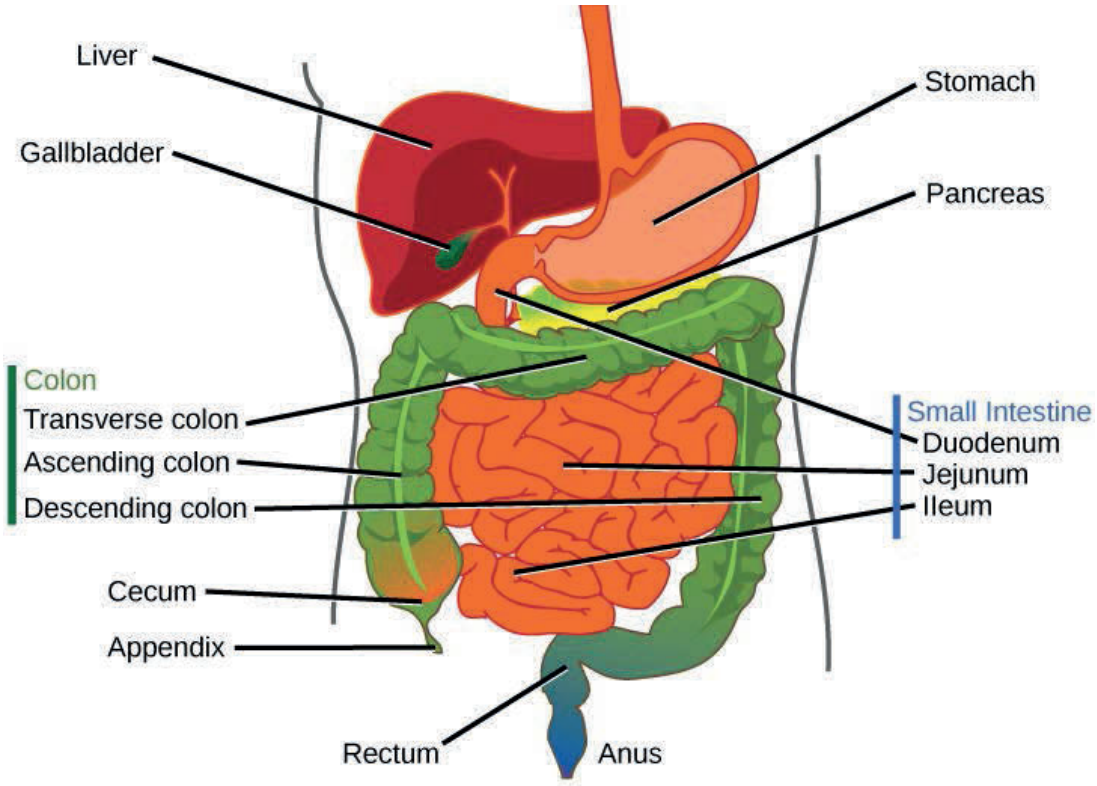
19. Dolphins and fish have similar body shapes. Is this feature more likely a homologous or analogous trait?

20. Why is it so important for scientists to distinguish between homologous and analogous characteristics before building phylogenetic trees?

21. Describe maximum parsimony.

22. Compare three different ways that eukaryotic cells may have evolved.

23. Describe how aphids acquired the ability to change color.



CHAPTER SUMMARY

21.1 Viral Evolution, Morphology, and Classification

Viruses are tiny, acellular entities that can usually only be seen with an electron microscope. Their genomes contain either DNA or RNA—never both—and they replicate using the replication proteins of a host cell. Viruses are diverse, infecting archaea, bacteria, fungi, plants, and animals. Viruses consist of a nucleic acid core surrounded by a protein capsid with or without an outer lipid envelope. The capsid shape, presence of an envelope, and core composition dictate some elements of the classification of viruses. The most commonly used classification method, the Baltimore classification, categorizes viruses based on how they produce their mRNA.

21.2 Virus Infections and Hosts

Viral replication within a living cell always produces changes in the cell, sometimes resulting in cell death and sometimes slowly killing the infected cells. There are six basic stages in the virus replication cycle: attachment, penetration, uncoating, replication, assembly, and release. A viral infection may be productive, resulting in new virions, or nonproductive, which means that the virus remains inside the cell without producing new virions. Bacteriophages are viruses that infect bacteria. They have two different modes of replication: the lytic cycle, where the virus replicates and bursts out of the bacteria, and the lysogenic cycle, which involves the incorporation of the viral genome into the bacterial host genome. Animal viruses cause a variety of infections, with some causing chronic symptoms (hepatitis C), some intermittent symptoms (latent viruses such a herpes simplex virus 1), and others that cause very few symptoms, if any (human herpesviruses 6 and 7). Oncogenic viruses in animals have the ability to cause cancer by interfering with the regulation of the host cell cycle. Viruses of plants are responsible for significant economic damage in both agriculture and plants used for ornamentation.

21.3 Prevention and Treatment of Viral Infections

Viruses cause a variety of diseases in humans. Many of these diseases can be prevented by the use of viral vaccines, which stimulate protective immunity against the virus without causing major disease. Viral vaccines may also be used in active viral infections, boosting the ability of the immune system to control or destroy the virus. A series of antiviral drugs that target enzymes and other protein products of viral genes have been developed and used with mixed success. Combinations of anti-HIV drugs have been used to effectively control the virus, extending the lifespans of infected individuals. Viruses have many uses in medicines, such as in the treatment of genetic disorders, cancer, and bacterial infections.

21.4 Other Acellular Entities: Prions and Viroids

Prions are infectious agents that consist of protein, but no DNA or RNA, and seem to produce their deadly effects by duplicating their shapes and accumulating in tissues. They are thought to contribute to several progressive brain disorders, including mad cow disease and Creutzfeldt-Jakob disease. Viroids are single-stranded RNA pathogens that infect plants. Their presence can have a severe impact on the agriculture industry.

ART CONNECTION QUESTIONS

1. **Figure 21.4** Which of the following statements about virus structure is true?

a. All viruses are encased in a viral membrane.
b. The capsomere is made up of small protein subunits called capsids.
c. DNA is the genetic material in all viruses.
d. Glycoproteins help the virus attach to the host cell.

2. **Figure 21.8** Influenza virus is packaged in a viral envelope that fuses with the plasma membrane. This way, the virus can exit the host cell without killing it. What advantage does the virus gain by keeping the host cell alive?

3. **Figure 21.10** Which of the following statements is false?

a. In the lytic cycle, new phage are produced and released into the environment.
b. In the lysogenic cycle, phage DNA is incorporated into the host genome.
c. An environmental stressor can cause the phage to initiate the lysogenic cycle.
d. Cell lysis only occurs in the lytic cycle.

REVIEW QUESTIONS

4. Which statement is true?

a. A virion contains DNA and RNA.
b. Viruses are acellular.
c. Viruses replicate outside of the cell.
d. Most viruses are easily visualized with a light microscope.

5. The viral _____ plays a role in attaching a virion to the host cell.

a. core
b. capsid
c. envelope
d. both b and c

6. Viruses_____.

a. all have a round shape
b. cannot have a long shape
c. do not maintain any shape
d. vary in shape

7. Which statement is *not* true of viral replication?

a. A lysogenic cycle kills the host cell.
b. There are six basic steps in the viral replication cycle.
c. Viral replication does not affect host cell function.
d. Newly released virions can infect adjacent cells.

8. Which statement is true of viral replication?

a. In the process of apoptosis, the cell survives.
b. During attachment, the virus attaches at specific sites on the cell surface.
c. The viral capsid helps the host cell produce more copies of the viral genome.
d. mRNA works outside of the host cell to produce enzymes and proteins.

9. Which statement is true of reverse transcriptase?

a. It is a nucleic acid.
b. It infects cells.
c. It transcribes RNA to make DNA.
d. It is a lipid.

10. Oncogenic virus cores can be_____.

a. RNA
b. DNA
c. neither RNA nor DNA
d. either RNA or DNA

11. Which is true of DNA viruses?

a. They use the host cell's machinery to produce new copies of their genome.
b. They all have envelopes.
c. They are the only kind of viruses that can cause cancer.
d. They are not important plant pathogens.

12. A bacteriophage can infect _____.

a. the lungs
b. viruses
c. prions
d. bacteria

13. Which of the following is NOT used to treat active viral disease?

a. vaccines
b. antiviral drugs
c. antibiotics
d. phage therapy

14. Vaccines_____.

a. are similar to viroids
b. are only needed once
c. kill viruses
d. stimulate an immune response

15. Which of the following is not associated with prions?

a. replicating shapes
b. mad cow disease
c. DNA
d. toxic proteins

16. Which statement is true of viroids?

a. They are single-stranded RNA particles.
b. They reproduce only outside of the cell.
c. They produce proteins.
d. They affect both plants and animals.

CRITICAL THINKING QUESTIONS

17. The first electron micrograph of a virus (tobacco mosaic virus) was produced in 1939. Before that time, how did scientists know that viruses existed if they could not see them? (Hint: Early scientists called viruses "filterable agents.")

18. Why can't dogs catch the measles?

19. One of the first and most important targets for drugs to fight infection with HIV (a retrovirus) is the reverse transcriptase enzyme. Why?

20. In this section, you were introduced to different types of viruses and viral diseases. Briefly discuss the most interesting or surprising thing you learned about viruses.

21. Although plant viruses cannot infect humans, what are some of the ways in which they affect humans?

22. Why is immunization after being bitten by a rabid animal so effective and why aren't people vaccinated for rabies like dogs and cats are?

23. Prions are responsible for variant Creutzfeldt-Jakob Disease, which has resulted in over 100 human deaths in Great Britain during the last 10 years. How do humans obtain this disease?

24. How are viroids like viruses?

CHAPTER SUMMARY

22.1 Prokaryotic Diversity

Prokaryotes existed for billions of years before plants and animals appeared. Hot springs and hydrothermal vents may have been the environments in which life began. Microbial mats are thought to represent the earliest forms of life on Earth, and there is fossil evidence of their presence about 3.5 billion years ago. A microbial mat is a multi-layered sheet of prokaryotes that grows at interfaces between different types of material, mostly on moist surfaces. During the first 2 billion years, the atmosphere was anoxic and only anaerobic organisms were able to live. Cyanobacteria evolved from early phototrophs and began the oxygenation of the atmosphere. The increase in oxygen concentration allowed the evolution of other life forms. Fossilized microbial mats are called stromatolites and consist of laminated organo-sedimentary structures formed by precipitation of minerals by prokaryotes. They represent the earliest fossil record of life on Earth.

Bacteria and archaea grow in virtually every environment. Those that survive under extreme conditions are called extremophiles (extreme lovers). Some prokaryotes cannot grow in a laboratory setting, but they are not dead. They are in the viable-but-non-culturable (VBNC) state. The VBNC state occurs when prokaryotes enter a dormant state in response to environmental stressors. Most prokaryotes are social and prefer to live in communities where interactions take place. A biofilm is a microbial community held together in a gummy-textured matrix.

22.2 Structure of Prokaryotes

Prokaryotes (domains Archaea and Bacteria) are single-celled organisms lacking a nucleus. They have a single piece of circular DNA in the nucleoid area of the cell. Most prokaryotes have a cell wall that lies outside the boundary of the plasma membrane. Some prokaryotes may have additional structures such as a capsule, flagella, and pili. Bacteria and Archaea differ in the lipid composition of their cell membranes and the characteristics of the cell wall. In archaeal membranes, phytanyl units, rather than fatty acids, are linked to glycerol. Some archaeal membranes are lipid monolayers instead of bilayers.

The cell wall is located outside the cell membrane and prevents osmotic lysis. The chemical composition of cell walls varies between species. Bacterial cell walls contain peptidoglycan. Archaean cell walls do not have peptidoglycan, but they may have pseudopeptidoglycan, polysaccharides, glycoproteins, or protein-based cell walls. Bacteria can be divided into two major groups: Gram positive and Gram negative, based on the Gram stain reaction. Gram-positive organisms have a thick cell wall, together with teichoic acids. Gram-negative organisms have a thin cell wall and an outer envelope containing lipopolysaccharides and lipoproteins.

22.3 Prokaryotic Metabolism

Prokaryotes are the most metabolically diverse organisms; they flourish in many different environments with various carbon energy and carbon sources, variable temperature, pH, pressure, and water availability. Nutrients required in large amounts are called macronutrients, whereas those required in trace amounts are called micronutrients or trace elements. Macronutrients include C, H, O, N, P, S, K, Mg, Ca, and Na. In addition to these macronutrients, prokaryotes require various metallic elements for growth and enzyme function. Prokaryotes use different sources of energy to assemble macromolecules from smaller molecules. Phototrophs obtain their energy from sunlight, whereas chemotrophs obtain energy from chemical compounds.

Prokaryotes play roles in the carbon and nitrogen cycles. Carbon is returned to the atmosphere by the respiration of animals and other chemoorganotrophic organisms. Consumers use organic compounds generated by producers and release carbon dioxide into the atmosphere. The most important contributor of carbon dioxide to the atmosphere is microbial decomposition of dead material. Nitrogen is recycled in nature from organic compounds to ammonia, ammonium ions, nitrite, nitrate, and nitrogen gas. Gaseous nitrogen is transformed into ammonia through nitrogen fixation. Ammonia is anaerobically catabolized by some prokaryotes, yielding N_2 as the final product. Nitrification is the conversion of ammonium into nitrite. Nitrification in soils is carried out by bacteria. Denitrification is also performed by bacteria and transforms nitrate from soils into gaseous nitrogen compounds, such as N_2O, NO, and N_2.

22.4 Bacterial Diseases in Humans

Devastating diseases and plagues have been among us since early times. There are records about microbial diseases as far back as 3000 B.C. Infectious diseases remain among the leading causes of

death worldwide. Emerging diseases are those rapidly increasing in incidence or geographic range. They can be new or re-emerging diseases (previously under control). Many emerging diseases affecting humans, such as brucellosis, are zoonoses. The WHO has identified a group of diseases whose re-emergence should be monitored: Those caused by bacteria include bubonic plague, diphtheria, and cholera.

Biofilms are considered responsible for diseases such as bacterial infections in patients with cystic fibrosis, Legionnaires' disease, and otitis media. They produce dental plaque; colonize catheters, prostheses, transcutaneous, and orthopedic devices; and infect contact lenses, open wounds, and burned tissue. Biofilms also produce foodborne diseases because they colonize the surfaces of food and food-processing equipment. Biofilms are resistant to most of the methods used to control microbial growth. The excessive use of antibiotics has resulted in a major global problem, since resistant forms of bacteria have been selected over time. A very dangerous strain, methicillin-resistant *Staphylococcus aureus* (MRSA), has wreaked havoc recently. Foodborne diseases result from the consumption of contaminated food, pathogenic bacteria, viruses, or parasites that contaminate food.

22.5 Beneficial Prokaryotes

Pathogens are only a small percentage of all prokaryotes. In fact, our life would not be possible without prokaryotes. Nitrogen is usually the most limiting element in terrestrial ecosystems; atmospheric nitrogen, the largest pool of available nitrogen, is unavailable to eukaryotes. Nitrogen can be "fixed," or converted into ammonia (NH_3) either biologically or abiotically. Biological nitrogen fixation (BNF) is exclusively carried out by prokaryotes. After photosynthesis, BNF is the second most important biological process on Earth. The most important source of BNF is the symbiotic interaction between soil bacteria and legume plants.

Microbial bioremediation is the use of microbial metabolism to remove pollutants. Bioremediation has been used to remove agricultural chemicals that leach from soil into groundwater and the subsurface. Toxic metals and oxides, such as selenium and arsenic compounds, can also be removed by bioremediation. Probably one of the most useful and interesting examples of the use of prokaryotes for bioremediation purposes is the cleanup of oil spills.

Human life is only possible due to the action of microbes, both those in the environment and those species that call us home. Internally, they help us digest our food, produce crucial nutrients for us, protect us from pathogenic microbes, and help train our immune systems to function correctly.

ART CONNECTION QUESTIONS

1. **Figure 22.8** Compared to free-floating bacteria, bacteria in biofilms often show increased resistance to antibiotics and detergents. Why do you think this might be the case?

2. **Figure 22.15** Which of the following statements is true?

a. Gram-positive bacteria have a single cell wall anchored to the cell membrane by lipoteichoic acid.
b. Porins allow entry of substances into both Gram-positive and Gram-negative bacteria.
c. The cell wall of Gram-negative bacteria is thick, and the cell wall of Gram-positive bacteria is thin.
d. Gram-negative bacteria have a cell wall made of peptidoglycan, whereas Gram-positive bacteria have a cell wall made of lipoteichoic acid.

3. **Figure 22.19** Which of the following statements about the nitrogen cycle is false?

a. Nitrogen fixing bacteria exist on the root nodules of legumes and in the soil.
b. Denitrifying bacteria convert nitrates (NO_3^-) into nitrogen gas (N_2).
c. Ammonification is the process by which ammonium ion (NH_4^+) is released from decomposing organic compounds.
d. Nitrification is the process by which nitrites (NO_2^-) are converted to ammonium ion (NH_4^+).

REVIEW QUESTIONS

4. The first forms of life on Earth were thought to be_____.

a. single-celled plants
b. prokaryotes
c. insects
d. large animals such as dinosaurs

5. Microbial mats _____.

a. are the earliest forms of life on Earth
b. obtained their energy and food from hydrothermal vents

c. are multi-layered sheet of prokaryotes including mostly bacteria but also archaea
d. all of the above

6. The first organisms that oxygenated the atmosphere were
a. cyanobacteria
b. phototrophic organisms
c. anaerobic organisms
d. all of the above

7. Halophiles are organisms that require_____.
a. a salt concentration of at least 0.2 M
b. high sugar concentration
c. the addition of halogens
d. all of the above

8. The presence of a membrane-enclosed nucleus is a characteristic of _____.
a. prokaryotic cells
b. eukaryotic cells
c. all cells
d. viruses

9. Which of the following consist of prokaryotic cells?
a. bacteria and fungi
b. archaea and fungi
c. protists and animals
d. bacteria and archaea

10. The cell wall is _____.
a. interior to the cell membrane
b. exterior to the cell membrane
c. a part of the cell membrane
d. interior or exterior, depending on the particular cell

11. Organisms most likely to be found in extreme environments are _____.
a. fungi
b. bacteria
c. viruses
d. archaea

12. Prokaryotes stain as Gram-positive or Gram-negative because of differences in the cell _____.
a. wall
b. cytoplasm
c. nucleus
d. chromosome

13. Pseudopeptidoglycan is a characteristic of the walls of _____.
a. eukaryotic cells
b. bacterial prokaryotic cells
c. archaean prokaryotic cells
d. bacterial and archaean prokaryotic cells

14. The lipopolysaccharide layer (LPS) is a characteristic of the wall of _____.
a. archaean cells
b. Gram-negative bacteria
c. bacterial prokaryotic cells
d. eukaryotic cells

15. Which of the following elements is *not* a micronutrient?
a. boron
b. calcium
c. chromium
d. manganese

16. Prokaryotes that obtain their energy from chemical compounds are called _____.
a. phototrophs
b. auxotrophs
c. chemotrophs
d. lithotrophs

17. Ammonification is the process by which _____.
a. ammonia is released during the decomposition of nitrogen-containing organic compounds
b. ammonium is converted to nitrite and nitrate in soils
c. nitrate from soil is transformed to gaseous nitrogen compounds such as NO, N_2O, and N_2
d. gaseous nitrogen is fixed to yield ammonia

18. Plants use carbon dioxide from the air and are therefore called _____.
a. consumers
b. producers
c. decomposer
d. carbon fixers

19. A disease that is constantly present in a population is called _____.
a. pandemic
b. epidemic
c. endemic
d. re-emerging

20. Which of the statements about biofilms is incorrect?
a. Biofilms are considered responsible for diseases such as cystic fibrosis.
b. Biofilms produce dental plaque, and colonize catheters and prostheses.
c. Biofilms colonize open wounds and burned tissue.
d. All statements are incorrect.

21. Which of these statements is true?
a. An antibiotic is any substance produced by a organism that is antagonistic to the growth of prokaryotes.
b. An antibiotic is any substance produced by a prokaryote that is antagonistic to the growth of other viruses.
c. An antibiotic is any substance produced by a prokaryote that is antagonistic to the growth of eukaryotic cells.
d. An antibiotic is any substance produced by a prokaryote that prevents growth of the same prokaryote.

22. Which of these occurs through symbiotic nitrogen fixation?

a. The plant benefits from using an endless source of nitrogen.
b. The soil benefits from being naturally fertilized.
c. Bacteria benefit from using photosynthates from the plant.
d. All of the above occur.

23. Synthetic compounds found in an organism but not normally produced or expected to be present in that organism are called _____.

a. pesticides
b. bioremediators
c. recalcitrant compounds
d. xenobiotics

24. Bioremediation includes _____.

a. the use of prokaryotes that can fix nitrogen
b. the use of prokaryotes to clean up pollutants
c. the use of prokaryotes as natural fertilizers
d. All of the above

CRITICAL THINKING QUESTIONS

25. Describe briefly how you would detect the presence of a non-culturable prokaryote in an environmental sample.

26. Why do scientists believe that the first organisms on Earth were extremophiles?

27. Mention three differences between bacteria and archaea.

28. Explain the statement that both types, bacteria and archaea, have the same basic structures, but built from different chemical components.

29. Think about the conditions (temperature, light, pressure, and organic and inorganic materials) that you may find in a deep-sea hydrothermal vent. What type of prokaryotes, in terms of their metabolic needs (autotrophs, phototrophs, chemotrophs, etc.), would you expect to find there?

30. Explain the reason why the imprudent and excessive use of antibiotics has resulted in a major global problem.

31. Researchers have discovered that washing spinach with water several times does not prevent foodborne diseases due to *E. coli*. How can you explain this fact?

32. Your friend believes that prokaryotes are always detrimental and pathogenic. How would you explain to them that they are wrong?

CHAPTER SUMMARY

23.1 Eukaryotic Origins

The oldest fossil evidence of eukaryotes is about 2 billion years old. Fossils older than this all appear to be prokaryotes. It is probable that today's eukaryotes are descended from an ancestor that had a prokaryotic organization. The last common ancestor of today's Eukarya had several characteristics, including cells with nuclei that divided mitotically and contained linear chromosomes where the DNA was associated with histones, a cytoskeleton and endomembrane system, and the ability to make cilia/flagella during at least part of its life cycle. It was aerobic because it had mitochondria that were the

result of an aerobic alpha-proteobacterium that lived inside a host cell. Whether this host had a nucleus at the time of the initial symbiosis remains unknown. The last common ancestor may have had a cell wall for at least part of its life cycle, but more data are needed to confirm this hypothesis. Today's eukaryotes are very diverse in their shapes, organization, life cycles, and number of cells per individual.

23.2 Characteristics of Protists

Protists are extremely diverse in terms of their biological and ecological characteristics, partly because they are an artificial assemblage of phylogenetically unrelated groups. Protists display highly varied cell structures, several types of reproductive strategies, virtually every possible type of nutrition, and varied habitats. Most single-celled protists are motile, but these organisms use diverse structures for transportation.

23.3 Groups of Protists

The process of classifying protists into meaningful groups is ongoing, but genetic data in the past 20 years have clarified many relationships that were previously unclear or mistaken. The majority view at present is to order all eukaryotes into six supergroups: Excavata, Chromalveolata, Rhizaria, Archaeplastida, Amoebozoa, and Opisthokonta. The goal of this classification scheme is to create clusters of species that all are derived from a common ancestor. At present, the monophyly of some of the supergroups are better supported by genetic data than others. Although tremendous variation exists within the supergroups, commonalities at the morphological, physiological, and ecological levels can be identified.

23.4 Ecology of Protists

Protists function at several levels of the ecological food web: as primary producers, as direct food sources, and as decomposers. In addition, many protists are parasites of plants and animals that can cause deadly human diseases or destroy valuable crops.

ART CONNECTION QUESTIONS

1. **Figure 23.5** What evidence is there that mitochondria were incorporated into the ancestral eukaryotic cell before chloroplasts?

2. **Figure 23.15** Which of the following statements about *Paramecium* sexual reproduction is false?

a. The macronuclei are derived from micronuclei.
b. Both mitosis and meiosis occur during sexual reproduction.
c. The conjugate pair swaps macronuclei.
d. Each parent produces four daughter cells.

3. **Figure 23.18** Which of the following statements about the *Laminaria* life cycle is false?

a. 1*n* zoospores form in the sporangia.
b. The sporophyte is the *2n* plant.
c. The gametophyte is diploid.
d. Both the gametophyte and sporophyte stages are multicellular.

REVIEW QUESTIONS

4. What event is thought to have contributed to the evolution of eukaryotes?

a. global warming
b. glaciation
c. volcanic activity
d. oxygenation of the atmosphere

5. Which characteristic is shared by prokaryotes and eukaryotes?

a. cytoskeleton
b. nuclear envelope
c. DNA-based genome
d. mitochondria

6. Mitochondria most likely evolved by _____.

a. a photosynthetic cyanobacterium
b. cytoskeletal elements
c. endosymbiosis
d. membrane proliferation

7. Which of these protists is believed to have evolved following a secondary endosymbiosis?

a. green algae
b. cyanobacteria
c. red algae
d. chlorarachniophytes

8. Protists that have a pellicle are surrounded by _____.

a. silica dioxide

b. calcium carbonate
c. carbohydrates
d. proteins

9. Protists with the capabilities to perform photosynthesis and to absorb nutrients from dead organisms are called _____.
a. photoautotrophs
b. mixotrophs
c. saprobes
d. heterotrophs

10. Which of these locomotor organs would likely be the shortest?
a. a flagellum
b. a cilium
c. an extended pseudopod
d. a pellicle

11. Alternation of generations describes which of the following?
a. The haploid form can be multicellular; the diploid form is unicellular.
b. The haploid form is unicellular; the diploid form can be multicellular.
c. Both the haploid and diploid forms can be multicellular.
d. Neither the haploid nor the diploid forms can be multicellular.

12. Which protist group exhibits mitochondrial remnants with reduced functionality?
a. slime molds
b. diatoms
c. parabasalids
d. dinoflagellates

13. Conjugation between two *Paramecia* produces _____ total daughter cells.
a. 2
b. 4
c. 8
d. 16

14. What is the function of the raphe in diatoms?
a. locomotion
b. defense
c. capturing food
d. photosynthesis

15. What genus of protists appears to contradict the statement that unicellularity restricts cell size?
a. *Dictyostelium*
b. *Ulva*
c. *Plasmodium*
d. *Caulerpa*

16. An example of carbon fixation is _____.
a. photosynthesis
b. decomposition
c. phagocytosis
d. parasitism

17. Which parasitic protist evades the host immune system by altering its surface proteins with each generation?
a. *Paramecium caudatum*
b. *Trypanosoma brucei*
c. *Plasmodium falciparum*
d. *Phytophthora infestans*

CRITICAL THINKING QUESTIONS

18. Describe the hypothesized steps in the origin of eukaryotic cells.

19. Explain in your own words why sexual reproduction can be useful if a protist's environment changes.

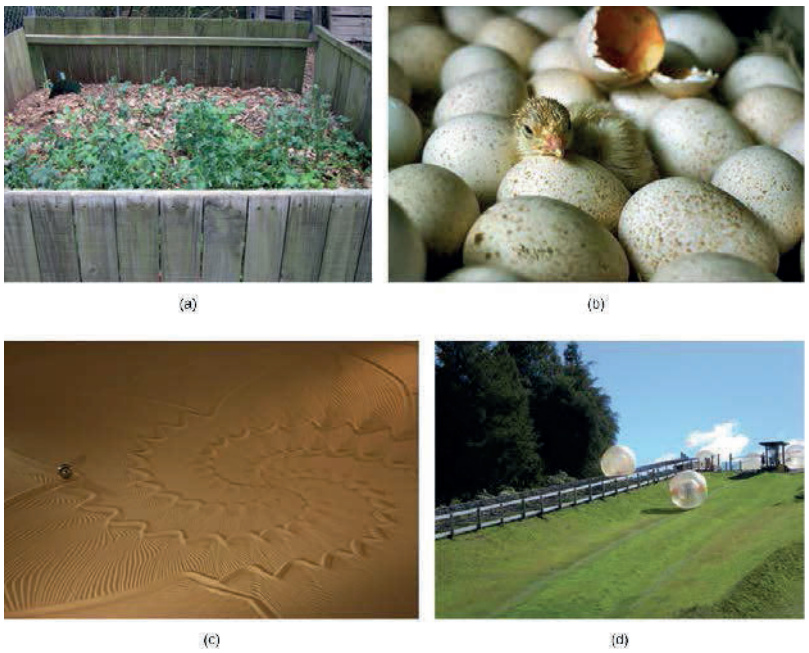
20. *Giardia lamblia* is a cyst-forming protist parasite that causes diarrhea if ingested. Given this information, against what type(s) of environments might *G. lamblia* cysts be particularly resistant?

21. The chlorophyte (green algae) genera *Ulva* and *Caulerpa* both have macroscopic leaf-like and stem-like structures, but only *Ulva* species are considered truly multicellular. Explain why.

22. Why might a light-sensing eyespot be ineffective for an obligate saprobe? Suggest an alternative organ for a saprobic protist.

23. How does killing *Anopheles* mosquitoes affect the *Plasmodium* protists?

24. Without treatment, why does African sleeping sickness invariably lead to death?



CHAPTER SUMMARY

24.1 Characteristics of Fungi

Fungi are eukaryotic organisms that appeared on land more than 450 million years ago. They are heterotrophs and contain neither photosynthetic pigments such as chlorophyll, nor organelles such as chloroplasts. Because fungi feed on decaying and dead matter, they are saprobes. Fungi are important decomposers that release essential elements into the environment. External enzymes digest nutrients that are absorbed by the body of the fungus, which is called a thallus. A thick cell wall made of chitin surrounds the cell. Fungi can be unicellular as yeasts, or develop a network of filaments called a mycelium, which is often described as mold. Most species multiply by asexual and sexual reproductive cycles and display an alternation of generations. Such fungi are called perfect fungi. Imperfect fungi do not have a sexual cycle. Sexual reproduction involves plasmogamy (the fusion of the cytoplasm), followed by karyogamy (the fusion of nuclei). Meiosis regenerates haploid individuals, resulting in haploid spores.

24.2 Classifications of Fungi

Chytridiomycota (chytrids) are considered the most primitive group of fungi. They are mostly aquatic, and their gametes are the only fungal cells known to have flagella. They reproduce both sexually and asexually; the asexual spores are called zoospores. Zygomycota (conjugated fungi) produce non-septated hyphae with many nuclei. Their hyphae fuse during sexual reproduction to produce a zygospore in a zygosporangium. Ascomycota (sac fungi) form spores in sacs called asci during sexual reproduction. Asexual reproduction is their most common form of reproduction. Basidiomycota (club fungi) produce showy fruiting bodies that contain basidia in the form of clubs. Spores are stored in the basidia. Most familiar mushrooms belong to this division. Deuteromycota (imperfect fungi) belong to a polyphyletic group that does not reproduce through sexual reproduction. Glomeromycota form tight associations (called mycorrhizae) with the roots of plants.

24.3 Ecology of Fungi

Fungi have colonized nearly all environments on Earth, but are frequently found in cool, dark, moist places with a supply of decaying material. Fungi are saprobes that decompose organic matter. Many successful mutualistic relationships involve a fungus and another organism. Many fungi establish complex mycorrhizal associations with the roots of plants. Some ants farm fungi as a supply of food. Lichens are a symbiotic relationship between a fungus and a photosynthetic organism, usually an alga or cyanobacterium. The photosynthetic organism provides energy derived from light and carbohydrates, while the fungus supplies minerals and protection. Some animals that consume fungi help disseminate spores over long distances.

24.4 Fungal Parasites and Pathogens

Fungi establish parasitic relationships with plants and animals. Fungal diseases can decimate crops and spoil food during storage. Compounds produced by fungi can be toxic to humans and other animals. Mycoses are infections caused by fungi. Superficial mycoses affect the skin, whereas systemic mycoses spread through the body. Fungal infections are difficult to cure.

24.5 Importance of Fungi in Human Life

Fungi are important to everyday human life. Fungi are important decomposers in most ecosystems. Mycorrhizal fungi are essential for the growth of most plants. Fungi, as food, play a role in human nutrition in the form of mushrooms, and also as agents of fermentation in the production of bread, cheeses, alcoholic beverages, and numerous other food preparations. Secondary metabolites of fungi are used as medicines, such as antibiotics and anticoagulants. Fungi are model organisms for the study of eukaryotic genetics and metabolism.

ART CONNECTION QUESTIONS

1. **Figure 24.13** Which of the following statements is true?

a. A dikaryotic ascus that forms in the ascocarp undergoes karyogamy, meiosis, and mitosis to form eight ascospores.
b. A diploid ascus that forms in the ascocarp undergoes karyogamy, meiosis, and mitosis to form eight ascospores.
c. A haploid zygote that forms in the ascocarp undergoes karyogamy, meiosis, and mitosis to form eight ascospores.
d. A dikaryotic ascus that forms in the ascocarp undergoes plasmogamy, meiosis, and mitosis to form eight ascospores.

2. **Figure 24.16** Which of the following statements is true?

a. A basidium is the fruiting body of a mushroom-producing fungus, and it forms four basidiocarps.
b. The result of the plasmogamy step is four basidiospores.
c. Karyogamy results directly in the formation of mycelia.
d. A basidiocarp is the fruiting body of a mushroom-producing fungus.

3. **Figure 24.20** If symbiotic fungi are absent from the soil, what impact do you think this would have on plant growth?

REVIEW QUESTIONS

4. Which polysaccharide is usually found in the cell wall of fungi?

a. starch
b. glycogen
c. chitin
d. cellulose

5. Which of these organelles is not found in a fungal cell?

a. chloroplast
b. nucleus
c. mitochondrion
d. Golgi apparatus

6. The wall dividing individual cells in a fungal filament is called a

a. thallus
b. hypha
c. mycelium
d. septum

7. During sexual reproduction, a homothallic mycelium contains

a. all septated hyphae
b. all haploid nuclei
c. both mating types
d. none of the above

8. The most primitive phylum of fungi is the _____.

a. Chytridiomycota
b. Zygomycota
c. Glomeromycota
d. Ascomycota

9. Members of which phylum produce a club-shaped structure that contains spores?

a. Chytridiomycota
b. Basidiomycota
c. Glomeromycota
d. Ascomycota

10. Members of which phylum establish a successful symbiotic relationship with the roots of trees?

a. Ascomycota
b. Deuteromycota
c. Basidiomycota
d. Glomeromycota

11. The imperfect fungi that do not reproduce sexually are classified as _____.

a. Ascomycota
b. Deuteromycota
c. Basidiomycota
d. Glomeromycota

12. What term describes the close association of a fungus with the root of a tree?

a. a rhizoid
b. a lichen
c. a mycorrhiza
d. an endophyte

13. Why are fungi important decomposers?

a. They produce many spores.
b. They can grow in many different environments.
c. They produce mycelia.
d. They recycle carbon and inorganic minerals by the process of decomposition.

14. A fungus that climbs up a tree reaching higher elevation to release its spores in the wind and does not receive any nutrients from the tree or contribute to the tree's welfare is described as a _____.

a. commensal
b. mutualist
c. parasite
d. pathogen

15. A fungal infection that affects nails and skin is classified as _____.

a. systemic mycosis
b. mycetismus
c. superficial mycosis
d. mycotoxicosis

16. Yeast is a facultative anaerobe. This means that alcohol fermentation takes place only if:

a. the temperature is close to 37°C
b. the atmosphere does not contain oxygen
c. sugar is provided to the cells
d. light is provided to the cells

17. The advantage of yeast cells over bacterial cells to express human proteins is that:

a. yeast cells grow faster
b. yeast cells are easier to manipulate genetically
c. yeast cells are eukaryotic and modify proteins similarly to human cells
d. yeast cells are easily lysed to purify the proteins

CRITICAL THINKING QUESTIONS

18. What are the evolutionary advantages for an organism to reproduce both asexually and sexually?

19. Compare plants, animals, and fungi, considering these components: cell wall, chloroplasts, plasma membrane, food source, and polysaccharide storage. Be sure to indicate fungi's similarities and differences to plants and animals.

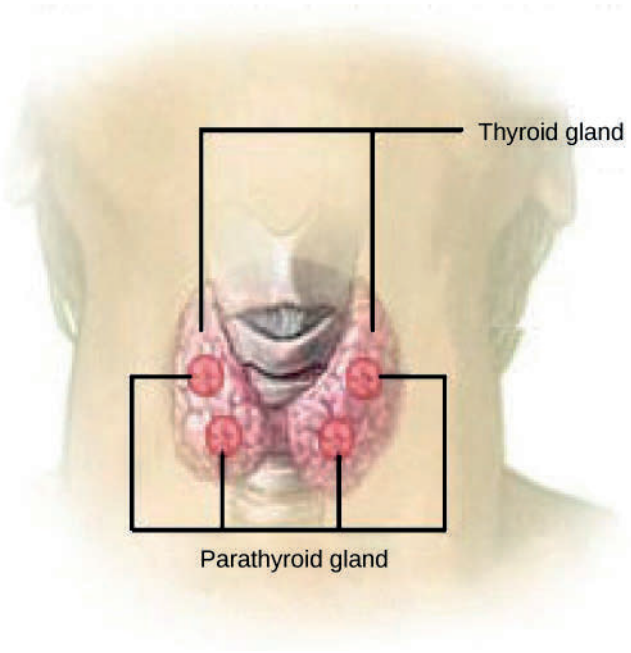
20. What is the advantage for a basidiomycete to produce a showy and fleshy fruiting body?

21. For each of the four groups of perfect fungi (Chytridiomycota, Zygomycota, Ascomycota, and Basidiomycota), compare the body structure and features, and provide an example.

22. Why does protection from light actually benefit the photosynthetic partner in lichens?

23. Why can superficial mycoses in humans lead to bacterial infections?

24. Historically, artisanal breads were produced by capturing wild yeasts from the air. Prior to the development of modern yeast strains, the production of artisanal breads was long and laborious because many batches of dough ended up being discarded. Can you explain this fact?



CHAPTER SUMMARY

25.1 Early Plant Life

Land plants acquired traits that made it possible to colonize land and survive out of the water. All land plants share the following characteristics: alternation of generations, with the haploid plant called a gametophyte, and the diploid plant called a sporophyte; protection of the embryo, formation of haploid spores in a sporangium, formation of gametes in a gametangium, and an apical meristem. Vascular tissues, roots, leaves, cuticle cover, and a tough outer layer that protects the spores contributed to the adaptation of plants to dry land. Land plants appeared about 500 million years ago in the Ordovician period.

25.2 Green Algae: Precursors of Land Plants

Green algae share more traits with land plants than other algae, according to structure and DNA analysis. Charales form sporopollenin and precursors of lignin, phragmoplasts, and have flagellated sperm. They do not exhibit alternation of generations.

25.3 Bryophytes

Seedless nonvascular plants are small, having the gametophyte as the dominant stage of the lifecycle. Without a vascular system and roots, they absorb water and nutrients on all their exposed surfaces. Collectively known as bryophytes, the three main groups include the liverworts, the hornworts, and the mosses. Liverworts are the most primitive plants and are closely related to the first land plants. Hornworts developed stomata and possess a single chloroplast per cell. Mosses have simple conductive cells and are attached to the substrate by rhizoids. They colonize harsh habitats and can regain moisture after drying out. The moss sporangium is a complex structure that allows release of spores away from the parent plant.

25.4 Seedless Vascular Plants

Vascular systems consist of xylem tissue, which transports water and minerals, and phloem tissue, which transports sugars and proteins. With the development of the vascular system, there appeared leaves to act as large photosynthetic organs, and roots to access water from the ground. Small

uncomplicated leaves are microphylls. Large leaves with vein patterns are megaphylls. Modified leaves that bear sporangia are sporophylls. Some sporophylls are arranged in cone structures called strobili.

The seedless vascular plants include club mosses, which are the most primitive; whisk ferns, which lost leaves and roots by reductive evolution; and horsetails and ferns. Ferns are the most advanced group of seedless vascular plants. They are distinguished by large leaves called fronds and small sporangia-containing structures called sori, which are found on the underside of the fronds.

Mosses play an essential role in the balance of the ecosystems; they are pioneering species that colonize bare or devastated environments and make it possible for a succession to occur. They contribute to the enrichment of the soil and provide shelter and nutrients for animals in hostile environments. Mosses and ferns can be used as fuels and serve culinary, medical, and decorative purposes.

ART CONNECTION QUESTIONS

1. **Figure 25.5** Which of the following statements about plant divisions is false?

a. Lycophytes and pterophytes are seedless vascular plants.
b. All vascular plants produce seeds.
c. All nonvascular embryophytes are bryophytes.
d. Seed plants include angiosperms and gymnosperms.

2. **Figure 25.14** Which of the following statements about the moss life cycle is false?

a. The mature gametophyte is haploid.
b. The sporophyte produces haploid spores.
c. The rhizoid buds to form a mature gametophyte.
d. The zygote is housed in the venter.

3. **Figure 25.21** Which of the following statements about the fern life cycle is false?

a. Sporangia produce haploid spores.
b. The sporophyte grows from a gametophyte.
c. The sporophyte is diploid and the gametophyte is haploid.
d. Sporangia form on the underside of the gametophyte.

REVIEW QUESTIONS

4. The land plants are probably descendants of which of these groups?

a. green algae
b. red algae
c. brown algae
d. angiosperms

5. Alternation of generations means that plants produce:

a. only haploid multicellular organisms
b. only diploid multicellular organisms
c. only diploid multicellular organisms with single-celled haploid gametes
d. both haploid and diploid multicellular organisms

6. Which of the following traits of land plants allows them to grow in height?

a. alternation of generations
b. waxy cuticle
c. tracheids
d. sporopollenin

7. What characteristic of Charales would enable them to survive a dry spell?

a. sperm with flagella
b. phragmoplasts
c. sporopollenin
d. chlorophyll *a*

8. Which one of these characteristics is present in land plants and not in Charales?

a. alternation of generations
b. flagellated sperm
c. phragmoplasts
d. plasmodesmata

9. Which of the following structures is not found in bryophytes?

a. a cellulose cell wall
b. chloroplast
c. sporangium
d. root

10. Stomata appear in which group of plants?

a. Charales
b. liverworts
c. hornworts
d. mosses

11. The chromosome complement in a moss protonema is:

a. 1*n*
b. 2*n*
c. 3*n*
d. varies with the size of the protonema

12. Why do mosses grow well in the Arctic tundra?

a. They grow better at cold temperatures.
b. They do not require moisture.
c. They do not have true roots and can grow on hard surfaces.

d. There are no herbivores in the tundra.

13. Microphylls are characteristic of which types of plants?

a. mosses
b. liverworts
c. club mosses
d. ferns

14. A plant in the understory of a forest displays a segmented stem and slender leaves arranged in a whorl. It is probably a _____.

a. club moss
b. whisk fern
c. fern
d. horsetail

15. The following structures are found on the underside of fern leaves and contain sporangia:

a. sori
b. rhizomes
c. megaphylls
d. microphylls

16. The dominant organism in fern is the _____.

a. sperm
b. spore
c. gamete
d. sporophyte

17. What seedless plant is a renewable source of energy?

a. club moss
b. horsetail
c. sphagnum moss
d. fern

18. How do mosses contribute to returning nitrogen to the soil?

a. Mosses fix nitrogen from the air.
b. Mosses harbor cyanobacteria that fix nitrogen.
c. Mosses die and return nitrogen to the soil.
d. Mosses decompose rocks and release nitrogen.

CRITICAL THINKING QUESTIONS

19. Why did land plants lose some of the accessory pigments present in brown and red algae?

20. What is the difference between extant and extinct?

21. To an alga, what is the main advantage of producing drought-resistant structures?

22. In areas where it rains often, mosses grow on roofs. How do mosses survive on roofs without soil?

23. What are the three classes of bryophytes?

24. How did the development of a vascular system contribute to the increase in size of plants?

25. Which plant is considered the most advanced seedless vascular plant and why?

CHAPTER SUMMARY

26.1 Evolution of Seed Plants

Seed plants appeared about one million years ago, during the Carboniferous period. Two major innovations—seed and pollen—allowed seed plants to reproduce in the absence of water. The gametophytes of seed plants shrank, while the sporophytes became prominent structures and the diploid stage became the longest phase of the lifecycle. Gymnosperms became the dominant group during the Triassic. In these, pollen grains and seeds protect against desiccation. The seed, unlike a spore, is a diploid embryo surrounded by storage tissue and protective layers. It is equipped to delay germination until growth conditions are optimal. Angiosperms bear both flowers and fruit. The structures protect the gametes and the embryo during its development. Angiosperms appeared during the Mesozoic era and have become the dominant plant life in terrestrial habitats.

26.2 Gymnosperms

Gymnosperms are heterosporous seed plants that produce naked seeds. They appeared in the Paleozoic period and were the dominant plant life during the Mesozoic. Modern-day gymnosperms belong to four phyla. The largest phylum, Coniferophyta, is represented by conifers, the predominant plants at high altitude and latitude. Cycads (phylum Cycadophyta) resemble palm trees and grow in tropical climates. *Gingko biloba* is the only representative of the phylum Gingkophyta. The last phylum, Gnetophyta, is a diverse group of shrubs that produce vessel elements in their wood.

26.3 Angiosperms

Angiosperms are the dominant form of plant life in most terrestrial ecosystems, comprising about 90 percent of all plant species. Most crops and ornamental plants are angiosperms. Their success comes from two innovative structures that protect reproduction from variability in the environment: the flower and the fruit. Flowers were derived from modified leaves. The main parts of a flower are the sepals and petals, which protect the reproductive parts: the stamens and the carpels. The stamens produce the male gametes in pollen grains. The carpels contain the female gametes (the eggs inside the ovules), which are within the ovary of a carpel. The walls of the ovary thicken after fertilization, ripening into fruit that ensures dispersal by wind, water, or animals.

The angiosperm life cycle is dominated by the sporophyte stage. Double fertilization is an event unique to angiosperms. One sperm in the pollen fertilizes the egg, forming a diploid zygote, while the other combines with the two polar nuclei, forming a triploid cell that develops into a food storage tissue called the endosperm. Flowering plants are divided into two main groups, the monocots and eudicots, according to the number of cotyledons in the seedlings. Basal angiosperms belong to an older lineage than monocots and eudicots.

26.4 The Role of Seed Plants

Angiosperm diversity is due in part to multiple interactions with animals. Herbivory has favored the development of defense mechanisms in plants, and avoidance of those defense mechanism in animals. Pollination (the transfer of pollen to a carpel) is mainly carried out by wind and animals, and angiosperms have evolved numerous adaptations to capture the wind or attract specific classes of animals.

Plants play a key role in ecosystems. They are a source of food and medicinal compounds, and provide raw materials for many industries. Rapid deforestation and industrialization, however, threaten plant biodiversity. In turn, this threatens the ecosystem.

ART CONNECTION QUESTIONS

1. **Figure 26.8** At what stage does the diploid zygote form?

a. When the female cone begins to bud from the tree
b. At fertilization
c. When the seeds drop from the tree
d. When the pollen tube begins to grow

2. **Figure 26.15** If a flower lacked a megasporangium, what type of gamete would not form? If the flower lacked a microsporangium, what type of gamete would not form?

REVIEW QUESTIONS

3. Seed plants are _____.

a. all homosporous.
b. mostly homosporous with some heterosporous.
c. mostly heterosporous with some homosporous.
d. all heterosporous.

4. Besides the seed, what other major structure diminishes a plant's reliance on water for reproduction?

a. flower
b. fruit
c. pollen
d. spore

5. In which of the following geological periods would gymnosperms dominate the landscape?

a. Carboniferous
b. Permian
c. Triassic
d. Eocene (present)

6. Which of the following structures widens the geographic range of a species and is an agent of dispersal?

a. seed
b. flower
c. leaf
d. root

7. Which of the following traits characterizes gymnosperms?

a. The plants carry exposed seeds on modified leaves.
b. Reproductive structures are located in a flower.
c. After fertilization, the ovary thickens and forms a fruit.
d. The gametophyte is longest phase of the life cycle.

8. Megasporocytes will eventually produce which of the following?

a. pollen grain
b. sporophytes
c. male gametophytes
d. female gametophytes

9. What is the ploidy of the following structures: gametophyte, seed, spore, sporophyte?
a. 1*n*, 1*n*, 2*n*, 2*n*
b. 1*n*, 2*n*, 1*n*, 2*n*
c. 2*n*, 1*n*, 2*n*, 1*n*
d. 2*n*, 2*n*, 1*n*, 1*n*

10. In the northern forests of Siberia, a tall tree is most likely a:
a. conifer
b. cycad
c. *Gingko biloba*
d. gnetophyte

11. Which of the following structures in a flower is not directly involved in reproduction?
a. the style
b. the stamen
c. the sepal
d. the anther

12. Pollen grains develop in which structure?
a. the anther
b. the stigma
c. the filament
d. the carpel

13. In the course of double fertilization, one sperm cell fuses with the egg and the second one fuses with _____.
a. the synergids
b. the polar nuclei of the center cell
c. the egg as well
d. the antipodal cells

14. Corn develops from a seedling with a single cotyledon, displays parallel veins on its leaves, and produces monosulcate pollen. It is most likely:
a. a gymnosperm
b. a monocot
c. a eudicot
d. a basal angiosperm

15. Which of the following plant structures is not a defense against herbivory?
a. thorns
b. spines
c. nectar
d. alkaloids

16. White and sweet-smelling flowers with abundant nectar are probably pollinated by
a. bees and butterflies
b. flies
c. birds
d. wind

17. Abundant and powdery pollen produced by small, indistinct flowers is probably transported by:
a. bees and butterflies
b. flies
c. birds
d. wind

18. Plants are a source of _____.
a. food
b. fuel
c. medicine
d. all of the above

CRITICAL THINKING QUESTIONS

19. The Triassic Period was marked by the increase in number and variety of angiosperms. Insects also diversified enormously during the same period. Can you propose the reason or reasons that could foster coevolution?

20. What role did the adaptations of seed and pollen play in the development and expansion of seed plants?

21. The Mediterranean landscape along the sea shore is dotted with pines and cypresses. The weather is not cold, and the trees grow at sea level. What evolutionary adaptation of conifers makes them suitable to the Mediterranean climate?

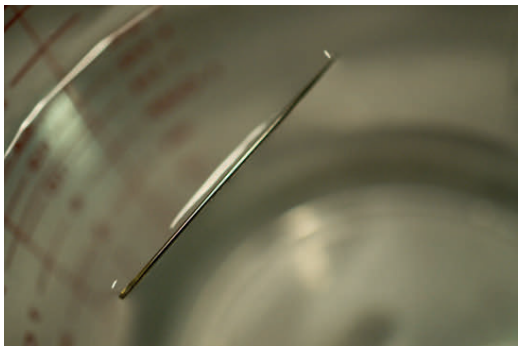
22. What are the four modern-day phyla of gymnosperms?

23. Some cycads are considered endangered species and their trade is severely restricted. Customs officials stop suspected smugglers who claim that the plants in their possession are palm trees, not cycads. How would a botanist distinguish between the two types of plants?

24. What are the two structures that allow angiosperms to be the dominant form of plant life in most terrestrial ecosystems?

25. Biosynthesis of nectar and nutrient-rich pollen is energetically very expensive for a plant. Yet, plants funnel large amounts of energy into animal pollination. What are the evolutionary advantages that offset the cost of attracting animal pollinators?

26. What is biodiversity and why is it important to an ecosystem?



CHAPTER SUMMARY

27.1 Features of the Animal Kingdom

Animals constitute an incredibly diverse kingdom of organisms. Although animals range in complexity from simple sea sponges to human beings, most members of the animal kingdom share certain features. Animals are eukaryotic, multicellular, heterotrophic organisms that ingest their food and usually develop into motile creatures with a fixed body plan. A major characteristic unique to the animal kingdom is the presence of differentiated tissues, such as nerve, muscle, and connective tissues, which are specialized to perform specific functions. Most animals undergo sexual reproduction, leading to a series of developmental embryonic stages that are relatively similar across the animal kingdom. A class of transcriptional control genes called *Hox* genes directs the organization of the major animal body plans, and these genes are strongly homologous across the animal kingdom.

27.2 Features Used to Classify Animals

Organisms in the animal kingdom are classified based on their body morphology and development. True animals are divided into those with radial versus bilateral symmetry. Generally, the simpler and often non-motile animals display radial symmetry. Animals with radial symmetry are also generally characterized by the development of two embryological germ layers, the endoderm and ectoderm, whereas animals with bilateral symmetry are generally characterized by the development of a third embryological germ layer, the mesoderm. Animals with three germ layers, called triploblasts, are further characterized by the presence or absence of an internal body cavity called a coelom. The presence of a coelom affords many advantages, and animals with a coelom may be termed true coelomates or pseudocoelomates, depending on which tissue gives rise to the coelom. Coelomates are further divided into one of two groups called protostomes and deuterostomes, based on a number of developmental characteristics, including differences in zygote cleavage and method of coelom formation.

27.3 Animal Phylogeny

Scientists are interested in the evolutionary history of animals and the evolutionary relationships among them. There are three main sources of data that scientists use to create phylogenetic evolutionary tree diagrams that illustrate such relationships: morphological information (which includes developmental morphologies), fossil record data, and, most recently, molecular data. The details of the modern phylogenetic tree change frequently as new data are gathered, and molecular data has recently contributed to many substantial modifications of the understanding of relationships between animal phyla.

27.4 The Evolutionary History of the Animal Kingdom

The most rapid diversification and evolution of animal species in all of history occurred during the Cambrian period of the Paleozoic Era, a phenomenon known as the Cambrian explosion. Until recently,

scientists believed that there were only very few tiny and simplistic animal species in existence before this period. However, recent fossil discoveries have revealed that additional, larger, and more complex animals existed during the Ediacaran period, and even possibly earlier, during the Cryogenian period. Still, the Cambrian period undoubtedly witnessed the emergence of the majority of animal phyla that we know today, although many questions remain unresolved about this historical phenomenon.

The remainder of the Paleozoic Era is marked by the growing appearance of new classes, families, and species, and the early colonization of land by certain marine animals. The evolutionary history of animals is also marked by numerous major extinction events, each of which wiped out a majority of extant species. Some species of most animal phyla survived these extinctions, allowing the phyla to persist and continue to evolve into species that we see today.

ART CONNECTION QUESTIONS

1. **Figure 27.5** If a *Hox 13* gene in a mouse was replaced with a *Hox 1* gene, how might this alter animal development?

2. **Figure 27.6** Which of the following statements is false?

a. Eumetazoans have specialized tissues and parazoans don't.
b. Lophotrochozoa and Ecdysozoa are both Bilataria.
c. Acoela and Cnidaria both possess radial symmetry.
d. Arthropods are more closely related to nematodes than they are to annelids.

3. **Figure 27.9** Which of the following statements about diploblasts and triploblasts is false?

a. Animals that display radial symmetry are diploblasts.
b. Animals that display bilateral symmetry are triploblasts.
c. The endoderm gives rise to the lining of the digestive tract and the respiratory tract.
d. The mesoderm gives rise to the central nervous system.

REVIEW QUESTIONS

4. Which of the following is not a feature common to *most* animals?

a. development into a fixed body plan
b. asexual reproduction
c. specialized tissues
d. heterotrophic nutrient sourcing

5. During embryonic development, unique cell layers develop and distinguish during a stage called _____.

a. the blastula stage
b. the germ layer stage
c. the gastrula stage
d. the organogenesis stage

6. Which of the following phenotypes would most likely be the result of a *Hox* gene mutation?

a. abnormal body length or height
b. two different eye colors
c. the contraction of a genetic illness
d. two fewer appendages than normal

7. Which of the following organism is most likely to be a diploblast?

a. sea star
b. shrimp
c. jellyfish
d. insect

8. Which of the following is not possible?

a. radially symmetrical diploblast
b. diploblastic eucoelomate
c. protostomic coelomate
d. bilaterally symmetrical deuterostome

9. An animal whose development is marked by radial cleavage and enterocoely is _____.

a. a deuterostome
b. an annelid or mollusk
c. either an acoelomate or eucoelomate
d. none of the above

10. Consulting the modern phylogenetic tree of animals, which of the following would not constitute a clade?

a. deuterostomes
b. lophotrochozoans
c. Parazoa
d. Bilateria

11. Which of the following is thought to be the most closely related to the common animal ancestor?

a. fungal cells
b. protist cells
c. plant cells
d. bacterial cells

12. As with the emergence of the Acoelomorpha phylum, it is common for ____ data to misplace animals in close relation to other species, whereas ____ data often reveals a different and more accurate evolutionary relationship.

a. molecular : morphological
b. molecular : fossil record

c. fossil record : morphological
d. morphological : molecular

13. Which of the following periods is the earliest during which animals may have appeared?

a. Ordovician period
b. Cambrian period
c. Ediacaran period
d. Cryogenian period

14. What type of data is primarily used to determine the existence and appearance of early animal species?

a. molecular data
b. fossil data
c. morphological data
d. embryological development data

15. The time between 542–488 million years ago marks which period?

a. Cambrian period
b. Silurian period
c. Ediacaran period
d. Devonian period

16. Until recent discoveries suggested otherwise, animals existing before the Cambrian period were believed to be:

a. small and ocean-dwelling
b. small and non-motile
c. small and soft-bodied
d. small and radially symmetrical or asymmetrical

17. Plant life first appeared on land during which of the following periods?

a. Cambrian period
b. Ordovician period
c. Silurian period
d. Devonian period

18. Approximately how many mass extinction events occurred throughout the evolutionary history of animals?

a. 3
b. 4
c. 5
d. more than 5

CRITICAL THINKING QUESTIONS

19. Why might the evolution of specialized tissues be important for animal function and complexity?

20. Describe and give examples of how humans display all of the features common to the animal kingdom.

21. How have *Hox* genes contributed to the diversity of animal body plans?

22. Using the following terms, explain what classifications and groups humans fall into, from the most general to the most specific: symmetry, germ layers, coelom, cleavage, embryological development.

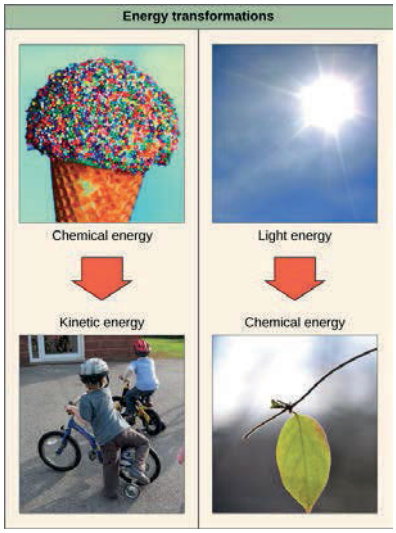
23. Explain some of the advantages brought about through the evolution of bilateral symmetry and coelom formation.

24. Describe at least two major changes to the animal phylogenetic tree that have come about due to molecular or genetic findings.

25. How is it that morphological data alone might lead scientists to group animals into erroneous evolutionary relationships?

26. Briefly describe at least two theories that attempt to explain the cause of the Cambrian explosion.

27. How is it that most, if not all, of the extant animal phyla today evolved during the Cambrian period if so many massive extinction events have taken place since then?



CHAPTER SUMMARY

28.1 Phylum Porifera

Animals included in phylum Porifera are Parazoans because they do not show the formation of true tissues (except in class Hexactinellida). These organisms show very simple organization, with a rudimentary endoskeleton. Sponges have multiple cell types that are geared toward executing various metabolic functions. Although these animals are very simple, they perform several complex physiological functions.

28.2 Phylum Cnidaria

Cnidarians represent a more complex level of organization than Porifera. They possess outer and inner tissue layers that sandwich a noncellular mesoglea. Cnidarians possess a well-formed digestive system and carry out extracellular digestion. The cnidocyte is a specialized cell for delivering toxins to prey as well as warning off predators. Cnidarians have separate sexes and have a lifecycle that involves morphologically distinct forms. These animals also show two distinct morphological forms—medusoid and polypoid—at various stages in their lifecycle.

28.3 Superphylum Lophotrochozoa

Phylum Annelida includes vermiform, segmented animals. Segmentation is seen in internal anatomy as well, which is called metamerism. Annelids are protostomes. These animals have well-developed neuronal and digestive systems. Some species bear a specialized band of segments known as a clitellum. Annelids show the presence numerous chitinous projections termed chaetae, and polychaetes possess parapodia. Suckers are seen in order Hirudinea. Reproductive strategies include sexual dimorphism, hermaphroditism, and serial hermaphroditism. Internal segmentation is absent in class Hirudinea.

Flatworms are acoelomate, triploblastic animals. They lack circulatory and respiratory systems, and have a rudimentary excretory system. This digestive system is incomplete in most species. There are four traditional classes of flatworms, the largely free-living turbellarians, the ectoparasitic monogeneans, and the endoparasitic trematodes and cestodes. Trematodes have complex lifecycles involving a molluscan secondary host and a primary host in which sexual reproduction takes place. Cestodes, or tapeworms, infect the digestive systems of primary vertebrate hosts.

The rotifers are microscopic, multicellular, mostly aquatic organisms that are currently under taxonomic revision. The group is characterized by the rotating, ciliated, wheel-like structure, the corona, on their head. The mastax or jawed pharynx is another structure unique to this group of organisms.

The nemertini are the simplest eucoelomates. These ribbon-shaped animals bear a specialized proboscis enclosed within a rhynchocoel. The development of a closed circulatory system derived from the coelom is a significant difference seen in this species compared to other pseudocoelomate phyla. Alimentary, nervous, and excretory systems are more developed in the nemertini than in less advanced phyla. Embryonic development of nemertine worms proceeds via a planuliform larval stage.

Phylum Mollusca is a large, marine group of invertebrates. Mollusks show a variety of morphological variations within the phylum. This phylum is also distinct in that some members exhibit a calcareous shell as an external means of protection. Some mollusks have evolved a reduced shell. Mollusks are protostomes. The dorsal epidermis in mollusks is modified to form the mantle, which encloses the mantle cavity and visceral organs. This cavity is quite distinct from the coelomic cavity, which in the adult animal surrounds the heart. Respiration is facilitated by gills known as ctenidia. A chitinous-toothed tongue called the radula is present in most mollusks. Early development in some species occurs via two larval stages: trochophore and veliger. Sexual dimorphism is the predominant sexual strategy in this phylum. Mollusks can be divided into seven classes, each with distinct morphological characteristics.

28.4 Superphylum Ecdysozoa

Nematodes are pseudocoelomate animals akin to flatworms, yet display more advanced neuronal development, a complete digestive system, and a body cavity. This phylum includes free-living as well as parasitic organisms like *Caenorhabditis elegans* and *Ascaris* spp., respectively. They include dioeceous as well as hermaphroditic species. Nematodes also possess an excretory system that is not quite well developed. Embryonic development is external and proceeds via three larval stages. A peculiar feature of nematodes is the secretion of a collagenous/chitinous cuticle outside the body.

Arthropods represent the most successful phylum of animal on Earth, in terms of the number of species as well as the number of individuals. These animals are characterized by a segmented body as well as the presence of jointed appendages. In the basic body plan, a pair of appendages is present per body segment. Within the phylum, traditional classification is based on mouthparts, number of appendages, and modifications of appendages present. Arthropods bear a chitinous exoskeleton. Gills, trachea, and book lungs facilitate respiration. Sexual dimorphism is seen in this phylum, and embryonic development includes multiple larval stages.

28.5 Superphylum Deuterostomia

Echinoderms are deuterostomic marine organisms. This phylum of animals bears a calcareous endoskeleton composed of ossicles. These animals also have spiny skin. Echinoderms possess water-based circulatory systems. A pore termed the madreporite is the point of entry and exit for water into the water vascular system. Osmoregulation is carried out by specialized cells known as podocytes.

The characteristic features of Chordata are a notochord, a dorsal hollow nerve cord, pharyngeal slits, and a post-anal tail. Chordata contains two clades of invertebrates: Urochordata (tunicates) and Cephalochordata (lancelets), together with the vertebrates in Vertebrata. Most tunicates live on the ocean floor and are suspension feeders. Lancelets are suspension feeders that feed on phytoplankton and other microorganisms.

ART CONNECTION QUESTIONS

1. **Figure 28.3** Which of the following statements is false?

a. Choanocytes have flagella that propel water through the body.
b. Pinacocytes can transform into any cell type.
c. Lophocytes secrete collagen.
d. Porocytes control the flow of water through pores in the sponge body.

2. **Figure 28.20** Which of the following statements about the anatomy of a mollusk is false?

a. Mollusks have a radula for grinding food.
b. A digestive gland is connected to the stomach.
c. The tissue beneath the shell is called the mantle.
d. The digestive system includes a gizzard, a stomach, a digestive gland, and the intestine.

3. **Figure 28.36** Which of the following statements about insects is false?

a. Insects have both dorsal and ventral blood vessels.
b. Insects have spiracles, openings that allow air to enter.
c. The trachea is part of the digestive system.
d. Insects have a developed digestive system with a mouth, crop, and intestine.

REVIEW QUESTIONS

4. Mesohyl contains:
- a. a polysaccharide gel and dead cells
- b. a collagen-like gel and suspended cells for various functions
- c. spicules composed of silica or calcium carbonate
- d. multiple pores

5. The large central opening in the Parazoan body is called the:
- a. gemmule
- b. spicule
- c. ostia
- d. osculum

6. Cnidocytes are found in _____.
- a. phylum Porifera
- b. phylum Nemertea
- c. phylum Nematoda
- d. phylum Cnidaria

7. Cubozoans are _____.
- a. polyps
- b. medusoids
- c. polymorphs
- d. sponges

8. Annelids have a:
- a. pseudocoelom
- b. a true coelom
- c. no coelom
- d. none of the above

9. Which group of flatworms are primarily ectoparasites of fish?
- a. monogeneans
- b. trematodes
- c. cestodes
- d. turbellarians

10. A mantle and mantle cavity are present in:
- a. phylum Echinodermata
- b. phylum Adversoidea
- c. phylum Mollusca
- d. phylum Nemertea

11. The rhynchocoel is a _____.
- a. circulatory system
- b. fluid-filled cavity
- c. primitive excretory system
- d. proboscis

12. The embryonic development in nematodes can have up to _____ larval stages.
- a. one
- b. two
- c. three
- d. five

13. The nematode cuticle contains _____.
- a. glucose
- b. skin cells
- c. chitin
- d. nerve cells

14. Crustaceans are _____.
- a. ecdysozoans
- b. nematodes
- c. arachnids
- d. parazoans

15. Flies are_____.
- a. chelicerates
- b. hexapods
- c. arachnids
- d. crustaceans

16. Echinoderms have _____.
- a. triangular symmetry
- b. radial symmetry
- c. hexagonal symmetry
- d. pentaradial symmetry

17. The circulatory fluid in echinoderms is _____.
- a. blood
- b. mesohyl
- c. water
- d. saline

CRITICAL THINKING QUESTIONS

18. Describe the different cell types and their functions in sponges.

19. Describe the feeding mechanism of sponges and identify how it is different from other animals.

20. Explain the function of nematocysts in cnidarians.

21. Compare the structural differences between Porifera and Cnidaria.

22. Describe the morphology and anatomy of mollusks.

23. What are the anatomical differences between nemertines and mollusks?

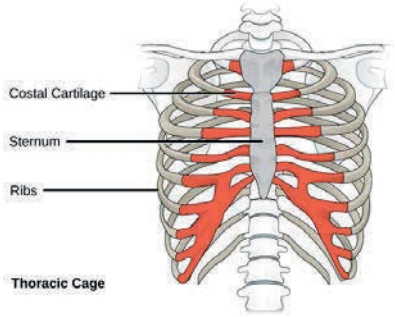
24. Enumerate features of *Caenorhabditis elegans* that make it a valuable model system for biologists.

25. What are the different ways in which nematodes can reproduce?

26. Describe the various superclasses that phylum Arthropoda can be divided into.

27. Compare and contrast the segmentation seen in phylum Annelida with that seen in phylum Arthropoda.

28. Describe the different classes of echinoderms using examples.



CHAPTER SUMMARY

29.1 Chordates

The characteristic features of Chordata are a notochord, a dorsal hollow nerve cord, pharyngeal slits, and a post-anal tail. Chordata contains two clades of invertebrates: Urochordata (tunicates) and Cephalochordata (lancelets), together with the vertebrates in Vertebrata. Most tunicates live on the ocean floor and are suspension feeders. Lancelets are suspension feeders that feed on phytoplankton and other microorganisms. Vertebrata is named for the vertebral column, which is a feature of almost all members of this clade.

29.2 Fishes

The earliest vertebrates that diverged from the invertebrate chordates were the jawless fishes. Fishes with jaws (gnathostomes) evolved later. Jaws allowed early gnathostomes to exploit new food sources. Agnathans include the hagfishes and lampreys. Hagfishes are eel-like scavengers that feed on dead invertebrates and other fishes. Lampreys are characterized by a toothed, funnel-like sucking mouth, and most species are parasitic on other fishes. Gnathostomes include the cartilaginous fishes and the bony fishes, as well as all other tetrapods. Cartilaginous fishes include sharks, rays, skates, and ghost sharks. Most cartilaginous fishes live in marine habitats, with a few species living in fresh water for part or all of their lives. The vast majority of present-day fishes belong to the clade Osteichthyes, which consists of approximately 30,000 species. Bony fishes can be divided into two clades: Actinopterygii (ray-finned fishes, virtually all extant species) and Sarcopterygii (lobe-finned fishes, comprising fewer than 10 extant species but which are the ancestors of tetrapods).

29.3 Amphibians

As tetrapods, most amphibians are characterized by four well-developed limbs, although some species of salamanders and all caecilians are limbless. The most important characteristic of extant amphibians is a moist, permeable skin used for cutaneous respiration. The fossil record provides evidence of amphibian species, now extinct, that arose over 400 million years ago as the first tetrapods. Amphibia can be divided into three clades: salamanders (Urodela), frogs (Anura), and caecilians (Apoda). The life cycle of frogs, like the majority of amphibians, consists of two distinct stages: the larval stage and metamorphosis to an adult stage. Some species in all orders bypass a free-living larval stage.

29.4 Reptiles

The amniotes are distinguished from amphibians by the presence of a terrestrially adapted egg protected by amniotic membranes. The amniotes include reptiles, birds, and mammals. The early amniotes diverged into two main lines soon after the first amniotes arose. The initial split was into synapsids (mammals) and sauropsids. Sauropsids can be further divided into anapsids (turtles) and diapsids (birds and reptiles). Reptiles are tetrapods either having four limbs or descending from such. Limbless reptiles (snakes) are classified as tetrapods, as they are descended from four-limbed organisms. One of the key adaptations that permitted reptiles to live on land was the development of scaly skin containing the protein keratin, which prevented water loss from the skin. Reptilia includes four living clades: Crocodilia (crocodiles and alligators), Sphenodontia (tuataras), Squamata (lizards and snakes), and Testudines (turtles).

29.5 Birds

Birds are endothermic, meaning they produce their own body heat and regulate their internal temperature independently of the external temperature. Feathers not only act as insulation but also

allow for flight, providing lift with secondary feathers and thrust with primary feathers. Pneumatic bones are bones that are hollow rather than filled with tissue, containing air spaces that are sometimes connected to air sacs. Airflow through bird lungs travels in one direction, creating a cross-current exchange with the blood. Birds are diapsids and belong to a group called the archosaurs. Birds are thought to have evolved from theropod dinosaurs. The oldest known fossil of a bird is that of *Archaeopteryx*, which is from the Jurassic period. Modern birds are now classified into two groups, Paleognathae and Neognathae.

29.6 Mammals

Mammals in general are vertebrates that possess hair and mammary glands. The mammalian integument includes various secretory glands, including sebaceous glands, eccrine glands, apocrine glands, and mammary glands. Mammals are synapsids, meaning that they have a single opening in the skull. A key characteristic of synapsids is endothermy rather than the ectothermy seen in other vertebrates. Mammals probably evolved from therapsids in the late Triassic period, as the earliest known mammal fossils are from the early Jurassic period. There are three groups of mammals living today: monotremes, marsupials, and eutherians. Monotremes are unique among mammals as they lay eggs, rather than giving birth to young. Eutherian mammals are sometimes called placental mammals, because all species possess a complex placenta that connects a fetus to the mother, allowing for gas, fluid, and nutrient exchange.

29.7 The Evolution of Primates

All primate species possess adaptations for climbing trees, as they all probably descended from tree-dwellers, although not all species are arboreal. Other characteristics of primates are brains that are larger than those of other mammals, claws that have been modified into flattened nails, typically only one young per pregnancy, stereoscopic vision, and a trend toward holding the body upright. Primates are divided into two groups: prosimians and anthropoids. Monkeys evolved from prosimians during the Oligocene Epoch. Apes evolved from catarrhines in Africa during the Miocene Epoch. Apes are divided into the lesser apes and the greater apes. Hominins include those groups that gave rise to our species, such as *Australopithecus* and *H. erectus*, and those groups that can be considered “cousins” of humans, such as Neanderthals. Fossil evidence shows that hominins at the time of *Australopithecus* were walking upright, the first evidence of bipedal hominins. A number of species, sometimes called archaic *H. sapiens*, evolved from *H. erectus* approximately 500,000 years ago. There is considerable debate about the origins of anatomically modern humans or *H. sapiens sapiens*.

ART CONNECTION QUESTIONS

1. **Figure 29.3** Which of the following statements about common features of chordates is true?

a. The dorsal hollow nerve cord is part of the chordate central nervous system.
b. In vertebrate fishes, the pharyngeal slits become the gills.
c. Humans are not chordates because humans do not have a tail.
d. Vertebrates do not have a notochord at any point in their development; instead, they have a vertebral column.

2. **Figure 29.20** Which of the following statements about the parts of an egg are false?

a. The allantois stores nitrogenous waste and facilitates respiration.
b. The chorion facilitates gas exchange.
c. The yolk provides food for the growing embryo.
d. The amniotic cavity is filled with albumen.

3. **Figure 29.22** Members of the order Testudines have an anapsid-like skull with one opening. However, molecular studies indicate that turtles descended from a diapsid ancestor. Why might this be the case?

REVIEW QUESTIONS

4. Which of the following is *not* contained in phylum Chordata?

a. Cephalochordata
b. Echinodermata
c. Urochordata
d. Vertebrata

5. Which group of invertebrates is most closely related to vertebrates?

a. cephalochordates
b. echinoderms

c. arthropods
d. urochordates

6. Members of Chondrichthyes differ from members of Osteichthyes by having a _____.

a. jaw
b. bony skeleton
c. cartilaginous skeleton
d. two sets of paired fins

7. Members of Chondrichthyes are thought to be descended from fishes that had _____.

a. a cartilaginous skeleton
b. a bony skeleton
c. mucus glands
d. slime glands

8. Which of the following is *not* true of *Acanthostega*?

a. It was aquatic.
b. It had gills.
c. It had four limbs.
d. It laid shelled eggs.

9. Frogs belong to which order?

a. Anura
b. Urodela
c. Caudata
d. Apoda

10. During the Mesozoic period, diapsids diverged into_____.

a. pterosaurs and dinosaurs
b. mammals and reptiles
c. lepidosaurs and archosaurs
d. Testudines and Sphenodontia

11. Squamata includes_____.

a. crocodiles and alligators
b. turtles
c. tuataras
d. lizards and snakes

12. A bird or feathered dinosaur is _____.

a. Neornithes
b. *Archaeopteryx*
c. Enantiornithes
d. Paleognathae

13. Which of the following feather types helps to reduce drag produced by wind resistance during flight?

a. flight feathers
b. primary feathers
c. secondary feathers
d. contour feathers

14. Eccrine glands produce _____.

a. sweat
b. lipids
c. scents
d. milk

15. Monotremes include:

a. kangaroos
b. koalas
c. bandicoots
d. platypuses

16. Which of the following is *not* an anthropoid?

a. lemurs
b. monkeys
c. apes
d. humans

17. Which of the following is part of a clade believed to have died out, leaving no descendants?

a. *Paranthropus robustus*
b. *Australopithecus africanus*
c. *Homo erectus*
d. *Homo sapiens sapiens*

CRITICAL THINKING QUESTIONS

18. What are the characteristic features of the chordates?

19. What can be inferred about the evolution of the cranium and vertebral column from examining hagfishes and lampreys?

20. Why did gnathostomes replace most agnathans?

21. Explain why frogs are restricted to a moist environment.

22. Describe the differences between the larval and adult stages of frogs.

23. Describe the functions of the three extra-embryonic membranes present in amniotic eggs.

24. What characteristics differentiate lizards and snakes?

25. Explain why birds are thought to have evolved from theropod dinosaurs.

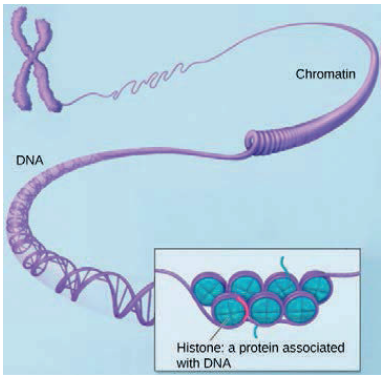
26. Describe three skeletal adaptations that allow for flight in birds.

27. Describe three unique features of the mammalian skeletal system.

28. Describe three characteristics of the mammalian brain that differ from other vertebrates.

29. How did archaic *Homo sapiens* differ from anatomically modern humans?

30. Why is it so difficult to determine the sequence of hominin ancestors that have led to modern *Homo sapiens*?



CHAPTER SUMMARY

30.1 The Plant Body

A vascular plant consists of two organ systems: the shoot system and the root system. The shoot system includes the aboveground vegetative portions (stems and leaves) and reproductive parts (flowers and fruits). The root system supports the plant and is usually underground. A plant is composed of two main types of tissue: meristematic tissue and permanent tissue. Meristematic tissue consists of actively dividing cells found in root and shoot tips. As growth occurs, meristematic tissue differentiates into permanent tissue, which is categorized as either simple or complex. Simple tissues are made up of similar cell types; examples include dermal tissue and ground tissue. Dermal tissue provides the outer covering of the plant. Ground tissue is responsible for photosynthesis; it also supports vascular tissue and may store water and sugars. Complex tissues are made up of different cell types. Vascular tissue, for example, is made up of xylem and phloem cells.

30.2 Stems

The stem of a plant bears the leaves, flowers, and fruits. Stems are characterized by the presence of nodes (the points of attachment for leaves or branches) and internodes (regions between nodes).

Plant organs are made up of simple and complex tissues. The stem has three tissue systems: dermal, vascular, and ground tissue. Dermal tissue is the outer covering of the plant. It contains epidermal cells, stomata, guard cells, and trichomes. Vascular tissue is made up of xylem and phloem tissues and conducts water, minerals, and photosynthetic products. Ground tissue is responsible for photosynthesis and support and is composed of parenchyma, collenchyma, and sclerenchyma cells.

Primary growth occurs at the tips of roots and shoots, causing an increase in length. Woody plants may also exhibit secondary growth, or increase in thickness. In woody plants, especially trees, annual rings may form as growth slows at the end of each season. Some plant species have modified stems that help to store food, propagate new plants, or discourage predators. Rhizomes, corms, stolons, runners, tubers, bulbs, tendrils, and thorns are examples of modified stems.

30.3 Roots

Roots help to anchor a plant, absorb water and minerals, and serve as storage sites for food. Taproots and fibrous roots are the two main types of root systems. In a taproot system, a main root grows vertically downward with a few lateral roots. Fibrous root systems arise at the base of the stem, where a cluster of roots forms a dense network that is shallower than a taproot. The growing root tip is protected by a root cap. The root tip has three main zones: a zone of cell division (cells are actively dividing), a zone of elongation (cells increase in length), and a zone of maturation (cells differentiate to form different kinds of cells). Root vascular tissue conducts water, minerals, and sugars. In some habitats, the roots of certain plants may be modified to form aerial roots or epiphytic roots.

30.4 Leaves

Leaves are the main site of photosynthesis. A typical leaf consists of a lamina (the broad part of the leaf, also called the blade) and a petiole (the stalk that attaches the leaf to a stem). The arrangement of leaves on a stem, known as phyllotaxy, enables maximum exposure to sunlight. Each plant species has a characteristic leaf arrangement and form. The pattern of leaf arrangement may be alternate, opposite, or spiral, while leaf form may be simple or compound. Leaf tissue consists of the epidermis, which forms the outermost cell layer, and mesophyll and vascular tissue, which make up the inner portion of the leaf. In some plant species, leaf form is modified to form structures such as tendrils, spines, bud scales, and needles.

30.5 Transport of Water and Solutes in Plants

Water potential (Ψ) is a measure of the difference in potential energy between a water sample and pure water. The water potential in plant solutions is influenced by solute concentration, pressure, gravity, and matric potential. Water potential and transpiration influence how water is transported through the xylem in plants. These processes are regulated by stomatal opening and closing. Photosynthates (mainly sucrose) move from sources to sinks through the plant's phloem. Sucrose is actively loaded into the sieve-tube elements of the phloem. The increased solute concentration causes water to move by osmosis from the xylem into the phloem. The positive pressure that is produced pushes water and solutes down the pressure gradient. The sucrose is unloaded into the sink, and the water returns to the xylem vessels.

30.6 Plant Sensory Systems and Responses

Plants respond to light by changes in morphology and activity. Irradiation by red light converts the photoreceptor phytochrome to its far-red light-absorbing form—Pfr. This form controls germination and flowering in response to length of day, as well as triggers photosynthesis in dormant plants or those that just emerged from the soil. Blue-light receptors, cryptochromes, and phototropins are responsible for phototropism. Amyloplasts, which contain heavy starch granules, sense gravity. Shoots exhibit negative gravitropism, whereas roots exhibit positive gravitropism. Plant hormones—naturally occurring compounds synthesized in small amounts—can act both in the cells that produce them and in distant tissues and organs. Auxins are responsible for apical dominance, root growth, directional growth toward light, and many other growth responses. Cytokinins stimulate cell division and counter apical dominance in shoots. Gibberellins inhibit dormancy of seeds and promote stem growth. Abscisic acid induces dormancy in seeds and buds, and protects plants from excessive water loss by promoting stomatal closure. Ethylene gas speeds up fruit ripening and dropping of leaves. Plants respond to touch by rapid movements (thigmotropy and thigmonasty) and slow differential growth (thigmomorphogenesis). Plants have evolved defense mechanisms against predators and pathogens. Physical barriers like bark and spines protect tender tissues. Plants also have chemical defenses, including toxic secondary metabolites and hormones, which elicit additional defense mechanisms.

ART CONNECTION QUESTIONS

1. **Figure 30.7** Which layers of the stem are made of parenchyma cells?

A. cortex and pith
B. epidermis
C. sclerenchyma
D. epidermis and cortex.

2. **Figure 30.32** Positive water potential is placed on the left side of the tube by increasing Ψ_p such that the water level rises on the right side. Could you equalize the water level on each side of the tube by adding solute, and if so, how?

3. **Figure 30.34** Which of the following statements is false?

a. Negative water potential draws water into the root hairs. Cohesion and adhesion draw water up the xylem. Transpiration draws water from the leaf.
b. Negative water potential draws water into the root hairs. Cohesion and adhesion draw water up the phloem. Transpiration draws water from the leaf.
c. Water potential decreases from the roots to the top of the plant.
d. Water enters the plants through root hairs and exits through stoma.

REVIEW QUESTIONS

4. Plant regions of continuous growth are made up of _____.
- a. dermal tissue
- b. vascular tissue
- c. meristematic tissue
- d. permanent tissue

5. Which of the following is the major site of photosynthesis?
- a. apical meristem
- b. ground tissue
- c. xylem cells
- d. phloem cells

6. Stem regions at which leaves are attached are called _____.
- a. trichomes
- b. lenticels
- c. nodes
- d. internodes

7. Which of the following cell types forms most of the inside of a plant?
- a. meristem cells
- b. collenchyma cells
- c. sclerenchyma cells
- d. parenchyma cells

8. Tracheids, vessel elements, sieve-tube cells, and companion cells are components of _____.
- a. vascular tissue
- b. meristematic tissue
- c. ground tissue
- d. dermal tissue

9. The primary growth of a plant is due to the action of the _____.
- a. lateral meristem
- b. vascular cambium
- c. apical meristem
- d. cork cambium

10. Which of the following is an example of secondary growth?
- a. increase in length
- b. increase in thickness or girth
- c. increase in root hairs
- d. increase in leaf number

11. Secondary growth in stems is usually seen in _____.
- a. monocots
- b. dicots
- c. both monocots and dicots
- d. neither monocots nor dicots

12. Roots that enable a plant to grow on another plant are called _____.
- a. epiphytic roots
- b. prop roots
- c. adventitious roots
- d. aerial roots

13. The _____ forces selective uptake of minerals in the root.
- a. pericycle
- b. epidermis
- c. endodermis
- d. root cap

14. Newly-formed root cells begin to form different cell types in the _____.
- a. zone of elongation
- b. zone of maturation
- c. root meristem
- d. zone of cell division

15. The stalk of a leaf is known as the _____.
- a. petiole
- b. lamina
- c. stipule
- d. rachis

16. Leaflets are a characteristic of _____ leaves.
- a. alternate
- b. whorled
- c. compound
- d. opposite

17. Cells of the _____ contain chloroplasts.
- a. epidermis
- b. vascular tissue
- c. stomata
- d. mesophyll

18. Which of the following is most likely to be found in a desert environment?
- a. broad leaves to capture sunlight
- b. spines instead of leaves
- c. needle-like leaves
- d. wide, flat leaves that can float

19. When stomata open, what occurs?
- a. Water vapor is lost to the external environment, increasing the rate of transpiration.
- b. Water vapor is lost to the external environment, decreasing the rate of transpiration.
- c. Water vapor enters the spaces in the mesophyll, increasing the rate of transpiration.
- d. Water vapor enters the spaces in the mesophyll, increasing the rate of transpiration.

20. Which cells are responsible for the movement of photosynthates through a plant?
- a. tracheids, vessel elements
- b. tracheids, companion cells
- c. vessel elements, companion cells
- d. sieve-tube elements, companion cells

21. The main photoreceptor that triggers phototropism is a _____.
- a. phytochrome
- b. cryptochrome
- c. phototropin
- d. carotenoid

22. Phytochrome is a plant pigment protein that:

a. mediates plant infection
b. promotes plant growth
c. mediates morphological changes in response to red and far-red light
d. inhibits plant growth

23. A mutant plant has roots that grow in all directions. Which of the following organelles would you expect to be missing in the cell?

a. mitochondria
b. amyloplast
c. chloroplast
d. nucleus

24. After buying green bananas or unripe avocadoes, they can be kept in a brown bag to ripen. The hormone released by the fruit and trapped in the bag is probably:

a. abscisic acid
b. cytokinin
c. ethylene
d. gibberellic acid

25. A decrease in the level of which hormone releases seeds from dormancy?

a. abscisic acid
b. cytokinin
c. ethylene
d. gibberellic acid

26. A seedling germinating under a stone grows at an angle away from the stone and upward. This response to touch is called _____.

a. gravitropism
b. thigmonasty
c. thigmotropism
d. skototropism

CRITICAL THINKING QUESTIONS

27. What type of meristem is found only in monocots, such as lawn grasses? Explain how this type of meristematic tissue is beneficial in lawn grasses that are mowed each week.

28. Which plant part is responsible for transporting water, minerals, and sugars to different parts of the plant? Name the two types of tissue that make up this overall tissue, and explain the role of each.

29. Describe the roles played by stomata and guard cells. What would happen to a plant if these cells did not function correctly?

30. Compare the structure and function of xylem to that of phloem.

31. Explain the role of the cork cambium in woody plants.

32. What is the function of lenticels?

33. Besides the age of a tree, what additional information can annual rings reveal?

34. Give two examples of modified stems and explain how each example benefits the plant.

35. Compare a tap root system with a fibrous root system. For each type, name a plant that provides a food in the human diet. Which type of root system is found in monocots? Which type of root system is found in dicots?

36. What might happen to a root if the pericycle disappeared?

37. How do dicots differ from monocots in terms of leaf structure?

38. Describe an example of a plant with leaves that are adapted to cold temperatures.

39. The process of bulk flow transports fluids in a plant. Describe the two main bulk flow processes.

40. Owners and managers of plant nurseries have to plan lighting schedules for a long-day plant that will flower in February. What lighting periods will be most effective? What color of light should be chosen?

41. What are the major benefits of gravitropism for a germinating seedling?

42. Fruit and vegetable storage facilities are usually refrigerated and well ventilated. Why are these conditions advantageous?

43. Stomata close in response to bacterial infection. Why is this response a mechanism of defense for the plant? Which hormone is most likely to mediate this response?

CHAPTER SUMMARY

31.1 Nutritional Requirements of Plants

Plants can absorb inorganic nutrients and water through their root system, and carbon dioxide from the environment. The combination of organic compounds, along with water, carbon dioxide, and sunlight, produce the energy that allows plants to grow. Inorganic compounds form the majority of the soil solution. Plants access water though the soil. Water is absorbed by the plant root, transports nutrients throughout the plant, and maintains the structure of the plant. Essential elements are indispensable elements for plant growth. They are divided into macronutrients and micronutrients. The macronutrients plants require are carbon, nitrogen, hydrogen, oxygen, phosphorus, potassium, calcium, magnesium, and sulfur. Important micronutrients include iron, manganese, boron, molybdenum, copper, zinc, chlorine, nickel, cobalt, silicon and sodium.

31.2 The Soil

Plants obtain mineral nutrients from the soil. Soil is the outer loose layer that covers the surface of Earth. Soil quality depends on the chemical composition of the soil, the topography, the presence of living organisms, the climate, and time. Agricultural practice and history may also modify the characteristics and fertility of soil. Soil consists of four major components: 1) inorganic mineral matter, 2) organic matter, 3) water and air, and 4) living matter. The organic material of soil is made of humus, which improves soil structure and provides water and minerals. Soil inorganic material consists of rock slowly broken down into smaller particles that vary in size, such as sand, silt, and loam.

Soil formation results from a combination of biological, physical, and chemical processes. Soil is not homogenous because its formation results in the production of layers called a soil profile. Factors that affect soil formation include: parent material, climate, topography, biological factors, and time. Soils are classified based on their horizons, soil particle size, and proportions. Most soils have four distinct horizons: O, A, B, and C.

31.3 Nutritional Adaptations of Plants

Atmospheric nitrogen is the largest pool of available nitrogen in terrestrial ecosystems. However, plants cannot use this nitrogen because they do not have the necessary enzymes. Biological nitrogen fixation (BNF) is the conversion of atmospheric nitrogen to ammonia. The most important source of BNF is the symbiotic interaction between soil bacteria and legumes. The bacteria form nodules on the legume's roots in which nitrogen fixation takes place. Fungi form symbiotic associations (mycorrhizae) with plants, becoming integrated into the physical structure of the root. Through mycorrhization, the plant obtains minerals from the soil and the fungus obtains photosynthate from the plant root. Ectomycorrhizae form an extensive dense sheath around the root, while endomycorrhizae are embedded within the root tissue. Some plants—parasites, saprophytes, symbionts, epiphytes, and insectivores—have evolved adaptations to obtain their organic or mineral nutrition from various sources.

ART CONNECTION QUESTIONS

1. **Figure 31.5** Soil compaction can result when soil is compressed by heavy machinery or even foot traffic. How might this compaction change the soil composition?

2. **Figure 31.6** Which horizon is considered the topsoil, and which is considered the subsoil?

3. **Figure 31.9** Farmers often rotate corn (a cereal crop) and soy beans (a legume) planting a field with each crop in alternate seasons. What advantage might this crop rotation confer?

REVIEW QUESTIONS

4. For an element to be regarded as essential, all of the following criteria must be met, except:

a. No other element can perform the function.
b. The element is directly involved in plant nutrition.
c. The element is inorganic.
d. The plant cannot complete its lifecycle without the element.

5. The nutrient that is part of carbohydrates, proteins, and nucleic acids, and that forms biomolecules, is _____.

a. nitrogen
b. carbon
c. magnesium
d. iron

6. Most _____ are necessary for enzyme function.

a. micronutrients
b. macronutrients
c. biomolecules
d. essential nutrients

7. What is the main water source for land plants?

a. rain
b. soil
c. biomolecules
d. essential nutrients

8. Which factors affect soil quality?

a. chemical composition
b. history of the soil
c. presence of living organisms and topography
d. all of the above

9. Soil particles that are 0.1 to 2 mm in diameter are called _____.

a. sand
b. silt
c. clay
d. loam

10. A soil consists of layers called _____ that taken together are called a _____.

a. soil profiles : horizon
b. horizons : soil profile
c. horizons : humus
d. humus : soil profile

11. What is the term used to describe the solid rock that lies beneath the soil?

a. sand
b. bedrock
c. clay
d. loam

12. Which process produces an inorganic compound that plants can easily use?

a. photosynthesis
b. nitrogen fixation
c. mycorrhization
d. Calvin cycle

13. Through mycorrhization, a plant obtains important nutrients such as _____.

a. phosphorus, zinc, and copper
b. phosphorus, zinc, and calcium
c. nickel, calcium, and zinc
d. all of the above

14. What term describes a plant that requires nutrition from a living host plant?

a. parasite
b. saprophyte
c. epiphyte
d. insectivorous

15. What is the term for the symbiotic association between fungi and cyanobacteria?

a. lichen
b. mycorrhizae
c. epiphyte
d. nitrogen-fixing nodule

CRITICAL THINKING QUESTIONS

16. What type of plant problems result from nitrogen and calcium deficiencies?

17. What did the van Helmont experiment show?

18. List two essential macronutrients and two essential nutrients.

19. Describe the main differences between a mineral soil and an organic soil.

20. Name and briefly explain the factors that affect soil formation.

21. Describe how topography influences the characteristics and fertility of a soil.

22. Why is biological nitrogen fixation an environmentally friendly way of fertilizing plants?

23. What is the main difference, from an energy point of view, between photosynthesis and biological nitrogen fixation?

24. Why is a root nodule a nutritional adaptation of a plant?

CHAPTER SUMMARY

32.1 Reproductive Development and Structure

The flower contains the reproductive structures of a plant. All complete flowers contain four whorls: the calyx, corolla, androecium, and gynoecium. The stamens are made up of anthers, in which pollen grains are produced, and a supportive strand called the filament. The pollen contains two cells— a generative cell and a tube cell—and is covered by two layers called the intine and the exine. The carpels, which are the female reproductive structures, consist of the stigma, style, and ovary. The female gametophyte is formed from mitotic divisions of the megaspore, forming an eight-nuclei ovule sac. This is covered by a layer known as the integument. The integument contains an opening called the micropyle, through which the pollen tube enters the embryo sac.

The diploid sporophyte of angiosperms and gymnosperms is the conspicuous and long-lived stage of the life cycle. The sporophytes differentiate specialized reproductive structures called sporangia, which are dedicated to the production of spores. The microsporangium contains microspore mother cells, which divide by meiosis to produce haploid microspores. The microspores develop into male gametophytes that are released as pollen. The megasporangium contains megaspore mother cells, which divide by meiosis to produce haploid megaspores. A megaspore develops into a female gametophyte containing a haploid egg. A new diploid sporophyte is formed when a male gamete from a pollen grain enters the ovule sac and fertilizes this egg.

32.2 Pollination and Fertilization

For fertilization to occur in angiosperms, pollen has to be transferred to the stigma of a flower: a process known as pollination. Gymnosperm pollination involves the transfer of pollen from a male cone to a female cone. When the pollen of the flower is transferred to the stigma of the same flower, it is called self-pollination. Cross-pollination occurs when pollen is transferred from one flower to another flower on the same plant, or another plant. Cross-pollination requires pollinating agents such as water, wind, or animals, and increases genetic diversity. After the pollen lands on the stigma, the tube cell gives rise to the pollen tube, through which the generative nucleus migrates. The pollen tube gains entry through the micropyle on the ovule sac. The generative cell divides to form two sperm cells: one fuses with the egg to form the diploid zygote, and the other fuses with the polar nuclei to form the endosperm, which is triploid in nature. This is known as double fertilization. After fertilization, the zygote divides to form the embryo and the fertilized ovule forms the seed. The walls of the ovary form the fruit in which the seeds develop. The seed, when mature, will germinate under favorable conditions and give rise to the diploid sporophyte.

32.3 Asexual Reproduction

Many plants reproduce asexually as well as sexually. In asexual reproduction, part of the parent plant is used to generate a new plant. Grafting, layering, and micropropagation are some methods used for artificial asexual reproduction. The new plant is genetically identical to the parent plant from which the stock has been taken. Asexually reproducing plants thrive well in stable environments.

Plants have different life spans, dependent on species, genotype, and environmental conditions. Parts of the plant, such as regions containing meristematic tissue, continue to grow, while other parts experience programmed cell death. Leaves that are no longer photosynthetically active are shed from the plant as part of senescence, and the nutrients from these leaves are recycled by the plant. Other factors, including the presence of hormones, are known to play a role in delaying senescence.

ART CONNECTION QUESTIONS

1. **Figure 32.3** If the anther is missing, what type of reproductive structure will the flower be unable to produce? What term is used to describe a flower that is normally lacking the androecium? What term describes a flower lacking a gynoecium?

2. **Figure 32.8** An embryo sac is missing the synergids. What specific impact would you expect this to have on fertilization?

a. The pollen tube will be unable to form.
b. The pollen tube will form but will not be guided toward the egg.
c. Fertilization will not occur because the synergid is the egg.
d. Fertilization will occur but the embryo will not be able to grow.

3. **Figure 32.20** What is the function of the cotyledon?

a. It develops into the root.
b. It provides nutrition for the embryo.
c. It forms the embryo.
d. It protects the embryo.

REVIEW QUESTIONS

4. In a plant's male reproductive organs, development of pollen takes place in a structure known as the _____.
a. stamen
b. microsporangium
c. anther
d. tapetum

5. The stamen consists of a long stalk called the filament that supports the _____.
a. stigma
b. sepal
c. style
d. anther

6. The _____ are collectively called the calyx.
a. sepals
b. petals
c. tepals
d. stamens

7. The pollen lands on which part of the flower?
a. stigma
b. style
c. ovule
d. integument

8. After double fertilization, a zygote and _____ form.
a. an ovule
b. endosperm
c. a cotyledon
d. a suspensor

9. The fertilized ovule gives rise to the _____.
a. fruit
b. seed
c. endosperm
d. embryo

10. What is the term for a fruit that develops from tissues other than the ovary?
a. simple fruit
b. aggregate fruit
c. multiple fruit
d. accessory fruit

11. The _____ is the outermost covering of a fruit.
a. endocarp
b. pericarp
c. exocarp
d. mesocarp

12. _____ is a useful method of asexual reproduction for propagating hard-to-root plants.
a. grafting
b. layering
c. cuttings
d. budding

13. Which of the following is an advantage of asexual reproduction?
a. Cuttings taken from an adult plant show increased resistance to diseases.
b. Grafted plants can more successfully endure drought.
c. When cuttings or buds are taken from an adult plant or plant parts, the resulting plant will grow into an adult faster than a seedling.
d. Asexual reproduction takes advantage of a more diverse gene pool.

14. Plants that flower once in their lifetime are known as _____.
a. monoecious
b. dioecious
c. polycarpic
d. monocarpic

15. Plant species that complete their lifecycle in one season are known as _____.
a. biennials
b. perennials
c. annuals
d. polycarpic

CRITICAL THINKING QUESTIONS

16. Describe the reproductive organs inside a flower.

17. Describe the two-stage lifecycle of plants: the gametophyte stage and the sporophyte stage.

18. Describe the four main parts, or whorls, of a flower.

19. Discuss the differences between a complete flower and an incomplete flower.

20. Why do some seeds undergo a period of dormancy, and how do they break dormancy?

21. Discuss some ways in which fruit seeds are dispersed.

22. What are some advantages of asexual reproduction in plants?

23. Describe natural and artificial methods of asexual reproduction in plants.

24. Discuss the life cycles of various plants.

25. How are plants classified on the basis of flowering frequency?

CHAPTER SUMMARY

33.1 Animal Form and Function

Animal bodies come in a variety of sizes and shapes. Limits on animal size and shape include impacts to their movement. Diffusion affects their size and development. Bioenergetics describes how animals use and obtain energy in relation to their body size, activity level, and environment.

33.2 Animal Primary Tissues

The basic building blocks of complex animals are four primary tissues. These are combined to form organs, which have a specific, specialized function within the body, such as the skin or kidney. Organs are organized together to perform common functions in the form of systems. The four primary tissues are epithelia, connective tissues, muscle tissues, and nervous tissues.

33.3 Homeostasis

Homeostasis is a dynamic equilibrium that is maintained in body tissues and organs. It is dynamic because it is constantly adjusting to the changes that the systems encounter. It is in equilibrium because body functions are kept within a normal range, with some fluctuations around a set point for the processes.

ART CONNECTION QUESTIONS

1. **Figure 33.11** Which of the following statements about types of epithelial cells is false?

a. Simple columnar epithelial cells line the tissue of the lung.
b. Simple cuboidal epithelial cells are involved in the filtering of blood in the kidney.
c. Pseudostratisfied columnar epithilia occur in a single layer, but the arrangement of nuclei makes it appear that more than one layer is present.
d. Transitional epithelia change in thickness depending on how full the bladder is.

2. **Figure 33.21** State whether each of the following processes are regulated by a positive feedback loop or a negative feedback loop.

a. A person feels satiated after eating a large meal.
b. The blood has plenty of red blood cells. As a result, erythropoietin, a hormone that stimulates the production of new red blood cells, is no longer released from the kidney.

3. **Figure 33.22** When bacteria are destroyed by leuckocytes, pyrogens are released into the blood. Pyrogens reset the body's thermostat to a higher temperature, resulting in fever. How might pyrogens cause the body temperature to rise?

REVIEW QUESTIONS

4. Which type of animal maintains a constant internal body temperature?
a. endotherm
b. ectotherm
c. coelomate
d. mesoderm

5. The symmetry found in animals that move swiftly is _____.
a. radial
b. bilateral
c. sequential
d. interrupted

6. What term describes the condition of a desert mouse that lowers its metabolic rate and "sleeps" during the hot day?
a. turgid
b. hibernation
c. estivation
d. normal sleep pattern

7. A plane that divides an animal into equal right and left portions is _____.
a. diagonal
b. midsagittal
c. coronal
d. transverse

8. A plane that divides an animal into dorsal and ventral portions is _____.
a. sagittal
b. midsagittal
c. coronal
d. transverse

9. The pleural cavity is a part of which cavity?
a. dorsal cavity
b. thoracic cavity
c. abdominal cavity
d. pericardial cavity

10. Which type of epithelial cell is best adapted to aid diffusion?
a. squamous
b. cuboidal
c. columnar
d. transitional

11. Which type of epithelial cell is found in glands?
a. squamous
b. cuboidal
c. columnar
d. transitional

12. Which type of epithelial cell is found in the urinary bladder?
a. squamous
b. cuboidal
c. columnar
d. transitional

13. Which type of connective tissue has the most fibers?
a. loose connective tissue
b. fibrous connective tissue
c. cartilage
d. bone

14. Which type of connective tissue has a mineralized different matrix?
a. loose connective tissue
b. fibrous connective tissue
c. cartilage
d. bone

15. The cell found in bone that breaks it down is called an _____.
a. osteoblast
b. osteocyte
c. osteoclast
d. osteon

16. The cell found in bone that makes the bone is called an _____.
a. osteoblast
b. osteocyte
c. osteoclast
d. osteon

17. Plasma is the _____.
a. fibers in blood
b. matrix of blood
c. cell that phagocytizes bacteria
d. cell fragment found in the tissue

18. The type of muscle cell under voluntary control is the _____.
a. smooth muscle
b. skeletal muscle
c. cardiac muscle
d. visceral muscle

19. The part of a neuron that contains the nucleus is the
a. cell body
b. dendrite
c. axon
d. glial

20. When faced with a sudden drop in environmental temperature, an endothermic animal will:

a. experience a drop in its body temperature
b. wait to see if it goes lower
c. increase muscle activity to generate heat
d. add fur or fat to increase insulation

21. Which is an example of negative feedback?

a. lowering of blood glucose after a meal
b. blood clotting after an injury
c. lactation during nursing
d. uterine contractions during labor

22. Which method of heat exchange occurs during direct contact between the source and animal?

a. radiation
b. evaporation
c. convection
d. conduction

23. The body's thermostat is located in the _____.

a. homeostatic receptor
b. hypothalamus
c. medulla
d. vasodilation center

CRITICAL THINKING QUESTIONS

24. How does diffusion limit the size of an organism? How is this counteracted?

25. What is the relationship between BMR and body size? Why?

26. How can squamous epithelia both facilitate diffusion and prevent damage from abrasion?

27. What are the similarities between cartilage and bone?

28. Why are negative feedback loops used to control body homeostasis?

29. Why is a fever a "good thing" during a bacterial infection?

30. How is a condition such as diabetes a good example of the failure of a set point in humans?

CHAPTER SUMMARY

34.1 Digestive Systems

Different animals have evolved different types of digestive systems specialized to meet their dietary needs. Humans and many other animals have monogastric digestive systems with a single-chambered

stomach. Birds have evolved a digestive system that includes a gizzard where the food is crushed into smaller pieces. This compensates for their inability to masticate. Ruminants that consume large amounts of plant material have a multi-chambered stomach that digests roughage. Pseudo-ruminants have similar digestive processes as ruminants but do not have the four-compartment stomach. Processing food involves ingestion (eating), digestion (mechanical and enzymatic breakdown of large molecules), absorption (cellular uptake of nutrients), and elimination (removal of undigested waste as feces).

Many organs work together to digest food and absorb nutrients. The mouth is the point of ingestion and the location where both mechanical and chemical breakdown of food begins. Saliva contains an enzyme called amylase that breaks down carbohydrates. The food bolus travels through the esophagus by peristaltic movements to the stomach. The stomach has an extremely acidic environment. An enzyme called pepsin digests protein in the stomach. Further digestion and absorption take place in the small intestine. The large intestine reabsorbs water from the undigested food and stores waste until elimination.

34.2 Nutrition and Energy Production

Animal diet should be balanced and meet the needs of the body. Carbohydrates, proteins, and fats are the primary components of food. Some essential nutrients are required for cellular function but cannot be produced by the animal body. These include vitamins, minerals, some fatty acids, and some amino acids. Food intake in more than necessary amounts is stored as glycogen in the liver and muscle cells, and in fat cells. Excess adipose storage can lead to obesity and serious health problems. ATP is the energy currency of the cell and is obtained from the metabolic pathways. Excess carbohydrates and energy are stored as glycogen in the body.

34.3 Digestive System Processes

Digestion begins with ingestion, where the food is taken in the mouth. Digestion and absorption take place in a series of steps with special enzymes playing important roles in digesting carbohydrates, proteins, and lipids. Elimination describes removal of undigested food contents and waste products from the body. While most absorption occurs in the small intestines, the large intestine is responsible for the final removal of water that remains after the absorptive process of the small intestines. The cells that line the large intestine absorb some vitamins as well as any leftover salts and water. The large intestine (colon) is also where feces is formed.

34.4 Digestive System Regulation

The brain and the endocrine system control digestive processes. The brain controls the responses of hunger and satiety. The endocrine system controls the release of hormones and enzymes required for digestion of food in the digestive tract.

ART CONNECTION QUESTIONS

1. **Figure 34.11** Which of the following statements about the digestive system is false?

a. Chyme is a mixture of food and digestive juices that is produced in the stomach.
b. Food enters the large intestine before the small intestine.
c. In the small intestine, chyme mixes with bile, which emulsifies fats.
d. The stomach is separated from the small intestine by the pyloric sphincter.

2. **Figure 34.12** Which of the following statements about the small intestine is false?

a. Absorptive cells that line the small intestine have microvilli, small projections that increase surface area and aid in the absorption of food.
b. The inside of the small intestine has many folds, called villi.
c. Microvilli are lined with blood vessels as well as lymphatic vessels.
d. The inside of the small intestine is called the lumen.

3. **Figure 34.19** Which of the following statements about digestive processes is true?

a. Amylase, maltase and lactase in the mouth digest carbohydrates.
b. Trypsin and lipase in the stomach digest protein.
c. Bile emulsifies lipids in the small intestine.

d. No food is absorbed until the small intestine.

REVIEW QUESTIONS

4. Which of the following is a pseudo-ruminant?

a. cow
b. pig
c. crow
d. horse

5. Which of the following statements is untrue?

a. Roughage takes a long time to digest.
b. Birds eat large quantities at one time so that they can fly long distances.
c. Cows do not have upper teeth.
d. In pseudo-ruminants, roughage is digested in the cecum.

6. The acidic nature of chyme is neutralized by _____.

a. potassium hydroxide
b. sodium hydroxide
c. bicarbonates
d. vinegar

7. The digestive juices from the liver are delivered to the _____.

a. stomach
b. liver
c. duodenum
d. colon

8. Which of the following statements is not true?

a. Essential nutrients can be synthesized by the body.
b. Vitamins are required in small quantities for bodily function.
c. Some amino acids can be synthesized by the body, while others need to be obtained from diet.
d. Vitamins come in two categories: fat-soluble and water-soluble.

9. Which of the following is a water-soluble vitamin?

a. vitamin A
b. vitamin E
c. vitamin K
d. vitamin C

10. What is the primary fuel for the body?

a. carbohydrates
b. lipids
c. protein
d. glycogen

11. Excess glucose is stored as _____.

a. fat
b. glucagon
c. glycogen
d. it is not stored in the body

12. Where does the majority of protein digestion take place?

a. stomach
b. duodenum
c. mouth
d. jejunum

13. Lipases are enzymes that break down _____.

a. disaccharides
b. lipids
c. proteins
d. cellulose

14. Which hormone controls the release of bile from the gallbladder

a. pepsin
b. amylase
c. CCK
d. gastrin

15. Which hormone stops acid secretion in the stomach?

a. gastrin
b. somatostatin
c. gastric inhibitory peptide
d. CCK

CRITICAL THINKING QUESTIONS

16. How does the polygastric digestive system aid in digesting roughage?

17. How do birds digest their food in the absence of teeth?

18. What is the role of the accessory organs in digestion?

19. Explain how the villi and microvilli aid in absorption.

20. What are essential nutrients?

21. What is the role of minerals in maintaining good health?

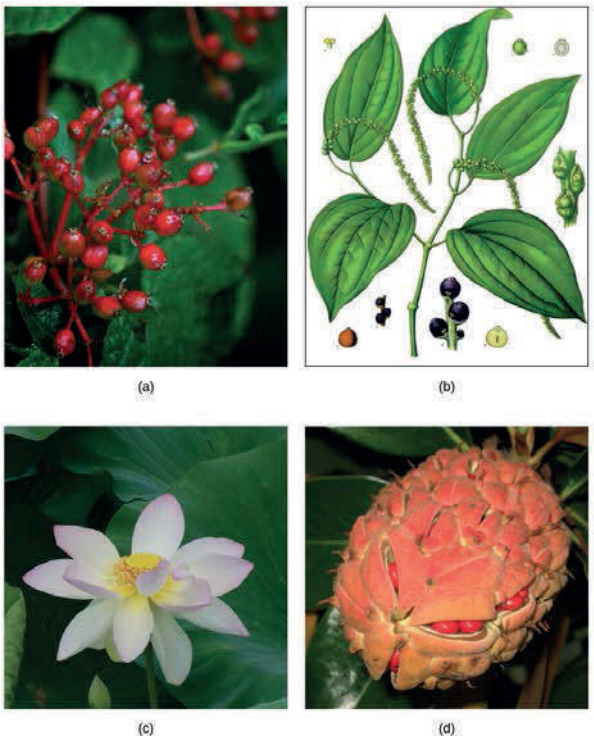
22. Discuss why obesity is a growing epidemic.

23. There are several nations where malnourishment is a common occurrence. What may be some of the health challenges posed by malnutrition?

24. Explain why some dietary lipid is a necessary part of a balanced diet.

25. Describe how hormones regulate digestion.

26. Describe one or more scenarios where loss of hormonal regulation of digestion can lead to diseases.



CHAPTER SUMMARY

35.1 Neurons and Glial Cells

The nervous system is made up of neurons and glia. Neurons are specialized cells that are capable of sending electrical as well as chemical signals. Most neurons contain dendrites, which receive these signals, and axons that send signals to other neurons or tissues. There are four main types of neurons: unipolar, bipolar, multipolar, and pseudounipolar neurons. Glia are non-neuronal cells in the nervous system that support neuronal development and signaling. There are several types of glia that serve different functions.

35.2 How Neurons Communicate

Neurons have charged membranes because there are different concentrations of ions inside and outside of the cell. Voltage-gated ion channels control the movement of ions into and out of a neuron. When a neuronal membrane is depolarized to at least the threshold of excitation, an action potential is fired. The action potential is then propagated along a myelinated axon to the axon terminals. In a chemical synapse, the action potential causes release of neurotransmitter molecules into the synaptic cleft. Through binding to postsynaptic receptors, the neurotransmitter can cause excitatory or inhibitory postsynaptic potentials by depolarizing or hyperpolarizing, respectively, the postsynaptic membrane. In electrical synapses, the action potential is directly communicated to the postsynaptic cell through gap junctions—large channel proteins that connect the pre-and postsynaptic membranes. Synapses are not static structures and can be strengthened and weakened. Two mechanisms of synaptic plasticity are long-term potentiation and long-term depression.

35.3 The Central Nervous System

The vertebrate central nervous system contains the brain and the spinal cord, which are covered and protected by three meninges. The brain contains structurally and functionally defined regions. In mammals, these include the cortex (which can be broken down into four primary functional lobes: frontal, temporal, occipital, and parietal), basal ganglia, thalamus, hypothalamus, limbic system, cerebellum, and brainstem—although structures in some of these designations overlap. While functions may be primarily localized to one structure in the brain, most complex functions, like language and sleep, involve neurons in multiple brain regions. The spinal cord is the information superhighway that connects the brain with the rest of the body through its connections with peripheral nerves. It transmits sensory and motor input and also controls motor reflexes.

35.4 The Peripheral Nervous System

The peripheral nervous system contains both the autonomic and sensory-somatic nervous systems. The autonomic nervous system provides unconscious control over visceral functions and has two divisions: the sympathetic and parasympathetic nervous systems. The sympathetic nervous system is activated in stressful situations to prepare the animal for a “fight or flight” response. The parasympathetic nervous system is active during restful periods. The sensory-somatic nervous system is made of cranial and spinal nerves that transmit sensory information from skin and muscle to the CNS and motor commands from the CNS to the muscles.

35.5 Nervous System Disorders

Some general themes emerge from the sampling of nervous system disorders presented above. The causes for most disorders are not fully understood—at least not for all patients—and likely involve a combination of nature (genetic mutations that become risk factors) and nurture (emotional trauma, stress, hazardous chemical exposure). Because the causes have yet to be fully determined, treatment options are often lacking and only address symptoms.

ART CONNECTION QUESTIONS

1. **Figure 35.3** Which of the following statements is false?

a. The soma is the cell body of a nerve cell.
b. Myelin sheath provides an insulating layer to the dendrites.
c. Axons carry the signal from the soma to the target.
d. Dendrites carry the signal to the soma.

2. **Figure 35.11** Potassium channel blockers, such as amiodarone and procainamide, which are used to treat abnormal electrical activity in the heart, called cardiac dysrhythmia, impede the movement of K+ through voltage-gated K+ channels. Which part of the action potential would you expect potassium channels to affect?

3. **Figure 35.26** Which of the following statements is false?

a. The parasympathetic pathway is responsible for relaxing the body, while the sympathetic pathway is responsible for preparing for an emergency.
b. Most preganglionic neurons in the sympathetic pathway originate in the spinal cord.
c. Slowing of the heartbeat is a parasympathetic response.
d. Parasympathetic neurons are responsible for releasing norepinephrine on the

target organ, while sympathetic neurons are responsible for releasing acetylcholine.

REVIEW QUESTIONS

4. Neurons contain _____, which can receive signals from other neurons.
- a. axons
- b. mitochondria
- c. dendrites
- d. Golgi bodies

5. A(n) _____ neuron has one axon and one dendrite extending directly from the cell body.
- a. unipolar
- b. bipolar
- c. multipolar
- d. pseudounipolar

6. Glia that provide myelin for neurons in the brain are called _____.
- a. Schwann cells
- b. oligodendrocytes
- c. microglia
- d. astrocytes

7. For a neuron to fire an action potential, its membrane must reach _____.
- a. hyperpolarization
- b. the threshold of excitation
- c. the refractory period
- d. inhibitory postsynaptic potential

8. After an action potential, the opening of additional voltage-gated _____ channels and the inactivation of sodium channels, cause the membrane to return to its resting membrane potential.
- a. sodium
- b. potassium
- c. calcium
- d. chloride

9. What is the term for protein channels that connect two neurons at an electrical synapse?
- a. synaptic vesicles
- b. voltage-gated ion channels
- c. gap junction protein
- d. sodium-potassium exchange pumps

10. The _____ lobe contains the visual cortex.
- a. frontal
- b. parietal
- c. temporal
- d. occipital

11. The _____ connects the two cerebral hemispheres.
- a. limbic system
- b. corpus callosum
- c. cerebellum
- d. pituitary

12. Neurons in the _____ control motor reflexes.
- a. thalamus
- b. spinal cord
- c. parietal lobe
- d. hippocampus

13. Activation of the sympathetic nervous system causes:
- a. increased blood flow into the skin
- b. a decreased heart rate
- c. an increased heart rate
- d. increased digestion

14. Where are parasympathetic preganglionic cell bodies located?
- a. cerebellum
- b. brainstem
- c. dorsal root ganglia
- d. skin

15. _____ is released by motor nerve endings onto muscle.
- a. Acetylcholine
- b. Norepinephrine
- c. Dopamine
- d. Serotonin

16. Parkinson's disease is a caused by the degeneration of neurons that release _____.
- a. serotonin
- b. dopamine
- c. glutamate
- d. norepinephrine

17. _____ medications are often used to treat patients with ADHD.
- a. Tranquilizer
- b. Antibiotic
- c. Stimulant
- d. Anti-seizure

18. Strokes are often caused by _____.
- a. neurodegeneration
- b. blood clots or burst blood vessels
- c. seizures
- d. viruses

CRITICAL THINKING QUESTIONS

19. How are neurons similar to other cells? How are they unique?

20. Multiple sclerosis causes demyelination of axons in the brain and spinal cord. Why is this problematic?

21. How does myelin aid propagation of an action potential along an axon? How do the nodes of Ranvier help this process?

22. What are the main steps in chemical neurotransmission?

23. What methods can be used to determine the function of a particular brain region?

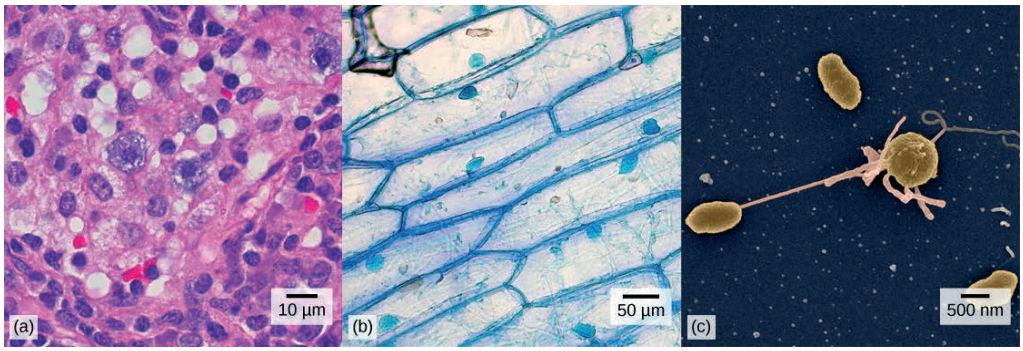
24. What are the main functions of the spinal cord?

25. What are the main differences between the sympathetic and parasympathetic branches of the autonomic nervous system?

26. What are the main functions of the sensory-somatic nervous system?

27. What are the main symptoms of Alzheimer's disease?

28. What are possible treatments for patients with major depression?



CHAPTER SUMMARY

36.1 Sensory Processes

A sensory activation occurs when a physical or chemical stimulus is processed into a neural signal (sensory transduction) by a sensory receptor. Perception is an individual interpretation of a sensation and is a brain function. Humans have special senses: olfaction, gustation, equilibrium, and hearing, plus the general senses of somatosensation.

Sensory receptors are either specialized cells associated with sensory neurons or the specialized ends of sensory neurons that are a part of the peripheral nervous system, and they are used to receive information about the environment (internal or external). Each sensory receptor is modified for the type of stimulus it detects. For example, neither gustatory receptors nor auditory receptors are sensitive to light. Each sensory receptor is responsive to stimuli within a specific region in space, which is known as that receptor's receptive field. The most fundamental function of a sensory system is the translation of a sensory signal to an electrical signal in the nervous system.

All sensory signals, except those from the olfactory system, enter the central nervous system and are routed to the thalamus. When the sensory signal exits the thalamus, it is conducted to the specific area of the cortex dedicated to processing that particular sense.

36.2 Somatosensation

Somatosensation includes all sensation received from the skin and mucous membranes, as well as from the limbs and joints. Somatosensation occurs all over the exterior of the body and at some interior locations as well, and a variety of receptor types, embedded in the skin and mucous membranes, play a role.

There are several types of specialized sensory receptors. Rapidly adapting free nerve endings detect nociception, hot and cold, and light touch. Slowly adapting, encapsulated Merkel's disks are found in fingertips and lips, and respond to light touch. Meissner's corpuscles, found in glabrous skin, are rapidly adapting, encapsulated receptors that detect touch, low-frequency vibration, and flutter. Ruffini endings are slowly adapting, encapsulated receptors that detect skin stretch, joint activity, and warmth. Hair receptors are rapidly adapting nerve endings wrapped around the base of hair follicles that detect hair movement and skin deflection. Finally, Pacinian corpuscles are encapsulated, rapidly adapting receptors that detect transient pressure and high-frequency vibration.

36.3 Taste and Smell

There are five primary tastes in humans: sweet, sour, bitter, salty, and umami. Each taste has its own receptor type that responds only to that taste. Tastants enter the body and are dissolved in saliva. Taste cells are located within taste buds, which are found on three of the four types of papillae in the mouth.

Regarding olfaction, there are many thousands of odorants, but humans detect only about 10,000. Like taste receptors, olfactory receptors are each responsive to only one odorant. Odorants dissolve in nasal mucosa, where they excite their corresponding olfactory sensory cells. When these cells detect an odorant, they send their signals to the main olfactory bulb and then to other locations in the brain, including the olfactory cortex.

36.4 Hearing and Vestibular Sensation

Audition is important for territory defense, predation, predator defense, and communal exchanges. The vestibular system, which is not auditory, detects linear acceleration and angular acceleration and deceleration. Both the auditory system and vestibular system use hair cells as their receptors.

Auditory stimuli are sound waves. The sound wave energy reaches the outer ear (pinna, canal, tympanum), and vibrations of the tympanum send the energy to the middle ear. The middle ear bones shift and the stapes transfers mechanical energy to the oval window of the fluid-filled inner ear cochlea. Once in the cochlea, the energy causes the basilar membrane to flex, thereby bending the stereocilia on receptor hair cells. This activates the receptors, which send their auditory neural signals to the brain.

The vestibular system has five parts that work together to provide the sense of direction, thus helping to maintain balance. The utricle and saccule measure head orientation: their calcium carbonate crystals shift when the head is tilted, thereby activating hair cells. The semicircular canals work similarly, such that when the head is turned, the fluid in the canals bends stereocilia on hair cells. The vestibular hair cells also send signals to the thalamus and to somatosensory cortex, but also to the cerebellum, the structure above the brainstem that plays a large role in timing and coordination of movement.

36.5 Vision

Vision is the only photo responsive sense. Visible light travels in waves and is a very small slice of the electromagnetic radiation spectrum. Light waves differ based on their frequency (wavelength = hue) and amplitude (intensity = brightness).

In the vertebrate retina, there are two types of light receptors (photoreceptors): cones and rods. Cones, which are the source of color vision, exist in three forms—L, M, and S—and they are differentially sensitive to different wavelengths. Cones are located in the retina, along with the dim-light, achromatic receptors (rods). Cones are found in the fovea, the central region of the retina, whereas rods are found in the peripheral regions of the retina.

Visual signals travel from the eye over the axons of retinal ganglion cells, which make up the optic nerves. Ganglion cells come in several versions. Some ganglion cell axons carry information on form, movement, depth, and brightness, while other axons carry information on color and fine detail. Visual information is sent to the superior colliculi in the midbrain, where coordination of eye movements and integration of auditory information takes place. Visual information is also sent to the suprachiasmatic nucleus (SCN) of the hypothalamus, which plays a role in the circadian cycle.

ART CONNECTION QUESTIONS

1. **Figure 36.5** Which of the following statements about mechanoreceptors is false?

a. Pacini corpuscles are found in both glabrous and hairy skin.
b. Merkel's disks are abundant on the fingertips and lips.
c. Ruffini endings are encapsulated mechanoreceptors.

d. Meissner's corpuscles extend into the lower dermis.

2. **Figure 36.14** Cochlear implants can restore hearing in people who have a nonfunctional cochlear. The implant consists of a microphone that picks up sound. A speech processor selects sounds in the range of human speech, and a transmitter converts these sounds to electrical impulses, which are then sent to the auditory nerve. Which of the following types of hearing loss would not be restored by a cochlear implant?

a. Hearing loss resulting from absence or loss of hair cells in the organ of Corti.
b. Hearing loss resulting from an abnormal auditory nerve.
c. Hearing loss resulting from fracture of the cochlea.
d. Hearing loss resulting from damage to bones of the middle ear.

3. **Figure 36.17** Which of the following statements about the human eye is false?

a. Rods detect color, while cones detect only shades of gray.
b. When light enters the retina, it passes the ganglion cells and bipolar cells before reaching photoreceptors at the rear of the eye.
c. The iris adjusts the amount of light coming into the eye.
d. The cornea is a protective layer on the front of the eye.

REVIEW QUESTIONS

4. Where does perception occur?
a. spinal cord
b. cerebral cortex
c. receptors
d. thalamus

5. If a person's cold receptors no longer convert cold stimuli into sensory signals, that person has a problem with the process of _____.
a. reception
b. transmission
c. perception
d. transduction

6. After somatosensory transduction, the sensory signal travels through the brain as a(n) _____ signal.
a. electrical
b. pressure
c. optical
d. thermal

7. _____ are found only in _____ skin, and detect skin deflection.
a. Meissner's corpuscles: hairy
b. Merkel's disks: glabrous
c. hair receptors: hairy
d. Krause end bulbs: hairy

8. If you were to burn your epidermis, what receptor type would you most likely burn?

a. free nerve endings
b. Ruffini endings
c. Pacinian corpuscle
d. hair receptors

9. Which of the following has the fewest taste receptors?
a. fungiform papillae
b. circumvallate papillae
c. foliate papillae
d. filiform papillae

10. How many different taste molecules do taste cells each detect?
a. one
b. five
c. ten
d. It depends on the spot on the tongue

11. Salty foods activate the taste cells by _____.

a. exciting the taste cell directly
b. causing hydrogen ions to enter the cell
c. causing sodium channels to close
d. binding directly to the receptors

12. All sensory signals except _____ travel to the _____ in the brain before the cerebral cortex.

a. vision; thalamus
b. olfaction; thalamus
c. vision; cranial nerves
d. olfaction; cranial nerves

13. In sound, pitch is measured in _____, and volume is measured in _____.
a. nanometers (nm); decibels (dB)
b. decibels (dB); nanometers (nm)
c. decibels (dB); hertz (Hz)
d. hertz (Hz); decibels (dB)

14. Auditory hair cells are indirectly anchored to the _____.
a. basilar membrane
b. oval window
c. tectorial membrane
d. ossicles

15. Which of the following are found both in the auditory system and the vestibular system?

a. basilar membrane
b. hair cells
c. semicircular canals
d. ossicles

16. Why do people over 55 often need reading glasses?

a. Their cornea no longer focuses correctly.
b. Their lens no longer focuses correctly.
c. Their eyeball has elongated with age, causing images to focus in front of their retina.
d. Their retina has thinned with age, making vision more difficult.

17. Why is it easier to see images at night using peripheral, rather than the central, vision?

a. Cones are denser in the periphery of the retina.
b. Bipolar cells are denser in the periphery of the retina.
c. Rods are denser in the periphery of the retina.
d. The optic nerve exits at the periphery of the retina.

18. A person catching a ball must coordinate her head and eyes. What part of the brain is helping to do this?

a. hypothalamus
b. pineal gland
c. thalamus
d. superior colliculus

CRITICAL THINKING QUESTIONS

19. If a person sustains damage to axons leading from sensory receptors to the central nervous system, which step or steps of sensory perception will be affected?

20. In what way does the overall magnitude of a stimulus affect the just-noticeable difference in the perception of that stimulus?

21. What can be inferred about the relative sizes of the areas of cortex that process signals from skin not densely innervated with sensory receptors and skin that is densely innervated with sensory receptors?

22. From the perspective of the recipient of the signal, in what ways do pheromones differ from other odorants?

23. What might be the effect on an animal of not being able to perceive taste?

24. How would a rise in altitude likely affect the speed of a sound transmitted through air? Why?

25. How might being in a place with less gravity than Earth has (such as Earth's moon) affect vestibular sensation, and why?

26. How could the pineal gland, the brain structure that plays a role in annual cycles, use visual information from the suprachiasmatic nucleus of the hypothalamus?

27. How is the relationship between photoreceptors and bipolar cells different from other sensory receptors and adjacent cells?

CHAPTER SUMMARY

37.1 Types of Hormones

There are three basic types of hormones: lipid-derived, amino acid-derived, and peptide. Lipid-derived hormones are structurally similar to cholesterol and include steroid hormones such as estradiol and testosterone. Amino acid-derived hormones are relatively small molecules and include the adrenal hormones epinephrine and norepinephrine. Peptide hormones are polypeptide chains or proteins and include the pituitary hormones, antidiuretic hormone (vasopressin), and oxytocin.

37.2 How Hormones Work

Hormones cause cellular changes by binding to receptors on target cells. The number of receptors on a target cell can increase or decrease in response to hormone activity. Hormones can affect cells directly through intracellular hormone receptors or indirectly through plasma membrane hormone receptors.

Lipid-derived (soluble) hormones can enter the cell by diffusing across the plasma membrane and binding to DNA to regulate gene transcription and to change the cell's activities by inducing production of proteins that affect, in general, the long-term structure and function of the cell. Lipid insoluble hormones bind to receptors on the plasma membrane surface and trigger a signaling pathway to change the cell's activities by inducing production of various cell products that affect the cell in the short-term. The hormone is called a first messenger and the cellular component is called a second messenger. G-proteins activate the second messenger (cyclic AMP), triggering the cellular response. Response to hormone binding is amplified as the signaling pathway progresses. Cellular responses to hormones include the production of proteins and enzymes and altered membrane permeability.

37.3 Regulation of Body Processes

Water levels in the body are controlled by antidiuretic hormone (ADH), which is produced in the hypothalamus and triggers the reabsorption of water by the kidneys. Underproduction of ADH can cause diabetes insipidus. Aldosterone, a hormone produced by the adrenal cortex of the kidneys, enhances Na^+ reabsorption from the extracellular fluids and subsequent water reabsorption by diffusion. The renin-angiotensin-aldosterone system is one way that aldosterone release is controlled.

The reproductive system is controlled by the gonadotropins follicle-stimulating hormone (FSH) and luteinizing hormone (LH), which are produced by the pituitary gland. Gonadotropin release is controlled by the hypothalamic hormone gonadotropin-releasing hormone (GnRH). FSH stimulates the maturation of sperm cells in males and is inhibited by the hormone inhibin, while LH stimulates the production of the androgen testosterone. FSH stimulates egg maturation in females, while LH stimulates the production of estrogens and progesterone. **Estrogens** are a group of steroid hormones produced by the ovaries that trigger the development of secondary sex characteristics in females as well as control the maturation of the ova. In females, the pituitary also produces prolactin, which stimulates milk production after childbirth, and oxytocin, which stimulates uterine contraction during childbirth and milk let-down during suckling.

Insulin is produced by the pancreas in response to rising blood glucose levels and allows cells to utilize blood glucose and store excess glucose for later use. Diabetes mellitus is caused by reduced insulin activity and causes high blood glucose levels, or hyperglycemia. Glucagon is released by the pancreas in response to low blood glucose levels and stimulates the breakdown of glycogen into glucose, which can be used by the body. The body's basal metabolic rate is controlled by the thyroid hormones thyroxine (T_4) and triiodothyronine (T_3). The anterior pituitary produces thyroid stimulating hormone (TSH), which controls the release of T_3 and T_4 from the thyroid gland. Iodine is necessary in the production of thyroid hormone, and the lack of iodine can lead to a condition called goiter.

Parathyroid hormone (PTH) is produced by the parathyroid glands in response to low blood Ca^{2+} levels. The parafollicular cells of the thyroid produce calcitonin, which reduces blood Ca^{2+} levels.

Growth hormone (GH) is produced by the anterior pituitary and controls the growth rate of muscle and bone. GH action is indirectly mediated by insulin-like growth factors (IGFs). Short-term stress causes the hypothalamus to trigger the adrenal medulla to release epinephrine and norepinephrine, which trigger the fight or flight response. Long-term stress causes the hypothalamus to trigger the anterior pituitary to release adrenocorticotropic hormone (ACTH), which causes the release of corticosteroids, glucocorticoids, and mineralocorticoids, from the adrenal cortex.

37.4 Regulation of Hormone Production

Hormone levels are primarily controlled through negative feedback, in which rising levels of a hormone inhibit its further release. The three mechanisms of hormonal release are humoral stimuli, hormonal stimuli, and neural stimuli. Humoral stimuli refers to the control of hormonal release in response to changes in extracellular fluid levels or ion levels. Hormonal stimuli refers to the release of hormones in response to hormones released by other endocrine glands. Neural stimuli refers to the release of hormones in response to neural stimulation.

37.5 Endocrine Glands

The pituitary gland is located at the base of the brain and is attached to the hypothalamus by the infundibulum. The anterior pituitary receives products from the hypothalamus by the hypophyseal portal system and produces six hormones. The posterior pituitary is an extension of the brain and releases hormones (antidiuretic hormone and oxytocin) produced by the hypothalamus.

The thyroid gland is located in the neck and is composed of two lobes connected by the isthmus. The thyroid is made up of follicle cells that produce the hormones thyroxine and triiodothyronine. Parafollicular cells of the thyroid produce calcitonin. The parathyroid glands lie on the posterior surface of the thyroid gland and produce parathyroid hormone.

The adrenal glands are located on top of the kidneys and consist of the renal cortex and renal medulla. The adrenal cortex is the outer part of the adrenal gland and produces the corticosteroids, glucocorticoids, and mineralocorticoids. The adrenal medulla is the inner part of the adrenal gland and produces the catecholamines epinephrine and norepinephrine.

The pancreas lies in the abdomen between the stomach and the small intestine. Clusters of endocrine cells in the pancreas form the islets of Langerhans, which are composed of alpha cells that release glucagon and beta cells that release insulin.

Some organs possess endocrine activity as a secondary function but have another primary function. The heart produces the hormone atrial natriuretic peptide, which functions to reduce blood volume, pressure, and Na^+ concentration. The gastrointestinal tract produces various hormones that aid in digestion. The kidneys produce renin, calcitriol, and erythropoietin. Adipose tissue produces leptin, which promotes satiety signals in the brain.

ART CONNECTION QUESTIONS

1. **Figure 37.5** Heat shock proteins (HSP) are so named because they help refold mis-folded proteins. In response to increased temperature (a “heat shock”), heat shock proteins are activated by release from the NR/HSP complex. At the same time, transcription of HSP genes is activated. Why do you think the cell responds to a heat shock by increasing the activity of proteins that help refold misfolded proteins?

2. **Figure 37.11** Pancreatic tumors may cause excess secretion of glucagon. Type I diabetes results from the failure of the pancreas to produce insulin. Which of the following statement about these two conditions is true?

a. A pancreatic tumor and type I diabetes will have the opposite effects on blood sugar levels.
b. A pancreatic tumor and type I diabetes will both cause hyperglycemia.
c. A pancreatic tumor and type I diabetes will both cause hypoglycemia.
d. Both pancreatic tumors and type I diabetes result in the inability of cells to take up glucose.

3. **Figure 37.14** Hyperthyroidism is a condition in which the thyroid gland is overactive. Hypothyroidism is a condition in which the thyroid gland is underactive. Which of the conditions are the following two patients most likely to have?

Patient A has symptoms including weight gain, cold sensitivity, low heart rate and fatigue.

Patient B has symptoms including weight loss, profuse sweating, increased heart rate and difficulty sleeping.

REVIEW QUESTIONS

4. A newly discovered hormone contains four amino acids linked together. Under which chemical class would this hormone be classified?

a. lipid-derived hormone
b. amino acid-derived hormone
c. peptide hormone
d. glycoprotein

5. Which class of hormones can diffuse through plasma membranes?

a. lipid-derived hormones
b. amino acid-derived hormones
c. peptide hormones
d. glycoprotein hormones

6. A new antagonist molecule has been discovered that binds to and blocks plasma membrane receptors. What effect will this antagonist have on testosterone, a steroid hormone?

a. It will block testosterone from binding to its receptor.
b. It will block testosterone from activating cAMP signaling.
c. It will increase testosterone-mediated signaling.
d. It will not affect testosterone-mediated signaling.

7. What effect will a cAMP inhibitor have on a peptide hormone-mediated signaling pathway?

a. It will prevent the hormone from binding its receptor.
b. It will prevent activation of a G-protein.
c. It will prevent activation of adenylate cyclase.
d. It will prevent activation of protein kinases.

8. Drinking alcoholic beverages causes an increase in urine output. This most likely occurs because alcohol:

a. inhibits ADH release
b. stimulates ADH release
c. inhibits TSH release
d. stimulates TSH release

9. FSH and LH release from the anterior pituitary is stimulated by _____.

a. TSH
b. GnRH
c. T_3
d. PTH

10. What hormone is produced by beta cells of the pancreas?

a. T_3
b. glucagon
c. insulin
d. T_4

11. When blood calcium levels are low, PTH stimulates:

a. excretion of calcium from the kidneys
b. excretion of calcium from the intestines
c. osteoblasts
d. osteoclasts

12. A rise in blood glucose levels triggers release of insulin from the pancreas. This mechanism of hormone production is stimulated by:

a. humoral stimuli
b. hormonal stimuli
c. neural stimuli
d. negative stimuli

13. Which mechanism of hormonal stimulation would be affected if signaling and hormone release from the hypothalamus was blocked?

a. humoral and hormonal stimuli
b. hormonal and neural stimuli
c. neural and humoral stimuli
d. hormonal and negative stimuli

14. Which endocrine glands are associated with the kidneys?

a. thyroid glands
b. pituitary glands
c. adrenal glands
d. gonads

15. Which of the following hormones is not produced by the anterior pituitary?

a. oxytocin
b. growth hormone
c. prolactin
d. thyroid-stimulating hormone

CRITICAL THINKING QUESTIONS

16. Although there are many different hormones in the human body, they can be divided into three classes based on their chemical structure. What are these classes and what is one factor that distinguishes them?

17. Where is insulin stored, and why would it be released?

18. Name two important functions of hormone receptors.

19. How can hormones mediate changes?

20. Name and describe a function of one hormone produced by the anterior pituitary and one hormone produced by the posterior pituitary.

21. Describe one direct action of growth hormone (GH).

22. How is hormone production and release primarily controlled?

23. Compare and contrast hormonal and humoral stimuli.

24. What does aldosterone regulate, and how is it stimulated?

25. The adrenal medulla contains two types of secretory cells, what are they and what are their functions?

CHAPTER SUMMARY

38.1 Types of Skeletal Systems

The three types of skeleton designs are hydrostatic skeletons, exoskeletons, and endoskeletons. A hydrostatic skeleton is formed by a fluid-filled compartment held under hydrostatic pressure; movement is created by the muscles producing pressure on the fluid. An exoskeleton is a hard external skeleton that protects the outer surface of an organism and enables movement through muscles attached on the inside. An endoskeleton is an internal skeleton composed of hard, mineralized tissue that also enables movement by attachment to muscles. The human skeleton is an endoskeleton that is composed of the axial and appendicular skeleton. The axial skeleton is composed of the bones of the skull, ossicles of the ear, hyoid bone, vertebral column, and ribcage. The skull consists of eight cranial bones and 14 facial bones. Six bones make up the ossicles of the middle ear, while the hyoid bone is located in the neck under the mandible. The vertebral column contains 26 bones, and it surrounds and protects the spinal cord. The thoracic cage consists of the sternum, ribs, thoracic vertebrae, and costal cartilages. The appendicular skeleton is made up of the limbs of the upper and lower limbs. The pectoral girdle is composed of the clavicles and the scapulae. The upper limb contains 30 bones in the arm, the forearm, and the hand. The pelvic girdle attaches the lower limbs to the axial skeleton. The lower limb includes the bones of the thigh, the leg, and the foot.

38.2 Bone

Bone, or osseous tissue, is connective tissue that includes specialized cells, mineral salts, and collagen fibers. The human skeleton can be divided into long bones, short bones, flat bones, and irregular bones. Compact bone tissue is composed of osteons and forms the external layer of all bones. Spongy bone tissue is composed of trabeculae and forms the inner part of all bones. Four types of cells compose bony tissue: osteocytes, osteoclasts, osteoprogenitor cells, and osteoblasts. Ossification is the process of bone formation by osteoblasts. Intramembranous ossification is the process of bone development from fibrous membranes. Endochondral ossification is the process of bone development from hyaline cartilage. Long bones lengthen as chondrocytes divide and secrete hyaline cartilage. Osteoblasts replace cartilage with bone. Appositional growth is the increase in the diameter of bones by the addition of bone tissue at the surface of bones. Bone remodeling involves the processes of bone deposition by osteoblasts and bone resorption by osteoclasts. Bone repair occurs in four stages and can take several months.

38.3 Joints and Skeletal Movement

The structural classification of joints divides them into bony, fibrous, cartilaginous, and synovial joints. The bones of fibrous joints are held together by fibrous connective tissue; the three types of fibrous joints are sutures, syndesomes, and gomphoses. Cartilaginous joints are joints in which the bones are connected by cartilage; the two types of cartilaginous joints are synchondroses and symphyses. Synovial joints are joints that have a space between the adjoining bones. The functional classification divides joints into three categories: synarthroses, amphiarthroses, and diarthroses. The movement of synovial joints can be classified as one of four different types: gliding, angular, rotational, or special movement. Gliding movements occur as relatively flat bone surfaces move past each other. Angular movements are produced when the angle between the bones of a joint changes. Rotational movement is the movement of a bone as it rotates around its own longitudinal axis. Special movements include inversion, eversion, protraction, retraction, elevation, depression, dorsiflexion, plantar flexion, supination, pronation, and opposition. Synovial joints are also classified into six different categories on the basis of the shape and structure of the joint: planar, hinge, pivot, condyloid, saddle, and ball-and-socket.

38.4 Muscle Contraction and Locomotion

The body contains three types of muscle tissue: skeletal muscle, cardiac muscle, and smooth muscle. Skeleton muscle tissue is composed of sarcomeres, the functional units of muscle tissue. Muscle contraction occurs when sarcomeres shorten, as thick and thin filaments slide past each other, which is called the sliding filament model of muscle contraction. ATP provides the energy for cross-bridge

formation and filament sliding. Regulatory proteins, such as troponin and tropomyosin, control cross-bridge formation. Excitation–contraction coupling transduces the electrical signal of the neuron, via acetylcholine, to an electrical signal on the muscle membrane, which initiates force production. The number of muscle fibers contracting determines how much force the whole muscle produces.

ART CONNECTION QUESTIONS

1. **Figure 38.19** Which of the following statements about bone tissue is false?

a. Compact bone tissue is made of cylindrical osteons that are aligned such that they travel the length of the bone.
b. Haversian canals contain blood vessels only.
c. Haversian canals contain blood vessels and nerve fibers.
d. Spongy tissue is found on the interior of the bone, and compact bone tissue is found on the exterior.

2. **Figure 38.37** Which of the following statements about muscle contraction is true?

a. The power stroke occurs when ATP is hydrolyzed to ADP and phosphate.
b. The power stroke occurs when ADP and phosphate dissociate from the myosin head.
c. The power stroke occurs when ADP and phosphate dissociate from the actin active site.
d. The power stroke occurs when Ca^{2+} binds the calcium head.

3. **Figure 38.38** The deadly nerve gas Sarin irreversibly inhibits acetycholinesterase. What effect would Sarin have on muscle contraction?

REVIEW QUESTIONS

4. The forearm consists of the:

a. radius and ulna
b. radius and humerus
c. ulna and humerus
d. humerus and carpus

5. The pectoral girdle consists of the:

a. clavicle and sternum
b. sternum and scapula
c. clavicle and scapula
d. clavicle and coccyx

6. All of the following are groups of vertebrae except _____, which is a curvature.

a. thoracic
b. cervical
c. lumbar
d. pelvic

7. Which of these is a facial bone?

a. frontal
b. occipital
c. lacrimal
d. temporal

8. The Haversian canal:

a. is arranged as rods or plates
b. contains the bone's blood vessels and nerve fibers
c. is responsible for the lengthwise growth of long bones
d. synthesizes and secretes matrix

9. The epiphyseal plate:

a. is arranged as rods or plates
b. contains the bone's blood vessels and nerve fibers
c. is responsible for the lengthwise growth of long bones
d. synthesizes and secretes bone matrix

10. The cells responsible for bone resorption are _____.

a. osteoclasts
b. osteoblasts
c. fibroblasts
d. osteocytes

11. Compact bone is composed of _____.

a. trabeculae
b. compacted collagen
c. osteons
d. calcium phosphate only

12. Synchondroses and symphyses are:

a. synovial joints
b. cartilaginous joints
c. fibrous joints
d. condyloid joints

13. The movement of bone away from the midline of the body is called _____.

a. circumduction
b. extension
c. adduction
d. abduction

14. Which of the following is not a characteristic of the synovial fluid?

a. lubrication
b. shock absorption
c. regulation of water balance in the joint
d. protection of articular cartilage

15. The elbow is an example of which type of joint?

a. hinge
b. pivot

c. saddle
d. gliding

16. In relaxed muscle, the myosin-binding site on actin is blocked by _____.
a. titin
b. troponin
c. myoglobin
d. tropomyosin

17. The cell membrane of a muscle fiber is called a _____.
a. myofibril
b. sarcolemma
c. sarcoplasm
d. myofilament

18. The muscle relaxes if no new nerve signal arrives. However the neurotransmitter from the previous stimulation is still present in the synapse. The activity of _____ helps to remove this neurotransmitter.
a. myosin
b. action potential
c. tropomyosin
d. acetylcholinesterase

19. The ability of a muscle to generate tension immediately after stimulation is dependent on:

a. myosin interaction with the M line
b. overlap of myosin and actin
c. actin attachments to the Z line
d. none of the above

CRITICAL THINKING QUESTIONS

20. What are the major differences between the male pelvis and female pelvis that permit childbirth in females?

21. What are the major differences between the pelvic girdle and the pectoral girdle that allow the pelvic girdle to bear the weight of the body?

22. What are the major differences between spongy bone and compact bone?

23. What are the roles of osteoblasts, osteocytes, and osteoclasts?

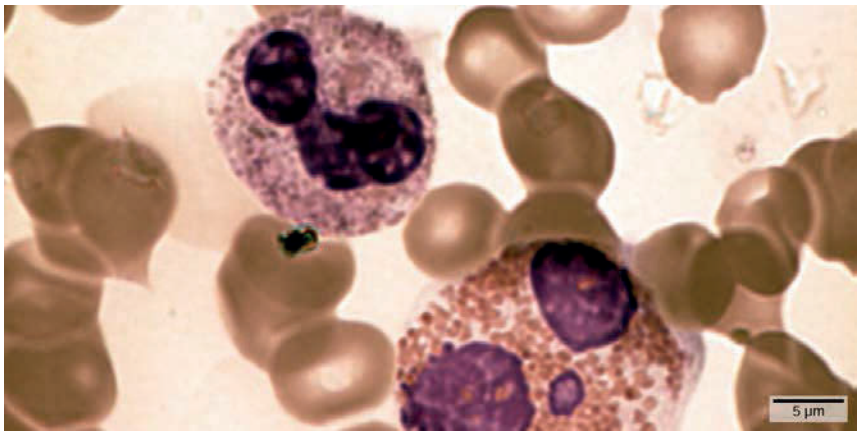
24. What movements occur at the hip joint and knees as you bend down to touch your toes?

25. What movement(s) occur(s) at the scapulae when you shrug your shoulders?

26. How would muscle contractions be affected if ATP was completely depleted in a muscle fiber?

27. What factors contribute to the amount of tension produced in an individual muscle fiber?

28. What effect will low blood calcium have on neurons? What effect will low blood calcium have on skeletal muscles?



CHAPTER SUMMARY

39.1 Systems of Gas Exchange

Animal respiratory systems are designed to facilitate gas exchange. In mammals, air is warmed and humidified in the nasal cavity. Air then travels down the pharynx, through the trachea, and into the lungs. In the lungs, air passes through the branching bronchi, reaching the respiratory bronchioles, which house the first site of gas exchange. The respiratory bronchioles open into the alveolar ducts, alveolar sacs, and alveoli. Because there are so many alveoli and alveolar sacs in the lung, the surface area for gas exchange is very large. Several protective mechanisms are in place to prevent damage or infection. These include the hair and mucus in the nasal cavity that trap dust, dirt, and other particulate matter before they can enter the system. In the lungs, particles are trapped in a mucus layer and transported via cilia up to the esophageal opening at the top of the trachea to be swallowed.

39.2 Gas Exchange across Respiratory Surfaces

The lungs can hold a large volume of air, but they are not usually filled to maximal capacity. Lung volume measurements include tidal volume, expiratory reserve volume, inspiratory reserve volume, and residual volume. The sum of these equals the total lung capacity. Gas movement into or out of the lungs is dependent on the pressure of the gas. Air is a mixture of gases; therefore, the partial pressure of each gas can be calculated to determine how the gas will flow in the lung. The difference between the partial pressure of the gas in the air drives oxygen into the tissues and carbon dioxide out of the body.

39.3 Breathing

The structure of the lungs and thoracic cavity control the mechanics of breathing. Upon inspiration, the diaphragm contracts and lowers. The intercostal muscles contract and expand the chest wall outward. The intrapleural pressure drops, the lungs expand, and air is drawn into the airways. When exhaling, the intercostal muscles and diaphragm relax, returning the intrapleural pressure back to the resting state. The lungs recoil and airways close. The air passively exits the lung. There is high surface tension at the air-airway interface in the lung. Surfactant, a mixture of phospholipids and lipoproteins, acts like a detergent in the airways to reduce surface tension and allow for opening of the alveoli.

Breathing and gas exchange are both altered by changes in the compliance and resistance of the lung. If the compliance of the lung decreases, as occurs in restrictive diseases like fibrosis, the airways stiffen and collapse upon exhalation. Air becomes trapped in the lungs, making breathing more difficult. If resistance increases, as happens with asthma or emphysema, the airways become obstructed, trapping

air in the lungs and causing breathing to become difficult. Alterations in the ventilation of the airways or perfusion of the arteries can affect gas exchange. These changes in ventilation and perfusion, called V/Q mismatch, can arise from anatomical or physiological changes.

39.4 Transport of Gases in Human Bodily Fluids

Hemoglobin is a protein found in red blood cells that is comprised of two alpha and two beta subunits that surround an iron-containing heme group. Oxygen readily binds this heme group. The ability of oxygen to bind increases as more oxygen molecules are bound to heme. Disease states and altered conditions in the body can affect the binding ability of oxygen, and increase or decrease its ability to dissociate from hemoglobin.

Carbon dioxide can be transported through the blood via three methods. It is dissolved directly in the blood, bound to plasma proteins or hemoglobin, or converted into bicarbonate. The majority of carbon dioxide is transported as part of the bicarbonate system. Carbon dioxide diffuses into red blood cells. Inside, carbonic anhydrase converts carbon dioxide into carbonic acid (H_2CO_3), which is subsequently hydrolyzed into bicarbonate (HCO_3^-) and H^+. The H^+ ion binds to hemoglobin in red blood cells, and bicarbonate is transported out of the red blood cells in exchange for a chloride ion. This is called the chloride shift. Bicarbonate leaves the red blood cells and enters the blood plasma. In the lungs, bicarbonate is transported back into the red blood cells in exchange for chloride. The H^+ dissociates from hemoglobin and combines with bicarbonate to form carbonic acid with the help of carbonic anhydrase, which further catalyzes the reaction to convert carbonic acid back into carbon dioxide and water. The carbon dioxide is then expelled from the lungs.

ART CONNECTION QUESTIONS

1. **Figure 39.7** Which of the following statements about the mammalian respiratory system is false?

a. When we breathe in, air travels from the pharynx to the trachea.
b. The bronchioles branch into bronchi.
c. Alveolar ducts connect to alveolar sacs.
d. Gas exchange between the lung and blood takes place in the alveolus.

2. **Figure 39.13** Which of the following statements is false?

a. In the tissues, P_{O_2} drops as blood passes from the arteries to the veins, while P_{CO_2} increases.
b. Blood travels from the lungs to the heart to body tissues, then back to the heart, then the lungs.
c. Blood travels from the lungs to the heart to body tissues, then back to the lungs, then the heart.
d. P_{O_2} is higher in air than in the lungs.

3. **Figure 39.20** The kidneys are responsible for removing excess H+ ions from the blood. If the kidneys fail, what would happen to blood pH and to hemoglobin affinity for oxygen?

REVIEW QUESTIONS

4. The respiratory system _____.

a. provides body tissues with oxygen
b. provides body tissues with oxygen and carbon dioxide
c. establishes how many breaths are taken per minute
d. provides the body with carbon dioxide

5. Air is warmed and humidified in the nasal passages. This helps to _____.

a. ward off infection
b. decrease sensitivity during breathing
c. prevent damage to the lungs
d. all of the above

6. Which is the order of airflow during inhalation?

a. nasal cavity, trachea, larynx, bronchi, bronchioles, alveoli
b. nasal cavity, larynx, trachea, bronchi, bronchioles, alveoli
c. nasal cavity, larynx, trachea, bronchioles, bronchi, alveoli
d. nasal cavity, trachea, larynx, bronchi, bronchioles, alveoli

7. The inspiratory reserve volume measures the _____.

a. amount of air remaining in the lung after a maximal exhalation
b. amount of air that the lung holds
c. amount of air the can be further exhaled after a normal breath

d. amount of air that can be further inhaled after a normal breath

8. Of the following, which does not explain why the partial pressure of oxygen is lower in the lung than in the external air?

a. Air in the lung is humidified; therefore, water vapor pressure alters the pressure.
b. Carbon dioxide mixes with oxygen.
c. Oxygen is moved into the blood and is headed to the tissues.
d. Lungs exert a pressure on the air to reduce the oxygen pressure.

9. The total lung capacity is calculated using which of the following formulas?

a. residual volume + tidal volume + inspiratory reserve volume
b. residual volume + expiratory reserve volume + inspiratory reserve volume
c. expiratory reserve volume + tidal volume + inspiratory reserve volume
d. residual volume + expiratory reserve volume + tidal volume + inspiratory reserve volume

10. How would paralysis of the diaphragm alter inspiration?

a. It would prevent contraction of the intercostal muscles.
b. It would prevent inhalation because the intrapleural pressure would not change.
c. It would decrease the intrapleural pressure and allow more air to enter the lungs.
d. It would slow expiration because the lung would not relax.

11. Restrictive airway diseases _____.

a. increase the compliance of the lung
b. decrease the compliance of the lung
c. increase the lung volume
d. decrease the work of breathing

12. Alveolar ventilation remains constant when _____.

a. the respiratory rate is increased while the volume of air per breath is decreased
b. the respiratory rate and the volume of air per breath are increased
c. the respiratory rate is decreased while increasing the volume per breath
d. both a and c

13. Which of the following will NOT facilitate the transfer of oxygen to tissues?

a. decreased body temperature
b. decreased pH of the blood
c. increased carbon dioxide
d. increased exercise

14. The majority of carbon dioxide in the blood is transported by _____.

a. binding to hemoglobin
b. dissolution in the blood
c. conversion to bicarbonate
d. binding to plasma proteins

15. The majority of oxygen in the blood is transported by _____.

a. dissolution in the blood
b. being carried as bicarbonate ions
c. binding to blood plasma
d. binding to hemoglobin

CRITICAL THINKING QUESTIONS

16. Describe the function of these terms and describe where they are located: main bronchus, trachea, alveoli, and acinus.

17. How does the structure of alveoli maximize gas exchange?

18. What does FEV1/FVC measure? What factors may affect FEV1/FVC?

19. What is the reason for having residual volume in the lung?

20. How can a decrease in the percent of oxygen in the air affect the movement of oxygen in the body?

21. If a patient has increased resistance in his or her lungs, how can this detected by a doctor? What does this mean?

22. How would increased airway resistance affect intrapleural pressure during inhalation?

23. Explain how a puncture to the thoracic cavity (from a knife wound, for instance) could alter the ability to inhale.

24. When someone is standing, gravity stretches the bottom of the lung down toward the floor to a greater extent than the top of the lung. What implication could this have on the flow of air in the lungs? Where does gas exchange occur in the lungs?

25. What would happen if no carbonic anhydrase were present in red blood cells?

26. How does the administration of 100 percent oxygen save a patient from carbon monoxide poisoning? Why wouldn't giving carbon dioxide work?

CHAPTER SUMMARY

40.1 Overview of the Circulatory System

In most animals, the circulatory system is used to transport blood through the body. Some primitive animals use diffusion for the exchange of water, nutrients, and gases. However, complex organisms use the circulatory system to carry gases, nutrients, and waste through the body. Circulatory systems may be open (mixed with the interstitial fluid) or closed (separated from the interstitial fluid). Closed circulatory systems are a characteristic of vertebrates; however, there are significant differences in the structure of the heart and the circulation of blood between the different vertebrate groups due to adaptions during evolution and associated differences in anatomy. Fish have a two-chambered heart with unidirectional circulation. Amphibians have a three-chambered heart, which has some mixing of the blood, and they have double circulation. Most non-avian reptiles have a three-chambered heart, but have little mixing of the blood; they have double circulation. Mammals and birds have a four-chambered heart with no mixing of the blood and double circulation.

40.2 Components of the Blood

Specific components of the blood include red blood cells, white blood cells, platelets, and the plasma, which contains coagulation factors and serum. Blood is important for regulation of the body's pH, temperature, osmotic pressure, the circulation of nutrients and removal of waste, the distribution of hormones from endocrine glands, and the elimination of excess heat; it also contains components for blood clotting. Red blood cells are specialized cells that contain hemoglobin and circulate through the body delivering oxygen to cells. White blood cells are involved in the immune response to identify and target invading bacteria, viruses, and other foreign organisms; they also recycle waste components, such as old red blood cells. Platelets and blood clotting factors cause the change of the soluble protein fibrinogen to the insoluble protein fibrin at a wound site forming a plug. Plasma consists of 90 percent water along with various substances, such as coagulation factors and antibodies. The serum is the plasma component of the blood without the coagulation factors.

40.3 Mammalian Heart and Blood Vessels

The heart muscle pumps blood through three divisions of the circulatory system: coronary, pulmonary, and systemic. There is one atrium and one ventricle on the right side and one atrium and one ventricle on the left side. The pumping of the heart is a function of cardiomyocytes, distinctive muscle cells that are striated like skeletal muscle but pump rhythmically and involuntarily like smooth muscle. The internal pacemaker starts at the sinoatrial node, which is located near the wall of the right atrium. Electrical charges pulse from the SA node causing the two atria to contract in unison; then the pulse reaches the atrioventricular node between the right atrium and right ventricle. A pause in the electric signal allows the atria to empty completely into the ventricles before the ventricles pump out the blood. The blood from the heart is carried through the body by a complex network of blood vessels; arteries take blood away from the heart, and veins bring blood back to the heart.

40.4 Blood Flow and Blood Pressure Regulation

Blood primarily moves through the body by the rhythmic movement of smooth muscle in the vessel wall and by the action of the skeletal muscle as the body moves. Blood is prevented from flowing backward in the veins by one-way valves. Blood flow through the capillary beds is controlled by precapillary sphincters to increase and decrease flow depending on the body's needs and is directed by nerve and hormone signals. Lymph vessels take fluid that has leaked out of the blood to the lymph nodes where it is cleaned before returning to the heart. During systole, blood enters the arteries, and the

artery walls stretch to accommodate the extra blood. During diastole, the artery walls return to normal. The blood pressure of the systole phase and the diastole phase gives the two pressure readings for blood pressure.

ART CONNECTION QUESTIONS

1. **Figure 40.10** Which of the following statements about the circulatory system is false?

a. Blood in the pulmonary vein is deoxygenated.
b. Blood in the inferior vena cava is deoxygenated.
c. Blood in the pulmonary artery is deoxygenated.
d. Blood in the aorta is oxygenated.

2. **Figure 40.11** Which of the following statements about the heart is false?

a. The mitral valve separates the left ventricle from the left atrium.
b. Blood travels through the bicuspid valve to the left atrium.
c. Both the aortic and the pulmonary valves are semilunar valves.
d. The mitral valve is an atrioventricular valve.

3. **Figure 40.17** Varicose veins are veins that become enlarged because the valves no longer close properly, allowing blood to flow backward. Varicose veins are often most prominent on the legs. Why do you think this is the case?

REVIEW QUESTIONS

4. Why are open circulatory systems advantageous to some animals?

a. They use less metabolic energy.
b. They help the animal move faster.
c. They do not need a heart.
d. They help large insects develop.

5. Some animals use diffusion instead of a circulatory system. Examples include:

a. birds and jellyfish
b. flatworms and arthropods
c. mollusks and jellyfish
d. None of the above

6. Blood flow that is directed through the lungs and back to the heart is called _____.

a. unidirectional circulation
b. gill circulation
c. pulmonary circulation
d. pulmocutaneous circulation

7. White blood cells:

a. can be classified as granulocytes or agranulocytes
b. defend the body against bacteria and viruses
c. are also called leucocytes
d. All of the above

8. Platelet plug formation occurs at which point?

a. when large megakaryocytes break up into thousands of smaller fragments
b. when platelets are dispersed through the blood stream
c. when platelets are attracted to a site of blood vessel damage
d. none of the above

9. In humans, the plasma comprises what percentage of the blood?

a. 45 percent
b. 55 percent
c. 25 percent
d. 90 percent

10. The red blood cells of birds differ from mammalian red blood cells because:

a. they are white and have nuclei
b. they do not have nuclei
c. they have nuclei
d. they fight disease

11. The heart's internal pacemaker beats by:

a. an internal implant that sends an electrical impulse through the heart
b. the excitation of cardiac muscle cells at the sinoatrial node followed by the atrioventricular node
c. the excitation of cardiac muscle cells at the atrioventricular node followed by the sinoatrial node
d. the action of the sinus

12. During the systolic phase of the cardiac cycle, the heart is _____.

a. contracting
b. relaxing
c. contracting and relaxing
d. filling with blood

13. Cardiomyocytes are similar to skeletal muscle because:

a. they beat involuntarily
b. they are used for weight lifting
c. they pulse rhythmically
d. they are striated

14. How do arteries differ from veins?

a. Arteries have thicker smooth muscle layers to accommodate the changes in pressure from the heart.

b. Arteries carry blood.
c. Arteries have thinner smooth muscle layers and valves and move blood by the action of skeletal muscle.
d. Arteries are thin walled and are used for gas exchange.

15. High blood pressure would be a result of _____.

a. a high cardiac output and high peripheral resistance
b. a high cardiac output and low peripheral resistance
c. a low cardiac output and high peripheral resistance
d. a low cardiac output and low peripheral resistance

CRITICAL THINKING QUESTIONS

16. Describe a closed circulatory system.

17. Describe systemic circulation.

18. Describe the cause of different blood type groups.

19. List some of the functions of blood in the body.

20. How does the lymphatic system work with blood flow?

21. Describe the cardiac cycle.

22. What happens in capillaries?

23. How does blood pressure change during heavy exercise?

CHAPTER SUMMARY

41.1 Osmoregulation and Osmotic Balance

Solute concentrations across a semi-permeable membranes influence the movement of water and solutes across the membrane. It is the number of solute molecules and not the molecular size that is important in osmosis. Osmoregulation and osmotic balance are important bodily functions, resulting in water and salt balance. Not all solutes can pass through a semi-permeable membrane. Osmosis is the movement of water across the membrane. Osmosis occurs to equalize the number of solute molecules across a semi-permeable membrane by the movement of water to the side of higher solute concentration. Facilitated diffusion utilizes protein channels to move solute molecules from areas of higher to lower concentration while active transport mechanisms are required to move solutes against concentration gradients. Osmolarity is measured in units of milliequivalents or milliosmoles, both of which take into consideration the number of solute particles and the charge on them. Fish that live in fresh water or saltwater adapt by being osmoregulators or osmoconformers.

41.2 The Kidneys and Osmoregulatory Organs

The kidneys are the main osmoregulatory organs in mammalian systems; they function to filter blood and maintain the osmolarity of body fluids at 300 mOsm. They are surrounded by three layers and are made up internally of three distinct regions—the cortex, medulla, and pelvis.

The blood vessels that transport blood into and out of the kidneys arise from and merge with the aorta and inferior vena cava, respectively. The renal arteries branch out from the aorta and enter the kidney where they further divide into segmental, interlobar, arcuate, and cortical radiate arteries.

The nephron is the functional unit of the kidney, which actively filters blood and generates urine. The nephron is made up of the renal corpuscle and renal tubule. Cortical nephrons are found in the renal cortex, while juxtamedullary nephrons are found in the renal cortex close to the renal medulla. The

nephron filters and exchanges water and solutes with two sets of blood vessels and the tissue fluid in the kidneys.

There are three steps in the formation of urine: glomerular filtration, which occurs in the glomerulus; tubular reabsorption, which occurs in the renal tubules; and tubular secretion, which also occurs in the renal tubules.

41.3 Excretion Systems

Many systems have evolved for excreting wastes that are simpler than the kidney and urinary systems of vertebrate animals. The simplest system is that of contractile vacuoles present in microorganisms. Flame cells and nephridia in worms perform excretory functions and maintain osmotic balance. Some insects have evolved Malpighian tubules to excrete wastes and maintain osmotic balance.

41.4 Nitrogenous Wastes

Ammonia is the waste produced by metabolism of nitrogen-containing compounds like proteins and nucleic acids. While aquatic animals can easily excrete ammonia into their watery surroundings, terrestrial animals have evolved special mechanisms to eliminate the toxic ammonia from their systems. Urea is the major byproduct of ammonia metabolism in vertebrate animals. Uric acid is the major byproduct of ammonia metabolism in birds, terrestrial arthropods, and reptiles.

41.5 Hormonal Control of Osmoregulatory Functions

Hormonal cues help the kidneys synchronize the osmotic needs of the body. Hormones like epinephrine, norepinephrine, renin-angiotensin, aldosterone, anti-diuretic hormone, and atrial natriuretic peptide help regulate the needs of the body as well as the communication between the different organ systems.

ART CONNECTION QUESTIONS

1. **Figure 41.5** Which of the following statements about the kidney is false?

a. The renal pelvis drains into the ureter.
b. The renal pyramids are in the medulla.
c. The cortex covers the capsule.
d. Nephrons are in the renal cortex.

2. **Figure 41.6** Which of the following statements about the nephron is false?

a. The collecting duct empties into the distal convoluted tubule.
b. The Bowman's capsule surrounds the glomerulus.
c. The loop of Henle is between the proximal and distal convoluted tubules.
d. The loop of Henle empties into the distal convoluted tubule.

3. **Figure 41.8** Loop diuretics are drugs sometimes used to treat hypertension. These drugs inhibit the reabsorption of Na^+ and Cl^- ions by the ascending limb of the loop of Henle. A side effect is that they increase urination. Why do you think this is the case?

REVIEW QUESTIONS

4. When a dehydrated human patient needs to be given fluids intravenously, he or she is given:

a. water, which is hypotonic with respect to body fluids
b. saline at a concentration that is isotonic with respect to body fluids
c. glucose because it is a non-electrolyte
d. blood

5. The sodium ion is at the highest concentration in:

a. intracellular fluid
b. extracellular fluid
c. blood plasma
d. none of the above

6. Cells in a hypertonic solution tend to:

a. shrink due to water loss
b. swell due to water gain
c. stay the same size due to water moving into and out of the cell at the same rate
d. none of the above

7. The macula densa is/are:

a. present in the renal medulla.
b. dense tissue present in the outer layer of the kidney.
c. cells present in the DCT and collecting tubules.
d. present in blood capillaries.

8. The osmolarity of body fluids is maintained at _____.

a. 100 mOsm
b. 300 mOsm
c. 1000 mOsm
d. it is not constantly maintained

9. The gland located at the top of the kidney is the _____ gland.

a. adrenal
b. pituitary
c. thyroid
d. thymus

10. Active transport of K^+ in Malpighian tubules ensures that:

a. water follows K^+ to make urine
b. osmotic balance is maintained between waste matter and bodily fluids
c. both a and b
d. neither a nor b

11. Contractile vacuoles in microorganisms:

a. exclusively perform an excretory function
b. can perform many functions, one of which is excretion of metabolic wastes
c. originate from the cell membrane
d. both b and c

12. Flame cells are primitive excretory organs found in _____.

a. arthropods
b. annelids
c. mammals
d. flatworms

13. BUN is _____.

a. blood urea nitrogen
b. blood uric acid nitrogen
c. an indicator of blood volume
d. an indicator of blood pressure

14. Human beings accumulate _____ before excreting nitrogenous waste.

a. nitrogen
b. ammonia
c. urea
d. uric acid

15. Renin is made by _____.

a. granular cells of the juxtaglomerular apparatus
b. the kidneys
c. the nephrons
d. All of the above.

16. Patients with Addison's disease _____.

a. retain water
b. retain salts
c. lose salts and water
d. have too much aldosterone

17. Which hormone elicits the “fight or flight” response?

a. epinephrine
b. mineralcorticoids
c. anti-diuretic hormone
d. thyroxine

CRITICAL THINKING QUESTIONS

18. Why is excretion important in order to achieve osmotic balance?

19. Why do electrolyte ions move across membranes by active transport?

20. Why are the loop of Henle and vasa recta important for the formation of concentrated urine?

21. Describe the structure of the kidney.

22. Why might specialized organs have evolved for excretion of wastes?

23. Explain two different excretory systems other than the kidneys.

24. In terms of evolution, why might the urea cycle have evolved in organisms?

25. Compare and contrast the formation of urea and uric acid.

26. Describe how hormones regulate blood pressure, blood volume, and kidney function.

27. How does the renin-angiotensin-aldosterone mechanism function? Why is it controlled by the kidneys?

CHAPTER SUMMARY

42.1 Innate Immune Response

The innate immune system serves as a first responder to pathogenic threats that bypass natural physical and chemical barriers of the body. Using a combination of cellular and molecular attacks, the innate immune system identifies the nature of a pathogen and responds with inflammation, phagocytosis, cytokine release, destruction by NK cells, and/or a complement system. When innate mechanisms are insufficient to clear an infection, the adaptive immune response is informed and mobilized.

42.2 Adaptive Immune Response

The adaptive immune response is a slower-acting, longer-lasting, and more specific response than the innate response. However, the adaptive response requires information from the innate immune system to function. APCs display antigens via MHC molecules to complementary naïve T cells. In response, the T cells differentiate and proliferate, becoming T_H cells or CTLs. T_H cells stimulate B cells that have engulfed and presented pathogen-derived antigens. B cells differentiate into plasma cells that secrete antibodies, whereas CTLs induce apoptosis in intracellularly infected or cancerous cells. Memory cells persist after a primary exposure to a pathogen. If re-exposure occurs, memory cells differentiate into effector cells without input from the innate immune system. The mucosal immune system is largely independent from the systemic immune system but functions in a parallel fashion to protect the extensive mucosal surfaces of the body.

42.3 Antibodies

Antibodies (immunoglobulins) are the molecules secreted from plasma cells that mediate the humoral immune response. There are five antibody classes; an antibody's class determines its mechanism of action and production site but does not control its binding specificity. Antibodies bind antigens via variable domains and can either neutralize pathogens or mark them for phagocytosis or activate the complement cascade.

42.4 Disruptions in the Immune System

Immune disruptions may involve insufficient immune responses or inappropriate immune targets. Immunodeficiency increases an individual's susceptibility to infections and cancers. Hypersensitivities are misdirected responses either to harmless foreign particles, as in the case of allergies, or to host factors, as in the case of autoimmunity. Reactions to self components may be the result of molecular mimicry.

ART CONNECTION QUESTIONS

1. **Figure 42.11** Which of the following statements about T cells is false?

a. Helper T cells release cytokines while cytotoxic T cells kill the infected cell.

b. Helper T cells are CD4+, while cytotoxic T cells are $CD8^+$.

c. MHC II is a receptor found on most body cells, while MHC I is a receptor found on immune cells only.
d. The T cell receptor is found on both $CD4^+$ and $CD8^+$ T cells.

2. **Figure 42.14** Based on what you know about MHC receptors, why do you think an organ transplanted from an incompatible donor to a recipient will be rejected?

3. **Figure 42.16** The Rh antigen is found on Rh-positive red blood cells. An Rh-negative female can usually carry an Rh-positive fetus to term without difficulty. However, if she has a second Rh-positive fetus, her body may launch an immune attack that causes hemolytic disease of the newborn. Why do you think hemolytic disease is only a problem during the second or subsequent pregnancies?

REVIEW QUESTIONS

4. Which of the following is a barrier against pathogens provided by the skin?
a. high pH
b. mucus
c. tears
d. desiccation

5. Although interferons have several effects, they are particularly useful against infections with which type of pathogen?
a. bacteria
b. viruses
c. fungi
d. helminths

6. Which organelle do phagocytes use to digest engulfed particles?
a. lysosome
b. nucleus
c. endoplasmic reticulum
d. mitochondria

7. Which innate immune system component uses MHC I molecules directly in its defense strategy?
a. macrophages
b. neutrophils
c. NK cells
d. interferon

8. Which of the following is both a phagocyte and an antigen-presenting cell?
a. NK cell
b. eosinophil
c. neutrophil
d. macrophage

9. Which immune cells bind MHC molecules on APCs via CD8 coreceptors on their cell surfaces?
a. T_H cells
b. CTLs
c. mast cells
d. basophils

10. What "self" pattern is identified by NK cells?
a. altered self
b. missing self
c. normal self
d. non-self

11. The acquired ability to prevent an unnecessary or destructive immune reaction to a harmless foreign particle, such as a food protein, is called _____.
a. the T_H2 response
b. allergy
c. immune tolerance
d. autoimmunity

12. A memory B cell can differentiate upon re-exposure to a pathogen of which cell type?
a. CTL
b. naïve B cell
c. memory T cell
d. plasma cell

13. Foreign particles circulating in the blood are filtered by the _____.
a. spleen
b. lymph nodes
c. MALT
d. lymph

14. The structure of an antibody is similar to the extracellular component of which receptor?
a. MHC I
b. MHC II
c. BCR
d. none of the above

15. The first antibody class to appear in the serum in response to a newly encountered pathogen is _____.
a. IgM
b. IgA
c. IgG
d. IgE

16. What is the most abundant antibody class detected in the serum upon reexposure to a pathogen or in reaction to a vaccine?
a. IgM
b. IgA
c. IgG
d. IgE

17. Breastfed infants typically are resistant to disease because of _____.
a. active immunity
b. passive immunity
c. immune tolerance

d. immune memory

18. Allergy to pollen is classified as:
a. an autoimmune reaction
b. immunodeficiency
c. delayed hypersensitivity
d. immediate hypersensitivity

19. A potential cause of acquired autoimmunity is _____.
a. tissue hypersensitivity
b. molecular mimicry
c. histamine release
d. radiation exposure

20. Autoantibodies are probably involved in:
a. reactions to poison ivy
b. pollen allergies
c. systemic lupus erythematosus
d. HIV/AIDS

21. Which of the following diseases is not due to autoimmunity?
a. rheumatic fever
b. systemic lupus erythematosus
c. diabetes mellitus
d. HIV/AIDS

CRITICAL THINKING QUESTIONS

22. Different MHC I molecules between donor and recipient cells can lead to rejection of a transplanted organ or tissue. Suggest a reason for this.

23. If a series of genetic mutations prevented some, but not all, of the complement proteins from binding antibodies or pathogens, would the entire complement system be compromised?

24. Explain the difference between an epitope and an antigen.

25. What is a naïve B or T cell?

26. How does the T_H1 response differ from the T_H2 response?

27. In mammalian adaptive immune systems, T cell receptors are extraordinarily diverse. What function of the immune system results from this diversity, and how is this diversity achieved?

28. How do B and T cells differ with respect to antigens that they bind?

29. Why is the immune response after reinfection much faster than the adaptive immune response after the initial infection?

30. What are the benefits and costs of antibody cross reactivity?

CHAPTER SUMMARY

43.1 Reproduction Methods

Reproduction may be asexual when one individual produces genetically identical offspring, or sexual when the genetic material from two individuals is combined to produce genetically diverse offspring. Asexual reproduction occurs through fission, budding, and fragmentation. Sexual reproduction may mean the joining of sperm and eggs within animals' bodies or it may mean the release of sperm and eggs into the environment. An individual may be one sex, or both; it may start out as one sex and switch during its life, or it may stay male or female.

43.2 Fertilization

Sexual reproduction starts with the combination of a sperm and an egg in a process called fertilization. This can occur either outside the bodies or inside the female. Both methods have advantages and disadvantages. Once fertilized, the eggs can develop inside the female or outside. If the egg develops outside the body, it usually has a protective covering over it. Animal anatomy evolved various ways to fertilize, hold, or expel the egg. The method of fertilization varies among animals. Some species release the egg and sperm into the environment, some species retain the egg and receive the sperm into the female body and then expel the developing embryo covered with shell, while still other species retain the developing offspring through the gestation period.

43.3 Human Reproductive Anatomy and Gametogenesis

As animals became more complex, specific organs and organ systems developed to support specific functions for the organism. The reproductive structures that evolved in land animals allow males and females to mate, fertilize internally, and support the growth and development of offspring. Processes developed to produce reproductive cells that had exactly half the number of chromosomes of each parent so that new combinations would have the appropriate amount of genetic material. Gametogenesis, the production of sperm (spermatogenesis) and eggs (oogenesis), takes place through the process of meiosis.

43.4 Hormonal Control of Human Reproduction

The male and female reproductive cycles are controlled by hormones released from the hypothalamus and anterior pituitary as well as hormones from reproductive tissues and organs. The hypothalamus monitors the need for the FSH and LH hormones made and released from the anterior pituitary. FSH and LH affect reproductive structures to cause the formation of sperm and the preparation of eggs for release and possible fertilization. In the male, FSH and LH stimulate Sertoli cells and interstitial cells of Leydig in the testes to facilitate sperm production. The Leydig cells produce testosterone, which also is responsible for the secondary sexual characteristics of males. In females, FSH and LH cause estrogen and progesterone to be produced. They regulate the female reproductive system which is divided into the ovarian cycle and the menstrual cycle. Menopause occurs when the ovaries lose their sensitivity to FSH and LH and the female reproductive cycles slow to a stop.

43.5 Human Pregnancy and Birth

Human pregnancy begins with fertilization of an egg and proceeds through the three trimesters of gestation. The labor process has three stages (contractions, delivery of the fetus, expulsion of the placenta), each propelled by hormones. The first trimester lays down the basic structures of the body, including the limb buds, heart, eyes, and the liver. The second trimester continues the development of all of the organs and systems. The third trimester exhibits the greatest growth of the fetus and culminates in labor and delivery. Prevention of a pregnancy can be accomplished through a variety of methods including barriers, hormones, or other means. Assisted reproductive technologies may help individuals who have infertility problems.

43.6 Fertilization and Early Embryonic Development

The early stages of embryonic development begin with fertilization. The process of fertilization is tightly controlled to ensure that only one sperm fuses with one egg. After fertilization, the zygote undergoes cleavage to form the blastula. The blastula, which in some species is a hollow ball of cells, undergoes a process called gastrulation, in which the three germ layers form. The ectoderm gives rise to the nervous system and the epidermal skin cells, the mesoderm gives rise to the muscle cells and connective tissue in the body, and the endoderm gives rise to columnar cells and internal organs.

43.7 Organogenesis and Vertebrate Formation

Organogenesis is the formation of organs from the germ layers. Each germ layer gives rise to specific tissue types. The first stage is the formation of the neural system in the ectoderm. The mesoderm gives rise to somites and the notochord. Formation of vertebrate axis is another important developmental stage.

ART CONNECTION QUESTIONS

1. **Figure 43.8** Which of the following statements about the male reproductive system is false?

a. The vas deferens carries sperm from the testes to the penis.
b. Sperm mature in seminiferous tubules in the testes.
c. Both the prostate and the bulbourethral glands produce components of the semen.
d. The prostate gland is located in the testes.

2. **Figure 43.15** Which of the following statements about hormone regulation of the female reproductive cycle is false?

a. LH and FSH are produced in the pituitary, and estradiol and progesterone are produced in the ovaries.
b. Estradiol and progesterone secreted from the corpus luteum cause the endometrium to thicken.
c. Both progesterone and estradiol are produced by the follicles.
d. Secretion of GnRH by the hypothalamus is inhibited by low levels of estradiol but stimulated by high levels of estradiol.

3. **Figure 43.17** Which of the following statements about the menstrual cycle is false?

a. Progesterone levels rise during the luteal phase of the ovarian cycle and the secretory phase of the uterine cycle.
b. Menstruation occurs just after LH and FSH levels peak.
c. Menstruation occurs after progesterone levels drop.
d. Estrogen levels rise before ovulation, while progesterone levels rise after.

REVIEW QUESTIONS

4. Which form of reproduction is thought to be best in a stable environment?

a. asexual
b. sexual
c. budding
d. parthenogenesis

5. Which form of reproduction can result from damage to the original animal?

a. asexual
b. fragmentation
c. budding
d. parthenogenesis

6. Which form of reproduction is useful to an animal with little mobility that reproduces sexually?
- a. fission
- b. budding
- c. parthenogenesis
- d. hermaphroditism

7. Genetically unique individuals are produced through _____.
- a. sexual reproduction
- b. parthenogenesis
- c. budding
- d. fragmentation

8. External fertilization occurs in which type of environment?
- a. aquatic
- b. forested
- c. savanna
- d. steppe

9. Which term applies to egg development within the female with nourishment derived from a yolk?
- a. oviparity
- b. viviparity
- c. ovoviparity
- d. ovovoparity

10. Which term applies to egg development outside the female with nourishment derived from a yolk?
- a. oviparity
- b. viviparity
- c. ovoviparity
- d. ovovoparity

11. Sperm are produced in the _____.
- a. scrotum
- b. seminal vesicles
- c. seminiferous tubules
- d. prostate gland

12. Most of the bulk of semen is made by the _____.
- a. scrotum
- b. seminal vesicles
- c. seminiferous tubules
- d. prostate gland

13. Which of the following cells in spermatogenesis is diploid?
- a. primary spermatocyte
- b. secondary spermatocyte
- c. spermatid
- d. sperm

14. Which female organ has the same embryonic origin as the penis?
- a. clitoris
- b. labia majora
- c. greater vestibular glands
- d. vagina

15. Which female organ has an endometrial lining that will support a developing baby?
- a. labia minora
- b. breast
- c. ovaries
- d. uterus

16. How many eggs are produced as a result of one meiotic series of cell divisions?
- a. one
- b. two
- c. three
- d. four

17. Which hormone causes Leydig cells to make testosterone?
- a. FSH
- b. LH
- c. inhibin
- d. estrogen

18. Which hormone causes FSH and LH to be released?
- a. testosterone
- b. estrogen
- c. GnRH
- d. progesterone

19. Which hormone signals ovulation?
- a. FSH
- b. LH
- c. inhibin
- d. estrogen

20. Which hormone causes the re-growth of the endometrial lining of the uterus?
- a. testosterone
- b. estrogen
- c. GnRH
- d. progesterone

21. Nutrient and waste requirements for the developing fetus are handled during the first few weeks by:
- a. the placenta
- b. diffusion through the endometrium
- c. the chorion
- d. the blastocyst

22. Progesterone is made during the third trimester by the:
- a. placenta
- b. endometrial lining
- c. chorion
- d. corpus luteum

23. Which contraceptive method is 100 percent effective at preventing pregnancy?
- a. condom
- b. oral hormonal methods
- c. sterilization
- d. abstinence

24. Which type of short term contraceptive method is generally more effective than others?
- a. barrier

b. hormonal
c. natural family planning
d. withdrawal

25. Which hormone is primarily responsible for the contractions during labor?
a. oxytocin
b. estrogen
c. β-HCG
d. progesterone

26. Major organs begin to develop during which part of human gestation?
a. fertilization
b. first trimester
c. second trimester
d. third trimester

27. Which of the following is false?
a. The endoderm, mesoderm, ectoderm are germ layers.
b. The trophoblast is a germ layer.
c. The inner cell mass is a source of embryonic stem cells.
d. The blastula is often a hollow ball of cells.

28. During cleavage, the mass of cells:
a. increases
b. decreases
c. doubles with every cell division
d. does not change significantly

29. Which of the following gives rise to the skin cells?
a. ectoderm
b. endoderm
c. mesoderm
d. none of the above

30. The ribs form from the _____.
a. notochord
b. neural plate
c. neural tube
d. somites

CRITICAL THINKING QUESTIONS

31. Why is sexual reproduction useful if only half the animals can produce offspring and two separate cells must be combined to form a third?

32. What determines which sex will result in offspring of birds and mammals?

33. What are the advantages and disadvantages of external and internal forms of fertilization?

34. Why would paired external fertilization be preferable to group spawning?

35. Describe the phases of the human sexual response.

36. Compare spermatogenesis and oogenesis as to timing of the processes and the number and type of cells finally produced.

37. If male reproductive pathways are not cyclical, how are they controlled?

38. Describe the events in the ovarian cycle leading up to ovulation.

39. Describe the major developments during each trimester of human gestation.

40. Describe the stages of labor.

41. What do you think would happen if multiple sperm fused with one egg?

42. Why do mammalian eggs have a small concentration of yolk, while bird and reptile eggs have a large concentration of yolk?

43. Explain how the different germ layers give rise to different tissue types.

44. Explain the role of axis formation in development.

CHAPTER SUMMARY

44.1 The Scope of Ecology

Ecology is the study of the interactions of living things with their environment. Ecologists ask questions across four levels of biological organization—organismal, population, community, and ecosystem. At the organismal level, ecologists study individual organisms and how they interact with their environments. At the population and community levels, ecologists explore, respectively, how a population of organisms changes over time and the ways in which that population interacts with other species in the community. Ecologists studying an ecosystem examine the living species (the biotic components) of the ecosystem as well as the nonliving portions (the abiotic components), such as air, water, and soil, of the environment.

44.2 Biogeography

Biogeography is the study of the geographic distribution of living things and the abiotic factors that affect their distribution. Endemic species are species that are naturally found only in a specific geographic area. The distribution of living things is influenced by several environmental factors that are, in part, controlled by the latitude or elevation at which an organism is found. Ocean upwelling and spring and fall turnovers are important processes regulating the distribution of nutrients and other abiotic factors important in aquatic ecosystems. Energy sources, temperature, water, inorganic nutrients, and soil are factors limiting the distribution of living things in terrestrial systems. Net primary productivity is a measure of the amount of biomass produced by a biome.

44.3 Terrestrial Biomes

The Earth has terrestrial biomes and aquatic biomes. Aquatic biomes include both freshwater and marine environments. There are eight major terrestrial biomes: tropical wet forests, savannas, subtropical deserts, chaparral, temperate grasslands, temperate forests, boreal forests, and Arctic tundra. The same biome can occur in different geographic locations with similar climates. Temperature and precipitation, and variations in both, are key abiotic factors that shape the composition of animal and

plant communities in terrestrial biomes. Some biomes, such as temperate grasslands and temperate forests, have distinct seasons, with cold weather and hot weather alternating throughout the year. In warm, moist biomes, such as the tropical wet forest, net primary productivity is high, as warm temperatures, abundant water, and a year-round growing season fuel plant growth. Other biomes, such as deserts and tundra, have low primary productivity due to extreme temperatures and a shortage of available water.

44.4 Aquatic Biomes

Aquatic ecosystems include both saltwater and freshwater biomes. The abiotic factors important for the structuring of aquatic ecosystems can be different than those seen in terrestrial systems. Sunlight is a driving force behind the structure of forests and also is an important factor in bodies of water, especially those that are very deep, because of the role of photosynthesis in sustaining certain organisms. Density and temperature shape the structure of aquatic systems. Oceans may be thought of as consisting of different zones based on water depth and distance from the shoreline and light penetrance. Different kinds of organisms are adapted to the conditions found in each zone. Coral reefs are unique marine ecosystems that are home to a wide variety of species. Estuaries are found where rivers meet the ocean; their shallow waters provide nourishment and shelter for young crustaceans, mollusks, fishes, and many other species. Freshwater biomes include lakes, ponds, rivers, streams, and wetlands. Bogs are an interesting type of wetland characterized by standing water, lower pH, and a lack of nitrogen.

44.5 Climate and the Effects of Global Climate Change

The Earth has gone through periodic cycles of increases and decreases in temperature. During the past 2000 years, the Medieval Climate Anomaly was a warmer period, while the Little Ice Age was unusually cool. Both of these irregularities can be explained by natural causes of changes in climate, and, although the temperature changes were small, they had significant effects. Natural drivers of climate change include Milankovitch cycles, changes in solar activity, and volcanic eruptions. None of these factors, however, leads to rapid increases in global temperature or sustained increases in carbon dioxide. The burning of fossil fuels is an important source of greenhouse gases, which plays a major role in the greenhouse effect. Long ago, global warming resulted in the Permian extinction: a large-scale extinction event that is documented in the fossil record. Currently, modern-day climate change is associated with the increased melting of glaciers and polar ice sheets, resulting in a gradual increase in sea level. Plants and animals can also be affected by global climate change when the timing of seasonal events, such as flowering or pollination, is affected by global warming.

ART CONNECTION QUESTIONS

1. **Figure 44.10** How might turnover in tropical lakes differ from turnover in lakes that exist in temperate regions?

2. **Figure 44.12** Which of the following statements about biomes is false?

a. Chaparral is dominated by shrubs.
b. Savannas and temperate grasslands are dominated by grasses.
c. Boreal forests are dominated by deciduous trees.
d. Lichens are common in the arctic tundra.

3. **Figure 44.21** In which of the following regions would you expect to find photosynthetic organisms?

a. the aphotic zone, the neritic zone, the oceanic zone, and the benthic realm
b. the photic zone, the intertidal zone, the neritic zone, and the oceanic zone
c. the photic zone, the abyssal zone, the neritic zone, and the oceanic zone
d. the pelagic realm, the aphotic zone, the neritic zone, and the oceanic zone

REVIEW QUESTIONS

4. Which of the following is a biotic factor?

a. wind
b. disease-causing microbe
c. temperature
d. soil particle size

5. The study of nutrient cycling though the environment is an example of which of the following?

a. organismal ecology
b. population ecology
c. community ecology
d. ecosystem ecology

6. Understory plants in a temperate forest have adaptations to capture limited _____.

a. water
b. nutrients
c. heat
d. sunlight

7. An ecologist hiking up a mountain may notice different biomes along the way due to changes in all of the following except:

a. elevation
b. rainfall
c. latitude
d. temperature

8. Which of the following biomes is characterized by abundant water resources?

a. deserts
b. boreal forests
c. savannas
d. tropical wet forests

9. Which of the following biomes is characterized by short growing seasons?

a. deserts
b. tropical wet forests
c. Arctic tundras
d. savannas

10. Where would you expect to find the most photosynthesis in an ocean biome?

a. aphotic zone
b. abyssal zone
c. benthic realm
d. intertidal zone

11. A key feature of estuaries is:

a. low light conditions and high productivity
b. salt water and fresh water
c. frequent algal blooms
d. little or no vegetation

12. Which of the following is an example of a weather event?

a. The hurricane season lasts from June 1 through November 30.
b. The amount of atmospheric CO_2 has steadily increased during the last century.
c. A windstorm blew down trees in the Boundary Waters Canoe Area in Minnesota on July 4, 1999.
d. Deserts are generally dry ecosystems having very little rainfall.

13. Which of the following natural forces is responsible for the release of carbon dioxide and other atmospheric gases?

a. the Milankovitch cycles
b. volcanoes
c. solar intensity
d. burning of fossil fuels

CRITICAL THINKING QUESTIONS

14. Ecologists often collaborate with other researchers interested in ecological questions. Describe the levels of ecology that would be easier for collaboration because of the similarities of questions asked. What levels of ecology might be more difficult for collaboration?

15. The population is an important unit in ecology as well as other biological sciences. How is a population defined, and what are the strengths and weaknesses of this definition? Are there some species that at certain times or places are not in populations?

16. Compare and contrast ocean upwelling and spring and fall turnovers.

17. Many endemic species are found in areas that are geographically isolated. Suggest a plausible scientific explanation for why this is so.

18. The extremely low precipitation of subtropical desert biomes might lead one to expect fire to be a major disturbance factor; however, fire is more common in the temperate grassland biome than in the subtropic desert biome. Why is this?

19. In what ways are the subtropical desert and the arctic tundra similar?

20. Scientists have discovered the bodies of humans and other living things buried in bogs for hundreds of years, but not yet decomposed. Suggest a possible biological explanation for why such bodies are so well-preserved.

21. Describe the conditions and challenges facing organisms living in the intertidal zone.

22. Compare and contrast how natural- and human-induced processes have influenced global climate change.

23. Predict possible consequences if carbon emissions from fossil fuels continue to rise.

CHAPTER SUMMARY

45.1 Population Demography

Populations are individuals of a species that live in a particular habitat. Ecologists measure characteristics of populations: size, density, dispersion pattern, age structure, and sex ratio. Life tables are useful to calculate life expectancies of individual population members. Survivorship curves show the number of individuals surviving at each age interval plotted versus time.

45.2 Life Histories and Natural Selection

All species have evolved a pattern of living, called a life history strategy, in which they partition energy for growth, maintenance, and reproduction. These patterns evolve through natural selection; they allow species to adapt to their environment to obtain the resources they need to successfully reproduce. There is an inverse relationship between fecundity and parental care. A species may reproduce early in life to ensure surviving to a reproductive age or reproduce later in life to become larger and healthier and better able to give parental care. A species may reproduce once (semelparity) or many times (iteroparity) in its life.

45.3 Environmental Limits to Population Growth

Populations with unlimited resources grow exponentially, with an accelerating growth rate. When resources become limiting, populations follow a logistic growth curve. The population of a species will level off at the carrying capacity of its environment.

45.4 Population Dynamics and Regulation

Populations are regulated by a variety of density-dependent and density-independent factors. Species are divided into two categories based on a variety of features of their life history patterns: *r*-selected species, which have large numbers of offspring, and *K*-selected species, which have few offspring. The *r*- and *K*-selection theory has fallen out of use; however, many of its key features are still used in newer, demographically-based models of population dynamics.

45.5 Human Population Growth

The world's human population is growing at an exponential rate. Humans have increased the world's carrying capacity through migration, agriculture, medical advances, and communication. The age structure of a population allows us to predict population growth. Unchecked human population growth could have dire long-term effects on our environment.

45.6 Community Ecology

Communities include all the different species living in a given area. The variety of these species is called species richness. Many organisms have developed defenses against predation and herbivory, including mechanical defenses, warning coloration, and mimicry, as a result of evolution and the interaction with other members of the community. Two species cannot exist in the same habitat competing directly for the same resources. Species may form symbiotic relationships such as commensalism or mutualism. Community structure is described by its foundation and keystone species. Communities respond to environmental disturbances by succession (the predictable appearance of different types of plant species) until a stable community structure is established.

45.7 Behavioral Biology: Proximate and Ultimate Causes of Behavior

Behaviors are responses to stimuli. They can either be instinctual/innate behaviors, which are not influenced by the environment, or learned behaviors, which are influenced by environmental changes. Instinctual behaviors include mating systems and methods of communication. Learned behaviors include imprinting and habituation, conditioning, and, most powerfully, cognitive learning. Although the connection between behavior, genetics, and evolution is well established, the explanation of human behavior as entirely genetic is controversial.

ART CONNECTION QUESTIONS

1. **Figure 45.2** As this graph shows, population density typically decreases with increasing body size. Why do you think this is the case?

2. **Figure 45.10b** If the major food source of the seals declines due to pollution or overfishing, which of the following would likely occur?

a. The carrying capacity of seals would decrease, as would the seal population.
b. The carrying capacity of seals would decrease, but the seal population would remain the same.
c. The number of seal deaths would increase but the number of births would also increase, so the population size would remain the same.
d. The carrying capacity of seals would remain the same, but the population of seals would decrease.

3. **Figure 45.16** Age structure diagrams for rapidly growing, slow growing and stable populations are shown in stages 1 through 3. What type of population change do you think stage 4 represents?

REVIEW QUESTIONS

4. Which of the following methods will tell an ecologist about both the size and density of a population?
a. mark and recapture
b. mark and release
c. quadrat
d. life table

5. Which of the following is best at showing the life expectancy of an individual within a population?
a. quadrat
b. mark and recapture
c. survivorship curve
d. life table

6. Humans have which type of survivorship curve?
a. Type I
b. Type II
c. Type III
d. Type IV

7. Which of the following is associated with long-term parental care?
a. few offspring
b. many offspring
c. semelparity
d. fecundity

8. Which of the following is associated with multiple reproductive episodes during a species' lifetime?
a. semiparity
b. iteroparity
c. semelparity
d. fecundity

9. Which of the following is associated with the reproductive potential of a species?
a. few offspring
b. many offspring
c. semelparity
d. fecundity

10. Species with limited resources usually exhibit a(n) _____ growth curve.
a. logistic
b. logical
c. experimental
d. exponential

11. The maximum rate of increased characteristic of a species is called its _____.
a. limit
b. carrying capacity
c. biotic potential
d. exponential growth pattern

12. The population size of a species capable of being supported by the environment is called its _____.
a. limit
b. carrying capacity
c. biotic potential
d. logistic growth pattern

13. Species that have many offspring at one time are usually:
a. *r*-selected
b. *K*-selected
c. both *r*- and *K*-selected
d. not selected

14. A forest fire is an example of _____ regulation.
a. density-dependent
b. density-independent
c. *r*-selected
d. *K*-selected

15. Primates are examples of:
a. density-dependent species
b. density-independent species
c. *r*-selected species
d. *K*-selected species

16. A country with zero population growth is likely to be _____.
a. in Africa
b. in Asia
c. economically developed
d. economically underdeveloped

17. Which type of country has the greatest proportion of young individuals?
a. economically developed

b. economically underdeveloped
c. countries with zero population growth
d. countries in Europe

18. Which of the following is not a way that humans have increased the carrying capacity of the environment?
a. agriculture
b. using large amounts of natural resources
c. domestication of animals
d. use of language

19. The first species to live on new land, such as that formed from volcanic lava, are called _____.
a. climax community
b. keystone species
c. foundation species
d. pioneer species

20. Which type of mimicry involves multiple species with similar warning coloration that are all toxic to predators?
a. Batesian mimicry
b. Müllerian mimicry
c. Emsleyan/Mertensian mimicry
d. Mertensian mimicry

21. A symbiotic relationship where both of the coexisting species benefit from the interaction is called _____.
a. commensalism
b. parasitism
c. mutualism
d. communism

22. The ability of rats to learn how to run a maze is an example of _____.
a. imprinting
b. classical conditioning
c. operant conditioning
d. cognitive learning

23. The training of animals usually involves _____.
a. imprinting
b. classical conditioning
c. operant conditioning
d. cognitive learning

24. The sacrifice of the life of an individual so that the genes of relatives may be passed on is called _____.
a. operant learning
b. kin selection
c. kinesis
d. imprinting

CRITICAL THINKING QUESTIONS

25. Describe how a researcher would determine the size of a penguin population in Antarctica using the mark and release method.

26. Why is long-term parental care not associated with having many offspring during a reproductive episode?

27. Describe the rate of population growth that would be expected at various parts of the S-shaped curve of logistic growth.

28. Give an example of how density-dependent and density-independent factors might interact.

29. Describe the age structures in rapidly growing countries, slowly growing countries, and countries with zero population growth.

30. Describe the competitive exclusion principle and its effects on competing species.

31. Describe Pavlov's dog experiments as an example of classical conditioning.

CHAPTER SUMMARY

46.1 Ecology of Ecosystems

Ecosystems exist on land, at sea, in the air, and underground. Different ways of modeling ecosystems are necessary to understand how environmental disturbances will affect ecosystem structure and dynamics. Conceptual models are useful to show the general relationships between organisms and the flow of materials or energy between them. Analytical models are used to describe linear food chains, and simulation models work best with holistic food webs.

46.2 Energy Flow through Ecosystems

Organisms in an ecosystem acquire energy in a variety of ways, which is transferred between trophic levels as the energy flows from the bottom to the top of the food web, with energy being lost at each

transfer. The efficiency of these transfers is important for understanding the different behaviors and eating habits of warm-blooded versus cold-blooded animals. Modeling of ecosystem energy is best done with ecological pyramids of energy, although other ecological pyramids provide other vital information about ecosystem structure.

46.3 Biogeochemical Cycles

Mineral nutrients are cycled through ecosystems and their environment. Of particular importance are water, carbon, nitrogen, phosphorus, and sulfur. All of these cycles have major impacts on ecosystem structure and function. As human activities have caused major disturbances to these cycles, their study and modeling is especially important. A variety of human activities, such as pollution, oil spills, and events) have damaged ecosystems, potentially causing global climate change. The health of Earth depends on understanding these cycles and how to protect the environment from irreversible damage.

ART CONNECTION QUESTIONS

1. **Figure 46.8** Why do you think the value for gross productivity of the primary producers is the same as the value for total heat and respiration (20,810 kcal/m^2/yr)?

2. **Figure 46.10** Pyramids depicting the number of organisms or biomass may be inverted, upright, or even diamond-shaped. Energy pyramids, however, are always upright. Why?

3. **Figure 46.17** Which of the following statements about the nitrogen cycle is false?

a. Ammonification converts organic nitrogenous matter from living organisms into ammonium (NH_4^+).
b. Denitrification by bacteria converts nitrates (NO_3^-) to nitrogen gas (N_2).
c. Nitrification by bacteria converts nitrates (NO_3^-) to nitrites (NO_2^-).
d. Nitrogen fixing bacteria convert nitrogen gas (N_2) into organic compounds.

REVIEW QUESTIONS

4. The ability of an ecosystem to return to its equilibrium state after an environmental disturbance is called _____.

a. resistance
b. restoration
c. reformation
d. resilience

5. A re-created ecosystem in a laboratory environment is known as a _____.

a. mesocosm
b. simulation
c. microcosm
d. reproduction

6. Decomposers are associated with which class of food web?

a. grazing
b. detrital
c. inverted
d. aquatic

7. The primary producers in an ocean grazing food web are usually _____.

a. plants
b. animals
c. fungi
d. phytoplankton

8. What term describes the use of mathematical equations in the modeling of linear aspects of ecosystems?

a. analytical modeling
b. simulation modeling
c. conceptual modeling
d. individual-based modeling

9. The position of an organism along a food chain is known as its _____.

a. locus
b. location
c. trophic level
d. microcosm

10. The weight of living organisms in an ecosystem at a particular point in time is called:

a. energy
b. production
c. entropy
d. biomass

11. Which term describes the process whereby toxic substances increase along trophic levels of an ecosystem?

a. biomassification
b. biomagnification
c. bioentropy
d. heterotrophy

12. Organisms that can make their own food using inorganic molecules are called:

a. autotrophs
b. heterotrophs
c. photoautotrophs
d. chemoautotrophs

13. In the English Channel ecosystem, the number of primary producers is smaller than the number of primary consumers because_____.

a. the apex consumers have a low turnover rate
b. the primary producers have a low turnover rate
c. the primary producers have a high turnover rate
d. the primary consumers have a high turnover rate

14. What law of chemistry determines how much energy can be transferred when it is converted from one form to another?

a. the first law of thermodynamics
b. the second law of thermodynamics
c. the conservation of matter
d. the conservation of energy

15. The movement of mineral nutrients through organisms and their environment is called a _____ cycle.

a. biological
b. bioaccumulation
c. biogeochemical
d. biochemical

16. Carbon is present in the atmosphere as _____.

a. carbon dioxide
b. carbonate ion
c. carbon dust
d. carbon monoxide

17. The majority of water found on Earth is:

a. ice
b. water vapor
c. fresh water
d. salt water

18. The average time a molecule spends in its reservoir is known as _____.

a. residence time
b. restriction time
c. resilience time
d. storage time

19. The process whereby oxygen is depleted by the growth of microorganisms due to excess nutrients in aquatic systems is called _____.

a. dead zoning
b. eutrophication
c. retrofication
d. depletion

20. The process whereby nitrogen is brought into organic molecules is called _____.

a. nitrification
b. denitrification
c. nitrogen fixation
d. nitrogen cycling

CRITICAL THINKING QUESTIONS

21. Compare and contrast food chains and food webs. What are the strengths of each concept in describing ecosystems?

22. Describe freshwater, ocean, and terrestrial ecosystems.

23. Compare grazing and detrital food webs. Why would they both be present in the same ecosystem?

24. Compare the three types of ecological pyramids and how well they describe ecosystem structure. Identify which ones can be inverted and give an example of an inverted pyramid for each.

25. How does the amount of food a warm blooded-animal (endotherm) eats relate to its net production efficiency (NPE)?

26. Describe nitrogen fixation and why it is important to agriculture.

27. What are the factors that cause dead zones? Describe eutrophication, in particular, as a cause.

28. Why are drinking water supplies still a major concern for many countries?

CHAPTER SUMMARY

47.1 The Biodiversity Crisis

Biodiversity exists at multiple levels of organization and is measured in different ways depending on the goals of those taking the measurements. These measurements include numbers of species, genetic diversity, chemical diversity, and ecosystem diversity. The number of described species is estimated to be 1.5 million with about 17,000 new species being described each year. Estimates for the total number

of species on Earth vary but are on the order of 10 million. Biodiversity is negatively correlated with latitude for most taxa, meaning that biodiversity is higher in the tropics. The mechanism for this pattern is not known with certainty, but several plausible hypotheses have been advanced.

Five mass extinctions with losses of more than 50 percent of extant species are observable in the fossil record. Biodiversity recovery times after mass extinctions vary, but have been up to 30 million years. Recent extinctions are recorded in written history and are the basis for one method of estimating contemporary extinction rates. The other method uses measures of habitat loss and species-area relationships. Estimates of contemporary extinction rates vary, but some rates are as high as 500 times the background rate, as determined from the fossil record, and are predicted to rise.

47.2 The Importance of Biodiversity to Human Life

Humans use many compounds that were first discovered or derived from living organisms as medicines: secondary plant compounds, animal toxins, and antibiotics produced by bacteria and fungi. More medicines are expected to be discovered in nature. Loss of biodiversity will impact the number of pharmaceuticals available to humans.

Crop diversity is a requirement for food security, and it is being lost. The loss of wild relatives to crops also threatens breeders' abilities to create new varieties. Ecosystems provide ecosystem services that support human agriculture: pollination, nutrient cycling, pest control, and soil development and maintenance. Loss of biodiversity threatens these ecosystem services and risks making food production more expensive or impossible. Wild food sources are mainly aquatic, but few are being managed for sustainability. Fisheries' ability to provide protein to human populations is threatened when extinction occurs.

Biodiversity may provide important psychological benefits to humans. Additionally, there are moral arguments for the maintenance of biodiversity.

47.3 Threats to Biodiversity

The core threats to biodiversity are human population growth and unsustainable resource use. To date, the most significant causes of extinctions are habitat loss, introduction of exotic species, and overharvesting. Climate change is predicted to be a significant cause of extinctions in the coming century. Habitat loss occurs through deforestation, damming of rivers, and other activities. Overharvesting is a threat particularly to aquatic species, while the taking of bush meat in the humid tropics threatens many species in Asia, Africa, and the Americas. Exotic species have been the cause of a number of extinctions and are especially damaging to islands and lakes. Exotic species' introductions are increasing because of the increased mobility of human populations and growing global trade and transportation. Climate change is forcing range changes that may lead to extinction. It is also affecting adaptations to the timing of resource availability that negatively affects species in seasonal environments. The impacts of climate change are greatest in the arctic. Global warming will also raise sea levels, eliminating some islands and reducing the area of all others.

47.4 Preserving Biodiversity

New technological methods such as DNA barcoding and information processing and accessibility are facilitating the cataloging of the planet's biodiversity. There is also a legislative framework for biodiversity protection. International treaties such as CITES regulate the transportation of endangered species across international borders. Legislation within individual countries protecting species and agreements on global warming have had limited success; there is at present no international agreement on targets for greenhouse gas emissions. In the United States, the Endangered Species Act protects listed species but is hampered by procedural difficulties and a focus on individual species. The Migratory Bird Act is an agreement between Canada and the United States to protect migratory birds. The non-profit sector is also very active in conservation efforts in a variety of ways.

Conservation preserves are a major tool in biodiversity protection. Presently, 11percent of Earth's land surface is protected in some way. The science of island biogeography has informed the optimal design of preserves; however, preserves have limitations imposed by political and economic forces. In addition, climate change will limit the effectiveness of preserves in the future. A downside of preserves is that they may lessen the pressure on human societies to function more sustainably outside the preserves.

Habitat restoration has the potential to restore ecosystems to previous biodiversity levels before species become extinct. Examples of restoration include reintroduction of keystone species and removal of

dams on rivers. Zoos have attempted to take a more active role in conservation and can have a limited role in captive breeding programs. Zoos also may have a useful role in education.

ART CONNECTION QUESTIONS

1. **Figure 47.6** Scientists measured the relative abundance of fern spores above and below the K-Pg boundary in this rock sample. Which of the following statements most likely represents their findings?

a. An abundance of fern spores from several species was found below the K-Pg boundary, but none was found above.
b. An abundance of fern spores from several species was found above the K-Pg boundary, but none was found below.
c. An abundance of fern spores was found both above and below the K-Pg boundary, but only one species was found below the boundary , and many species were found above the boundary.
d. Many species of fern spores were found both above and below the boundary, but the total number of spores was greater below the boundary.

2. **Figure 47.9** The Svalbard Global Seed Vault is located on Spitsbergen island in Norway, which has an arctic climate. Why might an arctic climate be good for seed storage?

3. Converting a prairie to a farm field is an example of _____.

a. overharvesting
b. habitat loss
c. exotic species
d. climate change

4. **Figure 47.16** Which of the following statements is not supported by this graph?

a. There are more vulnerable fishes than critically endangered and endangered fishes combined.
b. There are more critically endangered amphibians than vulnerable, endangered and critically endangered reptiles combined.
c. Within each group, there are more critically endangered species than vulnerable species.
d. A greater percentage of bird species are critically endangered than mollusk species.

REVIEW QUESTIONS

5. With an extinction rate of 100 E/MSY and an estimated 10 million species, how many extinctions are expected to occur in a century?

a. 100
b. 10, 000
c. 100, 000
d. 1, 000, 000

6. An adaptive radiation is_____.

a. a burst of speciation
b. a healthy level of UV radiation
c. a hypothesized cause of a mass extinction
d. evidence of an asteroid impact

7. The number of currently described species on the planet is about _____.

a. 17,000
b. 150,000
c. 1.5 million
d. 10 million

8. A mass extinction is defined as _____.

a. a loss of 95 percent of species
b. an asteroid impact
c. a boundary between geological periods
d. a loss of 50 percent of species

9. A secondary plant compound might be used for which of the following?

a. a new crop variety
b. a new drug
c. a soil nutrient
d. a pest of a crop pest

10. Pollination is an example of _____.

a. a possible source of new drugs
b. chemical diversity
c. an ecosystem service
d. crop pest control

11. What is an ecosystem service that performs the same function as a pesticide?

a. pollination
b. secondary plant compounds
c. crop diversity
d. predators of pests

12. Which two extinction risks may be a direct result of the pet trade?

a. climate change and exotic species introduction
b. habitat loss and overharvesting
c. overharvesting and exotic species introduction
d. habitat loss and climate change

13. Exotic species are especially threatening to what kind of ecosystem?

a. deserts
b. marine ecosystems

c. islands
d. tropical forests

14. Certain parrot species cannot be brought to the United States to be sold as pets. What is the name of the legislation that makes this illegal?

a. Red List
b. Migratory Bird Act
c. CITES
d. Endangered Species Act (ESA)

15. What was the name of the first international agreement on climate change?

a. Red List
b. Montreal Protocol
c. International Union for the Conservation of Nature (IUCN)
d. Kyoto Protocol

16. About what percentage of land on the planet is set aside as a preserve of some type?

a. 1 percent
b. 6 percent
c. 11 percent
d. 15 percent

CRITICAL THINKING QUESTIONS

17. Describe the evidence for the cause of the Cretaceous–Paleogene (K–Pg) mass extinction.

18. Describe the two methods used to calculate contemporary extinction rates.

19. Explain how biodiversity loss can impact crop diversity.

20. Describe two types of compounds from living things that are used as medications.

21. Describe the mechanisms by which human population growth and resource use causes increased extinction rates.

22. Explain what extinction threats a frog living on a mountainside in Costa Rica might face.

23. Describe two considerations in conservation preserve design.

24. Describe what happens to an ecosystem when a keystone species is removed.

ANSWER KEY

Chapter 1

1 Figure 1.6 1: C; 2: F; 3: A; 4: B; 5: D; 6: E. The original hypothesis is incorrect, as the coffeemaker works when plugged into the outlet. Alternative hypotheses include that the coffee maker might be broken or that the coffee maker wasn't turned on. **2** Figure 1.7 1: inductive; 2: deductive; 3: deductive; 4: inductive. **3** Figure 1.16 Communities exist within populations which exist within ecosystems. **4** B **5** A **6** D **7** D **8** C **9** A **10** C **11** A **12** B **13** C **14** D **15** D **16** Answers will vary, but should apply the steps of the scientific method. One possibility could be a car which doesn't start. The hypothesis could be that the car doesn't start because the battery is dead. The experiment would be to change the battery or to charge the battery and then check whether the car starts or not. If it starts, the problem was due to the battery, and the hypothesis is accepted. **17** Answers will vary. One example of how applied science has had a direct effect on daily life is the presence of vaccines. Vaccines to prevent diseases such polio, measles, tetanus, and even influenza affect daily life by contributing to individual and societal health. **18** Answers will vary. Topics that fall inside the area of biological study include how diseases affect human bodies, how pollution impacts a species' habitat, and how plants respond to their environments. Topics that fall outside of biology (the "study of life") include how metamorphic rock is formed and how planetary orbits function. **19** Answers will vary. Basic science: What evolutionary purpose might cancer serve? Applied science: What strategies might be found to prevent cancer from reproducing at the cellular level? **20** Answers will vary. Layers of sedimentary rock have order but are not alive. Technology is capable of regulation but is not, of itself, alive. **21** Smallest level of organization to largest: hydrogen atom, water molecule, skin cell, liver, elephant, wolf pack, tropical rainforest, planet Earth **22** During your walk, you may begin to perspire, which cools your body and helps your body to maintain a constant internal temperature. You might also become thirsty and pause long enough for a cool drink, which will help to restore the water lost during perspiration. **23** Researchers can approach biology from the smallest to the largest, and everything in between. For instance, an ecologist may study a population of individuals, the population's community, the community's ecosystem, and the ecosystem's part in the biosphere. When studying an individual organism, a biologist could examine the cell and its organelles, the tissues that the cells make up, the organs and their respective organ systems, and the sum total—the organism itself.

Chapter 2

1 Figure 2.3 Carbon-12 has six neutrons. Carbon-13 has seven neutrons. **2** Figure 2.7 Elements in group 1 need to lose one electron to achieve a stable electron configuration. Elements in groups 14 and 17 need to gain four and one electrons, respectively, to achieve a stable configuration. **3** Figure 2.24 C **4** A **5** D **6** C **7** A **8** D **9** A **10** C **11** B **12** D **13** A **14** Ionic bonds are created between ions. The electrons are not shared between the atoms, but rather are associated more with one ion than the other. Ionic bonds are strong bonds, but are weaker than covalent bonds, meaning it takes less energy to break an ionic bond compared with a covalent one. **15** Hydrogen bonds and van der Waals interactions form weak associations between different molecules or within different regions of the same molecule. They provide the structure and shape necessary for proteins and DNA within cells so that they function properly. **16** Buffers absorb the free hydrogen ions and hydroxide ions that result from chemical reactions. Because they can bond these ions, they prevent increases or decreases in pH. An example of a buffer system is the bicarbonate system in the human body. This system is able to absorb hydrogen and hydroxide ions to prevent changes in pH and keep cells functioning properly. **17** Some insects can walk on water, although they are heavier (denser) than water, because of the surface tension of water. Surface tension results from cohesion, or the attraction between water molecules at the surface of the body of water (the liquid-air/gas interface). **18** Carbon is unique and found in all living things because it can form up to four covalent bonds between atoms or molecules. These can be nonpolar or polar covalent bonds, and they allow for the formation of long chains of carbon molecules that combine to form proteins and DNA. **19** Saturated triglycerides contain no double bonds between carbon atoms; they are usually solid at room temperature. Unsaturated triglycerides contain at least one double bond between carbon atoms and are usually liquid at room temperature.

Chapter 3

1 Figure 3.5 Glucose and galactose are aldoses. Fructose is a ketose. **2** Figure 3.23 Polar and charged amino acid residues (the remainder after peptide bond formation) are more likely to be found on the surface of soluble proteins where they can interact with water, and nonpolar (e.g., amino acid side chains) are more likely to be found in the interior where they are sequestered from water. In membrane proteins, nonpolar and hydrophobic amino acid side chains associate with the hydrophobic tails of phospholipids, while polar and charged amino acid side chains interact with the polar head groups or with the aqueous solution. However,

there are exceptions. Sometimes, positively and negatively charged amino acid side chains interact with one another in the interior of a protein, and polar or charged amino acid side chains that interact with a ligand can be found in the ligand binding pocket. **3** **Figure 3.33** Adenine is larger than cytosine and will not be able to base pair properly with the guanine on the opposing strand. This will cause the DNA to bulge. DNA repair enzymes may recognize the bulge and replace the incorrect nucleotide. **4** B **5** A **6** D **7** D **8** B **9** B **10** D **11** A **12** C **13** B **14** C **15** D **16** Biological macromolecules are organic because they contain carbon. **17** In a dehydration synthesis reaction, the hydrogen of one monomer combines with the hydroxyl group of another monomer, releasing a molecule of water. This creates an opening in the outer shells of atoms in the monomers, which can share electrons and form covalent bonds. **18** Glycogen and starch are polysaccharides. They are the storage form of glucose. Glycogen is stored in animals in the liver and in muscle cells, whereas starch is stored in the roots, seeds, and leaves of plants. Starch has two different forms, one unbranched (amylose) and one branched (amylopectin), whereas glycogen is a single type of a highly branched molecule. **19** The β 1-4 glycosidic linkage in cellulose cannot be broken down by human digestive enzymes. Herbivores such as cows, buffalos, and horses are able to digest grass that is rich in cellulose and use it as a food source because bacteria and protists in their digestive systems, especially in the rumen, secrete the enzyme cellulase. Cellulases can break down cellulose into glucose monomers that can be used as an energy source by the animal. **20** Fat serves as a valuable way for animals to store energy. It can also provide insulation. Waxes can protect plant leaves and mammalian fur from getting wet. Phospholipids and steroids are important components of animal cell membranes, as well as plant, fungal, and bacterial membranes. **21** Trans fats are created artificially when hydrogen gas is bubbled through oils to solidify them. The double bonds of the *cis* conformation in the hydrocarbon chain may be converted to double bonds in the *trans* configuration. Some restaurants are banning trans fats because they cause higher levels of LDL, or "bad"cholesterol. **22** A change in gene sequence can lead to a different amino acid being added to a polypeptide chain instead of the normal one. This causes a change in protein structure and function. For example, in sickle cell anemia, the hemoglobin β chain has a single amino acid substitution—the amino acid glutamic acid in position six is substituted by valine. Because of this change, hemoglobin molecules form aggregates, and the disc-shaped red blood cells assume a crescent shape, which results in serious health problems. **23** The sequence and number of amino acids in a polypeptide chain is its primary structure. The local folding of the polypeptide in some regions is the secondary structure of the protein. The three-dimensional structure of a polypeptide is known as its tertiary structure, created in part by chemical interactions such as hydrogen bonds between polar side chains, van der Waals interactions, disulfide linkages, and hydrophobic interactions. Some proteins are formed from multiple polypeptides, also known as subunits, and the interaction of these subunits forms the quaternary structure. **24** DNA has a double-helix structure. The sugar and the phosphate are on the outside of the helix and the nitrogenous bases are in the interior. The monomers of DNA are nucleotides containing deoxyribose, one of the four nitrogenous bases (A, T, G and C), and a phosphate group. RNA is usually single-stranded and is made of ribonucleotides that are linked by phosphodiester linkages. A ribonucleotide contains ribose (the pentose sugar), one of the four nitrogenous bases (A,U, G, and C), and the phosphate group. **25** The four types of RNA are messenger RNA, ribosomal RNA, transfer RNA, and microRNA. Messenger RNA carries the information from the DNA that controls all cellular activities. The mRNA binds to the ribosomes that are constructed of proteins and rRNA, and tRNA transfers the correct amino acid to the site of protein synthesis. microRNA regulates the availability of mRNA for translation.

Chapter 4

1 **Figure 4.7** Substances can diffuse more quickly through small cells. Small cells have no need for organelles and therefore do not need to expend energy getting substances across organelle membranes. Large cells have organelles that can separate cellular processes, enabling them to build molecules that are more complex. **2** **Figure 4.8** Free ribosomes and rough endoplasmic reticulum (which contains ribosomes) would not be able to form. **3** **Figure 4.18** It would end up on the outside. After the vesicle passes through the Golgi apparatus and fuses with the plasma membrane, it turns inside out. **4** C **5** B **6** D **7** A **8** D **9** B **10** A **11** D **12** A **13** B **14** C **15** C **16** B **17** D **18** C **19** C **20** A light microscope would be ideal when viewing a small living organism, especially when the cell has been stained to reveal details. **21** A scanning electron microscope would be ideal when you want to view the minute details of a cell's surface, because its beam of electrons moves back and forth over the surface to convey the image. **22** A transmission electron microscope would be ideal for viewing the cell's internal structures, because many of the internal structures have membranes that are not visible by the light microscope. **23** The advantages of light microscopes are that they are easily obtained, and the light beam does not kill the cells. However, typical light microscopes are somewhat limited in the amount of detail they can reveal. Electron microscopes are ideal because you can view intricate details, but they are bulky and costly, and preparation for the microscopic examination kills the specimen. **24** The cell wall would be targeted by antibiotics as well as the bacteria's ability to replicate. This would inhibit the bacteria's ability to reproduce, and it would compromise its defense mechanisms. **25** Some microbes are beneficial. For instance, *E. coli* bacteria populate the human gut and help break down fiber in the diet. Some foods such as yogurt are formed by bacteria. **26** Ribosomes are abundant in muscle cells as well because muscle cells are constructed of the proteins made by the ribosomes. **27** Both are similar in that they are enveloped in a double membrane, both have an intermembrane space, and both make ATP. Both mitochondria and chloroplasts have DNA, and mitochondria have inner folds called cristae and a matrix,

while chloroplasts have chlorophyll and accessory pigments in the thylakoids that form stacks (grana) and a stroma. **28** "Form follows function" refers to the idea that the function of a body part dictates the form of that body part. As an example, compare your arm to a bat's wing. While the bones of the two correspond, the parts serve different functions in each organism and their forms have adapted to follow that function. **29** Since the external surface of the nuclear membrane is continuous with the rough endoplasmic reticulum, which is part of the endomembrane system, then it is correct to say that it is part of the system. **30** Centrioles and flagella are alike in that they are made up of microtubules. In centrioles, two rings of nine microtubule "triplets" are arranged at right angles to one another. This arrangement does not occur in flagella. **31** Cilia and flagella are alike in that they are made up of microtubules. Cilia are short, hair-like structures that exist in large numbers and usually cover the entire surface of the plasma membrane. Flagella, in contrast, are long, hair-like structures; when flagella are present, a cell has just one or two. **32** They differ because plant cell walls are rigid. Plasmodesmata, which a plant cell needs for transportation and communication, are able to allow movement of really large molecules. Gap junctions are necessary in animal cells for transportation and communication. **33** The extracellular matrix functions in support and attachment for animal tissues. It also functions in the healing and growth of the tissue.

Chapter 5

1 **Figure 5.12** No, it must have been hypotonic as a hypotonic solution would cause water to enter the cells, thereby making them burst. **2** **Figure 5.16** Cells typically have a high concentration of potassium in the cytoplasm and are bathed in a high concentration of sodium. Injection of potassium dissipates this electrochemical gradient. In heart muscle, the sodium/potassium potential is responsible for transmitting the signal that causes the muscle to contract. When this potential is dissipated, the signal can't be transmitted, and the heart stops beating. Potassium injections are also used to stop the heart from beating during surgery. **3** **Figure 5.19** A decrease in pH means an increase in positively charged H^+ ions, and an increase in the electrical gradient across the membrane. The transport of amino acids into the cell will increase. **4** A **5** D **6** A **7** C **8** C **9** A **10** D **11** C **12** D **13** C **14** B **15** C **16** The fluid characteristic of the cell membrane allows greater flexibility to the cell than it would if the membrane were rigid. It also allows the motion of membrane components, required for some types of membrane transport. **17** The hydrophobic, nonpolar regions must align with each other in order for the structure to have minimal potential energy and, consequently, higher stability. The fatty acid tails of the phospholipids cannot mix with water, but the phosphate "head" of the molecule can. Thus, the head orients to water, and the tail to other lipids. **18** Heavy molecules move more slowly than lighter ones. It takes more energy in the medium to move them along. Increasing or decreasing temperature increases or decreases the energy in the medium, affecting molecular movement. The denser a solution is, the harder it is for molecules to move through it, causing diffusion to slow down due to friction. Living cells require a steady supply of nutrients and a steady rate of waste removal. If the distance these substances need to travel is too great, diffusion cannot move nutrients and waste materials efficiently to sustain life. **19** Water moves through a membrane in osmosis because there is a concentration gradient across the membrane of solute and solvent. The solute cannot effectively move to balance the concentration on both sides of the membrane, so water moves to achieve this balance. **20** Injection of isotonic solutions ensures that there will be no perturbation of the osmotic balance, and no water taken from tissues or added to them from the blood. **21** The cell harvests energy from ATP produced by its own metabolism to power active transport processes, such as the activity of pumps. **22** The sodium-potassium pump forces out three (positive) Na^+ ions for every two (positive) K^+ ions it pumps in, thus the cell loses a positive charge at every cycle of the pump. **23** The proteins allow a cell to select what compound will be transported, meeting the needs of the cell and not bringing in anything else. **24** Ions are charged, and consequently, they are hydrophilic and cannot associate with the lipid portion of the membrane. Ions must be transported by carrier proteins or ion channels.

Chapter 6

1 **Figure 6.8** A compost pile decomposing is an exergonic process; enthalpy increases (energy is released) and entropy increases (large molecules are broken down into smaller ones). A baby developing from a fertilized egg is an endergonic process; enthalpy decreases (energy is absorbed) and entropy decreases. Sand art being destroyed is an exergonic process; there is no change in enthalpy, but entropy increases. A ball rolling downhill is an exergonic process; enthalpy decreases (energy is released), but there is no change in enthalpy. **2** **Figure 6.10** No. We can store chemical energy because of the need to overcome the barrier to its breakdown. **3** **Figure 6.14** Three sodium ions could be moved by the hydrolysis of one ATP molecule. The ΔG of the coupled reaction must be negative. Movement of three sodium ions across the membrane will take 6.3 kcal of energy (2.1 kcal × 3 Na^+ ions = 6.3 kcal). Hydrolysis of ATP provides 7.3 kcal of energy, more than enough to power this reaction. Movement of four sodium ions across the membrane, however, would require 8.4 kcal of energy, more than one ATP molecule can provide. **4** C **5** A **6** C **7** D **8** B **9** A **10** A **11** D **12** A **13** D **14** C **15** A **16** Physical exercise involves both anabolic and catabolic processes. Body cells break down sugars to provide ATP to do the work necessary for exercise, such as muscle contractions. This is catabolism. Muscle cells also must repair muscle tissue damaged by exercise by building new muscle.

This is anabolism. **17** Energy is required for cellular motion, through beating of cilia or flagella, as well as human motion, produced by muscle contraction. Cells also need energy to perform digestion, as humans require energy to digest food. **18** A spontaneous reaction is one that has a negative ΔG and thus releases energy. However, a spontaneous reaction need not occur quickly or suddenly like an instantaneous reaction. It may occur over long periods due to a large energy of activation, which prevents the reaction from occurring quickly. **19** The transition state is always higher in energy than the reactants and the products of a reaction (therefore, above), regardless of whether the reaction is endergonic or exergonic. **20** The ant farm had lower entropy before the earthquake because it was a highly ordered system. After the earthquake, the system became much more disordered and had higher entropy. **21** While cooking, food is heating up on the stove, but not all of the heat goes to cooking the food, some of it is lost as heat energy to the surrounding air, increasing entropy. While driving, cars burn gasoline to run the engine and move the car. This reaction is not completely efficient, as some energy during this process is lost as heat energy, which is why the hood and the components underneath it heat up while the engine is turned on. The tires also heat up because of friction with the pavement, which is additional energy loss. This energy transfer, like all others, also increases entropy. **22** The activation energy for hydrolysis is very low. Not only is ATP hydrolysis an exergonic process with a large $-\Delta G$, but ATP is also a very unstable molecule that rapidly breaks down into ADP + P_i if not utilized quickly. This suggests a very low E_A since it hydrolyzes so quickly. **23** Most vitamins and minerals act as coenzymes and cofactors for enzyme action. Many enzymes require the binding of certain cofactors or coenzymes to be able to catalyze their reactions. Since enzymes catalyze many important reactions, it is critical to obtain sufficient vitamins and minerals from the diet and from supplements. Vitamin C (ascorbic acid) is a coenzyme necessary for the action of enzymes that build collagen, an important protein component of connective tissue throughout the body. Magnesium ion (Mg++) is an important cofactor that is necessary for the enzyme pyruvate dehydrogenase to catalyze part of the pathway that breaks down sugar to produce energy. Vitamins cannot be produced in the human body and therefore must be obtained in the diet. **24** Feedback inhibition allows cells to control the amounts of metabolic products produced. If there is too much of a particular product relative to what the cell's needs, feedback inhibition effectively causes the cell to decrease production of that particular product. In general, this reduces the production of superfluous products and conserves energy, maximizing energy efficiency.

Chapter 7

1 **Figure 7.11** After DNP poisoning, the electron transport chain can no longer form a proton gradient, and ATP synthase can no longer make ATP. DNP is an effective diet drug because it uncouples ATP synthesis; in other words, after taking it, a person obtains less energy out of the food he or she eats. Interestingly, one of the worst side effects of this drug is hyperthermia, or overheating of the body. Since ATP cannot be formed, the energy from electron transport is lost as heat. **2** **Figure 7.12** After cyanide poisoning, the electron transport chain can no longer pump electrons into the intermembrane space. The pH of the intermembrane space would increase, the pH gradient would decrease, and ATP synthesis would stop. **3** **Figure 7.14** The illness is caused by lactate accumulation. Lactate levels rise after exercise, making the symptoms worse. Milk sickness is rare today, but was common in the Midwestern United States in the early 1800s. **4** A **5** B **6** C **7** D **8** B **9** B **10** C **11** A **12** C **13** A **14** A **15** C **16** A **17** A **18** ATP provides the cell with a way to handle energy in an efficient manner. The molecule can be charged, stored, and used as needed. Moreover, the energy from hydrolyzing ATP is delivered as a consistent amount. Harvesting energy from the bonds of several different compounds would result in energy deliveries of different quantities. **19** If glycolysis evolved relatively late, it likely would not be as universal in organisms as it is. It probably evolved in very primitive organisms and persisted, with the addition of other pathways of carbohydrate metabolism that evolved later. **20** All cells must consume energy to carry out basic functions, such as pumping ions across membranes. A red blood cell would lose its membrane potential if glycolysis were blocked, and it would eventually die. **21** In a circular pathway, the final product of the reaction is also the initial reactant. The pathway is self-perpetuating, as long as any of the intermediates of the pathway are supplied. Circular pathways are able to accommodate multiple entry and exit points, thus being particularly well suited for amphibolic pathways. In a linear pathway, one trip through the pathway completes the pathway, and a second trip would be an independent event. **22** Q and cytochrome c are transport molecules. Their function does not result directly in ATP synthesis in that they are not pumps. Moreover, Q is the only component of the electron transport chain that is not a protein. Ubiquinone and cytochrome c are small, mobile, electron carriers, whereas the other components of the electron transport chain are large complexes anchored in the inner mitochondrial membrane. **23** Few tissues except muscle produce the maximum possible amount of ATP from nutrients. The intermediates are used to produce needed amino acids, fatty acids, cholesterol, and sugars for nucleic acids. When NADH is transported from the cytoplasm to the mitochondria, an active transport mechanism is used, which decreases the amount of ATP that can be made. The electron transport chain differs in composition between species, so different organisms will make different amounts of ATP using their electron transport chains. **24** Fermentation uses glycolysis only. Anaerobic respiration uses all three parts of cellular respiration, including the parts in the mitochondria like the citric acid cycle and electron transport; it also uses a different final electron acceptor instead of oxygen gas. **25** They are very economical. The substrates, intermediates, and products move between pathways and do so in response to finely tuned feedback inhibition loops that keep metabolism balanced overall. Intermediates in

one pathway may occur in another, and they can move from one pathway to another fluidly in response to the needs of the cell. **26** Citrate can inhibit phosphofructokinase by feedback regulation. **27** Negative feedback mechanisms actually control a process; it can turn it off, whereas positive feedback accelerates the process, allowing the cell no control over it. Negative feedback naturally maintains homeostasis, whereas positive feedback drives the system away from equilibrium.

Chapter 8

1 **Figure 8.6** Levels of carbon dioxide (a necessary photosynthetic substrate) will immediately fall. As a result, the rate of photosynthesis will be inhibited. **2** **Figure 8.15** A. **3** **Figure 8.18** D **4** A **5** C **6** B **7** B **8** A **9** B **10** C **11** B **12** D **13** C **14** C **15** A **16** The outcome of light reactions in photosynthesis is the conversion of solar energy into chemical energy that the chloroplasts can use to do work (mostly anabolic production of carbohydrates from carbon dioxide). **17** Because lions eat animals that eat plants. **18** The energy carriers that move from the light-dependent reaction to the light-independent one are "full" because they bring energy. After the energy is released, the "empty" energy carriers return to the light-dependent reaction to obtain more energy. There is not much actual movement involved. Both ATP and NADPH are produced in the stroma where they are also used and reconverted into ADP, Pi, and $NADP^+$. **19** A photon of light hits an antenna molecule in photosystem II, and the energy released by it travels through other antenna molecules to the reaction center. The energy causes an electron to leave a molecule of chlorophyll *a* to a primary electron acceptor protein. The electron travels through the electron transport chain and is accepted by a pigment molecule in photosystem I. **20** Both of these molecules carry energy; in the case of NADPH, it has reducing power that is used to fuel the process of making carbohydrate molecules in light-independent reactions. **21** Because RuBP, the molecule needed at the start of the cycle, is regenerated from G3P. **22** None of the cycle could take place, because RuBisCO is essential in fixing carbon dioxide. Specifically, RuBisCO catalyzes the reaction between carbon dioxide and RuBP at the start of the cycle. **23** Because G3P has three carbon atoms, and each turn of the cycle takes in one carbon atom in the form of carbon dioxide.

Chapter 9

1 **Figure 9.8** C. The downstream cellular response would be inhibited. **2** **Figure 9.10** ERK would become permanently activated, resulting in cell proliferation, migration, adhesion, and the growth of new blood vessels. Apoptosis would be inhibited. **3** **Figure 9.17** C. **4** **Figure 9.18** *S. aureus* produces a biofilm because the higher cell density in the biofilm permits the formation of a dense surface that helps protect the bacteria from antibiotics. **5** B **6** C **7** B **8** A **9** D **10** C **11** B **12** B **13** D **14** C **15** C **16** D **17** Intracellular signaling occurs within a cell, and intercellular signaling occurs between cells. **18** The secreted ligands are quickly removed by degradation or reabsorption into the cell so that they cannot travel far. **19** Internal receptors are located inside the cell, and their ligands enter the cell to bind the receptor. The complex formed by the internal receptor and the ligand then enters the nucleus and directly affects protein production by binding to the chromosomal DNA and initiating the making of mRNA that codes for proteins. Cell-surface receptors, however, are embedded in the plasma membrane, and their ligands do not enter the cell. Binding of the ligand to the cell-surface receptor initiates a cell signaling cascade and does not directly influence the making of proteins; however, it may involve the activation of intracellular proteins. **20** An ion channel receptor opened up a pore in the membrane, which allowed the ionic dye to move into the cell. **21** Different cells produce different proteins, including cell-surface receptors and signaling pathway components. Therefore, they respond to different ligands, and the second messengers activate different pathways. Signal integration can also change the end result of signaling. **22** The binding of the ligand to the extracellular domain would activate the pathway normally activated by the receptor donating the intracellular domain. **23** If a kinase is mutated so that it is always activated, it will continuously signal through the pathway and lead to uncontrolled growth and possibly cancer. If a kinase is mutated so that it cannot function, the cell will not respond to ligand binding. **24** Receptors on the cell surface must be in contact with the extracellular matrix in order to receive positive signals that allow the cell to live. If the receptors are not activated by binding, the cell will undergo apoptosis. This ensures that cells are in the correct place in the body and helps to prevent invasive cell growth as occurs in metastasis in cancer. **25** Yeasts are eukaryotes and have many of the same systems that humans do; however, they are single-celled, so they are easy to grow, grow rapidly, have a short generation time, and are much simpler than humans. **26** Multicellular organisms must coordinate many different events in different cell types that may be very distant from each other. Single-celled organisms are only concerned with their immediate environment and the presence of other cells in the area.

Chapter 10

1 **Figure 10.6** D. The kinetochore becomes attached to the mitotic spindle. Sister chromatids line up at the metaphase plate. Cohesin proteins break down and the sister chromatids separate. The nucleus reforms and the cell divides. **2** **Figure 10.13** Rb and other negative regulatory proteins control cell division and therefore prevent the formation of tumors. Mutations that prevent these proteins from carrying out their function can

result in cancer. **3** Figure 10.14 D. E6 binding marks p53 for degradation. **4** C **5** B **6** D **7** D **8** B **9** D **10** B **11** B **12** D **13** C **14** A **15** A **16** A **17** C **18** D **19** D **20** C **21** A **22** C **23** C **24** D **25** D **26** C **27** B **28** Human somatic cells have 46 chromosomes: 22 pairs and 2 sex chromosomes that may or may not form a pair. This is the 2*n* or diploid condition. Human gametes have 23 chromosomes, one each of 23 unique chromosomes, one of which is a sex chromosome. This is the *n* or haploid condition. **29** The genome consists of the sum total of an organism's chromosomes. Each chromosome contains hundreds and sometimes thousands of genes, segments of DNA that code for a polypeptide or RNA, and a large amount of DNA with no known function. **30** The DNA double helix is wrapped around histone proteins to form structures called nucleosomes. Nucleosomes and the linker DNA in between them are coiled into a 30-nm fiber. During cell division, chromatin is further condensed by packing proteins. **31** During G_1, the cell increases in size, the genomic DNA is assessed for damage, and the cell stockpiles energy reserves and the components to synthesize DNA. During the S phase, the chromosomes, the centrosomes, and the centrioles (animal cells) duplicate. During the G_2 phase, the cell recovers from the S phase, continues to grow, duplicates some organelles, and dismantles other organelles. **32** The mitotic spindle is formed of microtubules. Microtubules are polymers of the protein tubulin; therefore, it is the mitotic spindle that is disrupted by these drugs. Without a functional mitotic spindle, the chromosomes will not be sorted or separated during mitosis. The cell will arrest in mitosis and die. **33** There are very few similarities between animal cell and plant cell cytokinesis. In animal cells, a ring of actin fibers is formed around the periphery of the cell at the former metaphase plate (cleavage furrow). The actin ring contracts inward, pulling the plasma membrane toward the center of the cell until the cell is pinched in two. In plant cells, a new cell wall must be formed between the daughter cells. Due to the rigid cell walls of the parent cell, contraction of the middle of the cell is not possible. Instead, a phragmoplast first forms. Subsequently, a cell plate is formed in the center of the cell at the former metaphase plate. The cell plate is formed from Golgi vesicles that contain enzymes, proteins, and glucose. The vesicles fuse and the enzymes build a new cell wall from the proteins and glucose. The cell plate grows toward and eventually fuses with the cell wall of the parent cell. **34** Many cells temporarily enter G_0 until they reach maturity. Some cells are only triggered to enter G_1 when the organism needs to increase that particular cell type. Some cells only reproduce following an injury to the tissue. Some cells never divide once they reach maturity. **35** If cohesin is not functional, chromosomes are not packaged after DNA replication in the S phase of interphase. It is likely that the proteins of the centromeric region, such as the kinetochore, would not form. Even if the mitotic spindle fibers could attach to the chromatids without packing, the chromosomes would not be sorted or separated during mitosis. **36** The G_1 checkpoint monitors adequate cell growth, the state of the genomic DNA, adequate stores of energy, and materials for S phase. At the G_2 checkpoint, DNA is checked to ensure that all chromosomes were duplicated and that there are no mistakes in newly synthesized DNA. Additionally, cell size and energy reserves are evaluated. The M checkpoint confirms the correct attachment of the mitotic spindle fibers to the kinetochores. **37** Positive cell regulators such as cyclin and Cdk perform tasks that advance the cell cycle to the next stage. Negative regulators such as Rb, p53, and p21 block the progression of the cell cycle until certain events have occurred. **38** Cdk must bind to a cyclin, and it must be phosphorylated in the correct position to become fully active. **39** Rb is active when it is dephosphorylated. In this state, Rb binds to E2F, which is a transcription factor required for the transcription and eventual translation of molecules required for the G_1/S transition. E2F cannot transcribe certain genes when it is bound to Rb. As the cell increases in size, Rb becomes phosphorylated, inactivated, and releases E2F. E2F can then promote the transcription of the genes it controls, and the transition proteins will be produced. **40** If one of the genes that produces regulator proteins becomes mutated, it produces a malformed, possibly non-functional, cell cycle regulator, increasing the chance that more mutations will be left unrepaired in the cell. Each subsequent generation of cells sustains more damage. The cell cycle can speed up as a result of the loss of functional checkpoint proteins. The cells can lose the ability to self-destruct and eventually become "immortalized." **41** A proto-oncogene is a segment of DNA that codes for one of the positive cell cycle regulators. If that gene becomes mutated so that it produces a hyperactivated protein product, it is considered an oncogene. A tumor suppressor gene is a segment of DNA that codes for one of the negative cell cycle regulators. If that gene becomes mutated so that the protein product becomes less active, the cell cycle will run unchecked. A single oncogene can initiate abnormal cell divisions; however, tumor suppressors lose their effectiveness only when both copies of the gene are damaged. **42** Regulatory mechanisms that might be lost include monitoring of the quality of the genomic DNA, recruiting of repair enzymes, and the triggering of apoptosis. **43** If a cell has damaged DNA, the likelihood of producing faulty proteins is higher. The daughter cells of such a damaged parent cell would also produce faulty proteins that might eventually become cancerous. If p53 recognizes this damage and triggers the cell to self-destruct, the damaged DNA is degraded and recycled. No further harm comes to the organism. Another healthy cell is triggered to divide instead. **44** The common components of eukaryotic cell division and binary fission are DNA duplication, segregation of duplicated chromosomes, and division of the cytoplasmic contents. **45** As the chromosome is being duplicated, each origin moves away from the starting point of replication. The chromosomes are attached to the cell membrane via proteins; the growth of the membrane as the cell elongates aids in their movement.

Chapter 11

1 **Figure 11.9** Yes, it will be able to reproduce asexually. **2** C **3** B **4** D **5** A **6** C **7** C **8** C **9** B **10** C **11** D **12** B **13** A **14** During the meiotic interphase, each chromosome is duplicated. The sister chromatids that are formed during synthesis are held together at the centromere region by cohesin proteins. All chromosomes are attached to the nuclear envelope by their tips. As the cell enters prophase I, the nuclear envelope begins to fragment, and the proteins holding homologous chromosomes locate each other. The four sister chromatids align lengthwise, and a protein lattice called the synaptonemal complex is formed between them to bind them together. The synaptonemal complex facilitates crossover between non-sister chromatids, which is observed as chiasmata along the length of the chromosome. As prophase I progresses, the synaptonemal complex breaks down and the sister chromatids become free, except where they are attached by chiasmata. At this stage, the four chromatids are visible in each homologous pairing and are called a tetrad. **15** Random alignment leads to new combinations of traits. The chromosomes that were originally inherited by the gamete-producing individual came equally from the egg and the sperm. In metaphase I, the duplicated copies of these maternal and paternal homologous chromosomes line up across the center of the cell. The orientation of each tetrad is random. There is an equal chance that the maternally derived chromosomes will be facing either pole. The same is true of the paternally derived chromosomes. The alignment should occur differently in almost every meiosis. As the homologous chromosomes are pulled apart in anaphase I, any combination of maternal and paternal chromosomes will move toward each pole. The gametes formed from these two groups of chromosomes will have a mixture of traits from the individual's parents. Each gamete is unique. **16** In metaphase I, the homologous chromosomes line up at the metaphase plate. In anaphase I, the homologous chromosomes are pulled apart and move to opposite poles. Sister chromatids are not separated until meiosis II. The fused kinetochore formed during meiosis I ensures that each spindle microtubule that binds to the tetrad will attach to both sister chromatids. **17** All of the stages of meiosis I, except possibly telophase I, are unique because homologous chromosomes are separated, not sister chromatids. In some species, the chromosomes do not decondense and the nuclear envelopes do not form in telophase I. All of the stages of meiosis II have the same events as the stages of mitosis, with the possible exception of prophase II. In some species, the chromosomes are still condensed and there is no nuclear envelope. Other than this, all processes are the same. **18** a. Crossover occurs in prophase I between non-sister homologous chromosomes. Segments of DNA are exchanged between maternally derived and paternally derived chromosomes, and new gene combinations are formed. b. Random alignment during metaphase I leads to gametes that have a mixture of maternal and paternal chromosomes. c. Fertilization is random, in that any two gametes can fuse. **19** a. In the haploid-dominant life cycle, the multicellular stage is haploid. The diploid stage is a spore that undergoes meiosis to produce cells that will divide mitotically to produce new multicellular organisms. Fungi have a haploid-dominant life cycle. b. In the diploid-dominant life cycle, the most visible or largest multicellular stage is diploid. The haploid stage is usually reduced to a single cell type, such as a gamete or spore. Animals, such as humans, have a diploid-dominant life cycle. c. In the alternation of generations life cycle, there are both haploid and diploid multicellular stages, although the haploid stage may be completely retained by the diploid stage. Plants have a life cycle with alternation of generations.

Chapter 12

1 **Figure 12.5** You cannot be sure if the plant is homozygous or heterozygous as the data set is too small: by random chance, all three plants might have acquired only the dominant gene even if the recessive one is present. If the round pea parent is heterozygous, there is a one-eighth probability that a random sample of three progeny peas will all be round. **2** **Figure 12.6** Individual 1 has the genotype *aa*. Individual 2 has the genotype *Aa*. Individual 3 has the genotype *Aa*. **3** **Figure 12.12** Half of the female offspring would be heterozygous (X^WX^w) with red eyes, and half would be homozygous recessive (X^wX^w) with white eyes. Half of the male offspring would be hemizygous dominant (X^WY) withe red yes, and half would be hemizygous recessive (X^wY) with white eyes. **4** **Figure 12.16** The possible genotypes are PpYY, PpYy, ppYY, and ppYy. The former two genotypes would result in plants with purple flowers and yellow peas, while the latter two genotypes would result in plants with white flowers with yellow peas, for a 1:1 ratio of each phenotype. You only need a 2 × 2 Punnett square (four squares total) to do this analysis because two of the alleles are homozygous. **5** A **6** B **7** B **8** C **9** A **10** C **11** D **12** D **13** C **14** A **15** B **16** D **17** The garden pea is sessile and has flowers that close tightly during self-pollination. These features help to prevent accidental or unintentional fertilizations that could have diminished the accuracy of Mendel's data. **18** Two sets of P_0 parents would be used. In the first cross, pollen would be transferred from a true-breeding tall plant to the stigma of a true-breeding dwarf plant. In the second cross, pollen would be transferred from a true-breeding dwarf plant to the stigma of a true-breeding tall plant. For each cross, F_1 and F_2 offspring would be analyzed to determine if offspring traits were affected according to which parent donated each trait. **19** Because axial is dominant, the gene would be designated as *A*. F_1 would be all heterozygous *Aa* with axial phenotype. F_2 would have possible genotypes of *AA*, *Aa*, and *aa*; these would correspond to axial, axial, and terminal phenotypes, respectively. **20** The Punnett square would be 2 × 2 and will have *T* and *T* along the top, and *T* and *t* along the left side. Clockwise from the top left, the genotypes listed within the boxes will be *Tt*, *Tt*,

tt, and *tt*. The phenotypic ratio will be 1 tall:1 dwarf. **21** No, males can only express color blindness. They cannot carry it because an individual needs two X chromosomes to be a carrier. **22** Considering each gene separately, the cross at *A* will produce offspring of which half are *AA* and half are *Aa*; *B* will produce all *Bb*; *C* will produce half *Cc* and half *cc*. Proportions then are (1/2) × (1) × (1/2), or 1/4 *AABbCc*; continuing for the other possibilities yields 1/4 *AABbcc*, 1/4 *AaBbCc*, and 1/4 *AaBbcc*. The proportions therefore are 1:1:1:1. **23** Epistasis describes an antagonistic interaction between genes wherein one gene masks or interferes with the expression of another. The gene that is interfering is referred to as epistatic, as if it is "standing upon" the other (hypostatic) gene to block its expression. **24** The cross can be represented as a 4 × 4 Punnett square, with the following gametes for each parent: *WY*, *Wy*, *wY*, and *wy*. For all 12 of the offspring that express a dominant *W* gene, the offspring will be white. The three offspring that are homozygous recessive for *w* but express a dominant *Y* gene will be yellow. The remaining *wwyy* offspring will be green.

Chapter 13

1 **Figure 13.3** No. The predicted frequency of recombinant offspring ranges from 0% (for linked traits) to 50% (for unlinked traits). **2** **Figure 13.4** D **3** **Figure 13.6** B. **4** A **5** C **6** C **7** A **8** B **9** C **10** C **11** A **12** D **13** A **14** The Chromosomal Theory of Inheritance proposed that genes reside on chromosomes. The understanding that chromosomes are linear arrays of genes explained linkage, and crossing over explained recombination. **15** Exact diagram style will vary; diagram should look like **Figure 13.6**.

Chapter 14

1 **Figure 14.10** Compartmentalization enables a eukaryotic cell to divide processes into discrete steps so it can build more complex protein and RNA products. But there is an advantage to having a single compartment as well: RNA and protein synthesis occurs much more quickly in a prokaryotic cell. **2** **Figure 14.14** DNA ligase, as this enzyme joins together Okazaki fragments. **3** **Figure 14.21** If three nucleotides are added, one additional amino acid will be incorporated into the protein chain, but the reading frame wont shift. **4** C **5** D **6** D **7** D **8** B **9** C **10** D **11** B **12** A **13** D **14** C **15** B **16** Live R cells acquired genetic information from the heat-killed S cells that "transformed" the R cells into S cells. **17** Sulfur is an element found in proteins and phosphorus is a component of nucleic acids. **18** The template DNA strand is mixed with a DNA polymerase, a primer, the 4 deoxynucleotides, and a limiting concentration of 4 dideoxynucleotides. DNA polymerase synthesizes a strand complementary to the template. Incorporation of ddNTPs at different locations results in DNA fragments that have terminated at every possible base in the template. These fragments are separated by gel electrophoresis and visualized by a laser detector to determine the sequence of bases. **19** DNA has two strands in anti-parallel orientation. The sugar-phosphate linkages form a backbone on the outside, and the bases are paired on the inside: A with T, and G with C, like rungs on a spiral ladder. **20** Meselson's experiments with *E. coli* grown in ^{15}N deduced this finding. **21** At an origin of replication, two replication forks are formed that are extended in two directions. On the lagging strand, Okazaki fragments are formed in a discontinuous manner. **22** Short DNA fragments are formed on the lagging strand synthesized in a direction away from the replication fork. These are synthesized by DNA pol. **23** 1333 seconds or 22.2 minutes. **24** At the replication fork, the events taking place are helicase action, binding of single-strand binding proteins, primer synthesis, and synthesis of new strands. If there is a mutated helicase gene, the replication fork will not be extended. **25** Primer provides a 3'-OH group for DNA pol to start adding nucleotides. There would be no reaction in the tube without a primer, and no bands would be visible on the electrophoresis. **26** Telomerase has an inbuilt RNA template that extends the 3' end, so primer is synthesized and extended. Thus, the ends are protected. **27** Mutations are not repaired, as in the case of xeroderma pigmentosa. Gene function may be affected or it may not be expressed.

Chapter 15

1 **Figure 15.11** No. Prokaryotes use different promoters than eukaryotes. **2** **Figure 15.13** Mutations in the spliceosome recognition sequence at each end of the intron, or in the proteins and RNAs that make up the spliceosome, may impair splicing. Mutations may also add new spliceosome recognition sites. Splicing errors could lead to introns being retained in spliced RNA, exons being excised, or changes in the location of the splice site. **3** **Figure 15.16** Tetracycline: a; Chloramphenicol: c. **4** D **5** C **6** D **7** B **8** B **9** B **10** D **11** A **12** C **13** A **14** For 200 commonly occurring amino acids, codons consisting of four types of nucleotides would have to be at least four nucleotides long, because $4^4 = 256$. There would be much less degeneracy in this case. **15** Codons that specify the same amino acid typically only differ by one nucleotide. In addition, amino acids with chemically similar side chains are encoded by similar codons. This nuance of the genetic code ensures that a single-nucleotide substitution mutation might either specify the same amino acid and have no effect, or may specify a similar amino acid, preventing the protein from being rendered completely nonfunctional. **16** DNA is different from RNA in that T nucleotides in DNA are replaced with U nucleotides in RNA. Therefore, they could never be identical in base sequence. **17** Rho-dependent termination is controlled by the rho protein, which tracks along behind the polymerase on the growing mRNA chain. Near

the end of the gene, the polymerase stalls at a run of G nucleotides on the DNA template. The rho protein collides with the polymerase and releases mRNA from the transcription bubble. Rho-independent termination is controlled by specific sequences in the DNA template strand. As the polymerase nears the end of the gene being transcribed, it encounters a region rich in C–G nucleotides. This creates an mRNA hairpin that causes the polymerase to stall right as it begins to transcribe a region rich in A–T nucleotides. Because A–U bonds are less thermostable, the core enzyme falls away. **18** The mRNA would be: 5'-AUGGCCGGUUAUUAAGCA-3'. The protein would be: MAGY. Even though there are six codons, the fifth codon corresponds to a stop, so the sixth codon would not be translated. **19** Nucleotide changes in the third position of codons may not change the amino acid and would have no effect on the protein. Other nucleotide changes that change important amino acids or create or delete start or stop codons would have severe effects on the amino acid sequence of the protein.

Chapter 16

1 **Figure 16.5** Tryptophan is an amino acid essential for making proteins, so the cell always needs to have some on hand. However, if plenty of tryptophan is present, it is wasteful to make more, and the expression of the *trp* receptor is repressed. Lactose, a sugar found in milk, is not always available. It makes no sense to make the enzymes necessary to digest an energy source that is not available, so the *lac* operon is only turned on when lactose is present. **2** **Figure 16.7** The nucleosomes would pack more tightly together. **3** **Figure 16.13** Protein synthesis would be inhibited. **4** D **5** B **6** B **7** D **8** A **9** D **10** C **11** B **12** D **13** D **14** A **15** C **16** C **17** Eukaryotic cells have a nucleus, whereas prokaryotic cells do not. In eukaryotic cells, DNA is confined within the nuclear region. Because of this, transcription and translation are physically separated. This creates a more complex mechanism for the control of gene expression that benefits multicellular organisms because it compartmentalizes gene regulation. Gene expression occurs at many stages in eukaryotic cells, whereas in prokaryotic cells, control of gene expression only occurs at the transcriptional level. This allows for greater control of gene expression in eukaryotes and more complex systems to be developed. Because of this, different cell types can arise in an individual organism. **18** The cell controls which proteins are expressed and to what level each protein is expressed in the cell. Prokaryotic cells alter the transcription rate to turn genes on or off. This method will increase or decrease protein levels in response to what is needed by the cell. Eukaryotic cells change the accessibility (epigenetic), transcription, or translation of a gene. This will alter the amount of RNA and the lifespan of the RNA to alter the amount of protein that exists. Eukaryotic cells also control protein translation to increase or decrease the overall levels. Eukaryotic organisms are much more complex and can manipulate protein levels by changing many stages in the process. **19** Environmental stimuli can increase or induce transcription in prokaryotic cells. In this example, lactose in the environment will induce the transcription of the *lac* operon, but only if glucose is not available in the environment. **20** A repressible operon uses a protein bound to the promoter region of a gene to keep the gene repressed or silent. This repressor must be actively removed in order to transcribe the gene. An inducible operon is either activated or repressed depending on the needs of the cell and what is available in the local environment. **21** You can create medications that reverse the epigenetic processes (to add histone acetylation marks or to remove DNA methylation) and create an open chromosomal configuration. **22** A mutation in the promoter region can change the binding site for a transcription factor that normally binds to increase transcription. The mutation could either decrease the ability of the transcription factor to bind, thereby decreasing transcription, or it can increase the ability of the transcription factor to bind, thus increasing transcription. **23** If too much of an activating transcription factor were present, then transcription would be increased in the cell. This could lead to dramatic alterations in cell function. **24** RNA binding proteins (RBP) bind to the RNA and can either increase or decrease the stability of the RNA. If they increase the stability of the RNA molecule, the RNA will remain intact in the cell for a longer period of time than normal. Since both RBPs and miRNAs bind to the RNA molecule, RBP can potentially bind first to the RNA and prevent the binding of the miRNA that will degrade it. **25** External stimuli can modify RNA-binding proteins (i.e., through phosphorylation of proteins) to alter their activity. **26** Because proteins are involved in every stage of gene regulation, phosphorylation of a protein (depending on the protein that is modified) can alter accessibility to the chromosome, can alter translation (by altering the transcription factor binding or function), can change nuclear shuttling (by influencing modifications to the nuclear pore complex), can alter RNA stability (by binding or not binding to the RNA to regulate its stability), can modify translation (increase or decrease), or can change post-translational modifications (add or remove phosphates or other chemical modifications). **27** If the RNA degraded, then less of the protein that the RNA encodes would be translated. This could have dramatic implications for the cell. **28** Environmental stimuli, like ultraviolet light exposure, can alter the modifications to the histone proteins or DNA. Such stimuli may change an actively transcribed gene into a silenced gene by removing acetyl groups from histone proteins or by adding methyl groups to DNA. **29** These drugs will keep the histone proteins and the DNA methylation patterns in the open chromosomal configuration so that transcription is feasible. If a gene is silenced, these drugs could reverse the epigenetic configuration to re-express the gene. **30** Understanding which genes are expressed in a cancer cell can help diagnose the specific form of cancer. It can also help identify treatment options for that patient. For example, if a breast cancer tumor expresses the EGFR in high numbers, it might respond to specific anti-EGFR therapy. If that receptor is not expressed, it would not respond to that therapy.

Chapter 17

1 Figure 17.6 B. The experiment would result in blue colonies only. **2** Figure 17.8 Dolly was a Finn-Dorset sheep because even though the original cell came from a Scottish blackface sheep and the surrogate mother was a Scottish blackface, the DNA came from a Finn-Dorset. **3** Figure 17.15 There are no right or wrong answers to these questions. While it is true that prostate cancer treatment itself can be harmful, many men would rather be aware that they have cancer so they can monitor the disease and begin treatment if it progresses. And while genetic screening may be useful, it is expensive and may cause needless worry. People with certain risk factors may never develop the disease, and preventative treatments may do more harm than good. **4** B **5** C **6** B **7** B **8** D **9** D **10** B **11** B **12** A **13** D **14** A **15** D **16** D **17** B **18** D **19** A **20** B **21** D **22** Southern blotting is the transfer of DNA that has been enzymatically cut into fragments and run on an agarose gel onto a nylon membrane. The DNA fragments that are on the nylon membrane can be denatured to make them single-stranded, and then probed with small DNA fragments that are radioactively or fluorescently labeled, to detect the presence of specific sequences. An example of the use of Southern blotting would be in analyzing the presence, absence, or variation of a disease gene in genomic DNA from a group of patients. **23** Cellular cloning of the breast cancer cells will establish a cell line, which can be used for further analysis **24** By identifying an herbicide resistance gene and cloning it into a plant expression vector system, like the Ti plasmid system from *Agrobacterium tumefaciens*. The scientist would then introduce it into the plant cells by transformation, and select cells that have taken up and integrated the herbicide-resistance gene into the genome. **25** What diseases am I prone to and what precautions should I take? Am I a carrier for any disease-causing genes that may be passed on to children? **26** Genome mapping has many different applications and provides comprehensive information that can be used for predictive purposes. **27** A human genetic map can help identify genetic markers and sequences associated with high cancer risk, which can help to screen and provide early detection of different types of cancer. **28** Metagenomics is revolutionary because it replaced the practice of using pure cultures. Pure cultures were used to study individual species in the laboratory, but did not accurately represent what happens in the environment. Metagenomics studies the genomes of bacterial populations in their environmental niche. **29** Genomics can provide the unique DNA sequence of an individual, which can be used for personalized medicine and treatment options. **30** Proteomics has provided a way to detect biomarkers and protein signatures, which have been used to screen for the early detection of cancer. **31** Personalized medicine is the use of an individual's genomic sequence to predict the risk for specific diseases. When a disease does occur, it can be used to develop a personalized treatment plan.

Chapter 18

1 Figure 18.14 Loss of genetic material is almost always lethal, so offspring with $2n+1$ chromosomes are more likely to survive. **2** Figure 18.22 Fusion is most likely to occur because the two species will interact more and similar traits in food acquisition will be selected. **3** Figure 18.23 Answer B **4** B **5** D **6** D **7** D **8** A **9** B **10** B **11** C **12** C **13** C **14** D **15** A **16** C **17** The plants that can best use the resources of the area, including competing with other individuals for those resources will produce more seeds themselves and those traits that allowed them to better use the resources will increase in the population of the next generation. **18** Vestigial structures are considered evidence for evolution because most structures do not exist in an organism without serving some function either presently or in the past. A vestigial structure indicates a past form or function that has since changed, but the structure remains present because it had a function in the ancestor. **19** In science, a theory is a thoroughly tested and verified set of explanations for a body of observations of nature. It is the strongest form of knowledge in science. In contrast, a theory in common vernacular can mean a guess or speculation about something, meaning that the knowledge implied by the theory is very weak. **20** The statement implies that there is a goal to evolution and that the monkey represents greater progress to that goal than the mouse. Both species are likely to be well adapted to their particular environments, which is the outcome of natural selection. **21** Organisms of one species can arrive to an island together and then disperse throughout the chain, each settling into different niches and exploiting different food resources to reduce competition. **22** It is likely the two species would start to reproduce with each other. Depending on the viability of their offspring, they may fuse back into one species. **23** The formation of gametes with new *n* numbers can occur in one generation. After a couple of generations, enough of these new hybrids can form to reproduce together as a new species. **24** Both models continue to conform to the rules of natural selection, and the influences of gene flow, genetic drift, and mutation. **25** If the hybrid offspring are as fit or more fit than the parents, reproduction would likely continue between both species and the hybrids, eventually bringing all organisms under the umbrella of one species.

Chapter 19

1 Figure 19.2 The expected distribution is 320 VV, 160Vv, and 20 vv plants. Plants with VV or Vv genotypes would have violet flowers, and plants with the vv genotype would have white flowers, so a total of 480 plants would be expected to have violet flowers, and 20 plants would have white flowers. **2** Figure 19.4 Genetic drift is likely to occur more rapidly on an island where smaller populations are expected to occur. **3**

Figure 19.8 Moths have shifted to a lighter color. **4** C **5** A **6** D **7** D **8** C **9** B **10** A **11** C **12** D **13** C **14** A **15** D **16** p = (8*2 + 4)/48 = .42; q = (12*2 + 4)/48 = .58; p^2 = .17; 2pq = .48; q^2 = .34 **17** The Hardy-Weinberg principle of equilibrium is used to describe the genetic makeup of a population. The theory states that a population's allele and genotype frequencies are inherently stable: unless some kind of evolutionary force is acting upon the population, generation after generation of the population would carry the same genes, and individuals would, as a whole, look essentially the same. **18** Red is recessive so q2 = 200/800 = 0.25; q = 0.5; p = 1-q = 0.5; p2 = 0.25; 2pq = 0.5. You would expect 200 homozygous blue flowers, 400 heterozygous blue flowers, and 200 red flowers. **19** A hurricane kills a large percentage of a population of sand-dwelling crustaceans—only a few individuals survive. The alleles carried by those surviving individuals would represent the entire population's gene pool. If those surviving individuals are not representative of the original population, the post-hurricane gene pool will differ from the original gene pool. **20** The theory of natural selection stems from the observation that some individuals in a population survive longer and have more offspring than others: thus, more of their genes are passed to the next generation. For example, a big, powerful male gorilla is much more likely than a smaller, weaker one to become the population's silverback: the pack's leader who mates far more than the other males of the group. Therefore, the pack leader will father more offspring who share half of his genes and are likely to grow bigger and stronger like their father. Over time, the genes for bigger size will increase in frequency in the population, and the average body size, as a result, grow larger on average. **21** A cline is a type of geographic variation that is seen in populations of a given species that vary gradually across an ecological gradient. For example, warm-blooded animals tend to have larger bodies in the cooler climates closer to the earth's poles, allowing them to better conserve heat. This is considered a latitudinal cline. Flowering plants tend to bloom at different times depending on where they are along the slope of a mountain. This is known as an altitudinal cline. **22** The peacock's tail is a good example of the handicap principle. The tail, which makes the males more visible to predators and less able to escape, is clearly a disadvantage to the bird's survival. But because it is a disadvantage, only the most fit males should be able to survive with it. Thus, the tail serves as an honest signal of quality to the females of the population; therefore, the male will earn more matings and greater reproductive success. **23** There are several ways evolution can affect population variation: stabilizing selection, directional selection, diversifying selection, frequency-dependent selection, and sexual selection. As these influence the allele frequencies in a population, individuals can either become more or less related, and the phenotypes displayed can become more similar or more disparate.

Chapter 20

1 **Figure 20.6** Cats and dogs are part of the same group at five levels: both are in the domain Eukarya, the kingdom Animalia, the phylum Chordata, the class Mammalia, and the order Carnivora. **2** **Figure 20.10** Rabbits and humans belong in the clade that includes animals with hair. The amniotic egg evolved before hair because the Amniota clade is larger than the clade that encompasses animals with hair. **3** **Figure 20.11** The largest clade encompasses the entire tree. **4** C **5** B **6** D **7** A **8** C **9** A **10** B **11** A **12** C **13** D **14** A **15** C **16** The phylogenetic tree shows the order in which evolutionary events took place and in what order certain characteristics and organisms evolved in relation to others. It does not relate to time. **17** In most cases, organisms that appear closely related actually are; however, there are cases where organisms evolved through convergence and appear closely related but are not. **18** domain, kingdom, phylum, class, order, family, genus, species **19** Dolphins are mammals and fish are not, which means that their evolutionary paths (phylogenies) are quite separate. Dolphins probably adapted to have a similar body plan after returning to an aquatic lifestyle, and, therefore, this trait is probably analogous. **20** Phylogenetic trees are based on evolutionary connections. If an analogous similarity were used on a tree, this would be erroneous and, furthermore, would cause the subsequent branches to be inaccurate. **21** Maximum parsimony hypothesizes that events occurred in the simplest, most obvious way, and the pathway of evolution probably includes the fewest major events that coincide with the evidence at hand. **22** Some hypotheses propose that mitochondria were acquired first, followed by the development of the nucleus. Others propose that the nucleus evolved first and that this new eukaryotic cell later acquired the mitochondria. Still others hypothesize that prokaryotes descended from eukaryotes by the loss of genes and complexity. **23** Aphids have acquired the ability to make the carotenoids on their own. DNA analysis has demonstrated that this ability is due to the transfer of fungal genes into the insect by HGT, presumably as the insect consumed fungi for food.

Chapter 21

1 **Figure 21.4** D **2** **Figure 21.8** The host cell can continue to make new virus particles. **3** **Figure 21.10** C **4** B **5** D **6** D **7** D **8** B **9** C **10** D **11** A **12** D **13** C **14** D **15** C **16** A **17** Viruses pass through filters that eliminated all bacteria that were visible in the light microscopes at the time. As the bacteria-free filtrate could still cause infections when given to a healthy organism, this observation demonstrated the existence of very small infectious agents. These agents were later shown to be unrelated to bacteria and were classified as viruses. **18** The virus can't attach to dog cells, because dog cells do not express the receptors for the virus and/or there is no cell within the dog that is permissive for viral replication. **19** Reverse transcriptase is needed to make more HIV-1 viruses, so targeting the reverse transcriptase enzyme may be a way to inhibit the replication

of the virus. Importantly, by targeting reverse transcriptase, we do little harm to the host cell, since host cells do not make reverse transcriptase. Thus, we can specifically attack the virus and not the host cell when we use reverse transcriptase inhibitors. **20** Answer is open and will vary. **21** Plant viruses infect crops, causing crop damage and failure, and considerable economic losses. **22** Rabies vaccine works after a bite because it takes week for the virus to travel from the site of the bite to the central nervous system, where the most severe symptoms of the disease occur. Adults are not routinely vaccinated for rabies for two reasons: first, because the routine vaccination of domestic animals makes it unlikely that humans will contract rabies from an animal bite; second, if one is bitten by a wild animal or a domestic animal that one cannot confirm has been immunized, there is still time to give the vaccine and avoid the often fatal consequences of the disease. **23** This prion-based disease is transmitted through human consumption of infected meat. **24** They both replicate in a cell, and they both contain nucleic acid.

Chapter 22

1 **Figure 22.8** The extracellular matrix and outer layer of cells protects the inner bacteria. The close proximity of cells also facilitates lateral gene transfer, a process by which genes such as antibiotic resistance genes are transferred from one bacterium to another. And even if lateral gene transfer does not occur, one bacterium that produces an exo-enzyme that destroys antibiotic may save neighboring bacteria. **2** **Figure 22.15** A **3** **Figure 22.19** D **4** A **5** D **6** A **7** A **8** B **9** D **10** B **11** B **12** A **13** C **14** B **15** B **16** C **17** A **18** B **19** C **20** D **21** A **22** D **23** D **24** B **25** As the organisms are non-culturable, the presence could be detected through molecular techniques, such as PCR. **26** Because the environmental conditions on Earth were extreme: high temperatures, lack of oxygen, high radiation, and the like. **27** Responses will vary. A possible answer is: Bacteria contain peptidoglycan in the cell wall; archaea do not. The cell membrane in bacteria is a lipid bilayer; in archaea, it can be a lipid bilayer or a monolayer. Bacteria contain fatty acids on the cell membrane, whereas archaea contain phytanyl. **28** Both bacteria and archaea have cell membranes and they both contain a hydrophobic portion. In the case of bacteria, it is a fatty acid; in the case of archaea, it is a hydrocarbon (phytanyl). Both bacteria and archaea have a cell wall that protects them. In the case of bacteria, it is composed of peptidoglycan, whereas in the case of archaea, it is pseudopeptidoglycan, polysaccharides, glycoproteins, or pure protein. Bacterial and archaeal flagella also differ in their chemical structure. **29** Responses will vary. In a deep-sea hydrothermal vent, there is no light, so prokaryotes would be chemotrophs instead of phototrophs. The source of carbon would be carbon dioxide dissolved in the ocean, so they would be autotrophs. There is not a lot of organic material in the ocean, so prokaryotes would probably use inorganic sources, thus they would be chemolitotrophs. The temperatures are very high in the hydrothermal vent, so the prokaryotes would be thermophilic. **30** Antibiotics kill bacteria that are sensitive to them; thus, only the resistant ones will survive. These resistant bacteria will reproduce, and therefore, after a while, there will be only resistant bacteria. **31** *E. coli* colonizes the surface of the leaf, forming a biofilm that is more difficult to remove than free (planktonic) cells. Additionally, bacteria can be taken up in the water that plants are grown in, thereby entering the plant tissues rather than simply residing on the leaf surface. **32** Remind them of the important roles prokaryotes play in decomposition and freeing up nutrients in biogeochemical cycles; remind them of the many prokaryotes that are not human pathogens and that fill very specialized niches. Furthermore, our normal bacterial symbionts are crucial for our digestion and in protecting us from pathogens.

Chapter 23

1 **Figure 23.5** All eukaryotic cells have mitochondria, but not all eukaryotic cells have chloroplasts. **2** **Figure 23.15** C **3** **Figure 23.18** C **4** D **5** C **6** C **7** D **8** D **9** B **10** B **11** C **12** C **13** C **14** A **15** D **16** A **17** B **18** Eukaryotic cells arose through endosymbiotic events that gave rise to the energy-producing organelles within the eukaryotic cells such as mitochondria and chloroplasts. The nuclear genome of eukaryotes is related most closely to the Archaea, so it may have been an early archaean that engulfed a bacterial cell that evolved into a mitochondrion. Mitochondria appear to have originated from an alpha-proteobacterium, whereas chloroplasts originated as a cyanobacterium. There is also evidence of secondary endosymbiotic events. Other cell components may also have resulted from endosymbiotic events. **19** The ability to perform sexual reproduction allows protists to recombine their genes and produce new variations of progeny that may be better suited to the new environment. In contrast, asexual reproduction generates progeny that are clones of the parent. **20** As an intestinal parasite, *Giardia* cysts would be exposed to low pH in the stomach acids of its host. To survive this environment and reach the intestine, the cysts would have to be resistant to acidic conditions. **21** Unlike *Ulva*, protists in the genus *Caulerpa* actually are large, multinucleate, single cells. Because these organisms undergo mitosis without cytokinesis and lack cytoplasmic divisions, they cannot be considered truly multicellular. **22** By definition, an obligate saprobe lacks the ability to perform photosynthesis, so it cannot directly obtain nutrition by searching for light. Instead, a chemotactic mechanism that senses the odors released during decay might be a more effective sensing organ for a saprobe. **23** *Plasmodium* parasites infect humans and cause malaria. However, they must complete part of their life cycle within *Anopheles* mosquitoes, and they can only infect humans via the bite wound of a mosquito. If the mosquito population is decreased, then fewer *Plasmodium* would be able to develop and infect humans, thereby reducing the incidence of human infections with this parasite. **24** The trypanosomes

that cause this disease are capable of expressing a glycoprotein coat with a different molecular structure with each generation. Because the immune system must respond to specific antigens to raise a meaningful defense, the changing nature of trypanosome antigens prevents the immune system from ever clearing this infection. Massive trypanosome infection eventually leads to host organ failure and death.

Chapter 24

1 Figure 24.13 A **2** Figure 24.16 D **3** Figure 24.20 Without mycorrhiza, plants cannot absorb adequate nutrients, which stunts their growth. Addition of fungal spores to sterile soil can alleviate this problem. **4** C **5** A **6** D **7** C **8** A **9** B **10** D **11** B **12** C **13** D **14** A **15** C **16** B **17** C **18** Asexual reproduction is fast and best under favorable conditions. Sexual reproduction allows the recombination of genetic traits and increases the odds of developing new adaptations better suited to a changed environment. **19** Animals have no cell walls; fungi have cell walls containing chitin; plants have cell walls containing cellulose. Chloroplasts are absent in both animals and fungi but are present in plants. Animal plasma membranes are stabilized with cholesterol, while fungi plasma membranes are stabilized with ergosterol, and plant plasma membranes are stabilized with phytosterols. Animals obtain N and C from food sources via internal digestion. Fungi obtain N and C from food sources via external digestion. Plants obtain organic N from the environment or through symbiotic N-fixing bacteria; they obtain C from photosynthesis. Animals and fungi store polysaccharides as glycogen, while plants store them as starch. **20** By ingesting spores and disseminating them in the environment as waste, animals act as agents of dispersal. The benefit to the fungus outweighs the cost of producing fleshy fruiting bodies. **21** Chytridiomycota (Chytrids) may have a unicellular or multicellular body structure; some are aquatic with motile spores with flagella; an example is the *Allomyces*. Zygomycota (conjugated fungi) have a multicellular body structure; features include zygospores and presence in soil; examples are bread and fruit molds. Ascomycota (sac fungi) may have unicellular or multicellular body structure; a feature is sexual spores in sacs (asci); examples include the yeasts used in bread, wine, and beer production. Basidiomycota (club fungi) have multicellular bodies; features includes sexual spores in the basidiocarp (mushroom) and that they are mostly decomposers; mushroom-producing fungi are an example. **22** Protection from excess light that may bleach photosynthetic pigments allows the photosynthetic partner to survive in environments unfavorable to plants. **23** Dermatophytes that colonize skin break down the keratinized layer of dead cells that protects tissues from bacterial invasion. Once the integrity of the skin is breached, bacteria can enter the deeper layers of tissues and cause infections. **24** The dough is often contaminated by toxic spores that float in the air. It was one of Louis Pasteur's achievements to purify reliable strains of baker's yeast to produce bread consistently.

Chapter 25

1 Figure 25.5 B. **2** Figure 25.14 C. **3** Figure 25.21 D. **4** A **5** D **6** C **7** C **8** A **9** D **10** C **11** A **12** C **13** C **14** D **15** A **16** D **17** C **18** D **19** Sunlight is not filtered by water or other algae on land; therefore, there is no need to collect light at additional wavelengths made available by other pigment coloration. **20** Paleobotanists distinguish between extinct species, which no longer live, and extant species, which are still living. **21** It allows for survival through periodic droughts and colonization of environments where the supply of water fluctuates. **22** Mosses absorb water and nutrients carried by the rain and do not need soil because they do not derive much nutrition from the soil. **23** The bryophytes are divided into three phyla: the liverworts or Hepaticophyta, the hornworts or Anthocerotophyta, and the mosses or true Bryophyta. **24** Plants became able to transport water and nutrients and not be limited by rates of diffusion. Vascularization allowed the development of leaves, which increased efficiency of photosynthesis and provided more energy for plant growth. **25** Ferns are considered the most advanced seedless vascular plants, because they display characteristics commonly observed in seed plants—they form large leaves and branching roots.

Chapter 26

1 Figure 26.8 B. The diploid zygote forms after the pollen tube has finished forming, so that the male generative nuclei can fuse with the female gametophyte. **2** Figure 26.15 Without a megasporangium, an egg would not form; without a microsporangium, pollen would not form. **3** D **4** A **5** C **6** A **7** A **8** D **9** B **10** A **11** C **12** A **13** B **14** B **15** C **16** A **17** D **18** D **19** Both pollination and herbivory contributed to diversity, with plants needing to attract some insects and repel others. **20** Seeds and pollen allowed plants to reproduce in absence of water. This allowed them to expand their range onto dry land and to survive drought conditions. **21** The trees are adapted to arid weather, and do not lose as much water due to transpiration as non-conifers. **22** The four modern-day phyla of gymnosperms are Coniferophyta, Cycadophyta, Gingkophyta, and Gnetophyta. **23** The resemblance between cycads and palm trees is only superficial. Cycads are gymnosperms and do not bear flowers or fruit. Cycads produce cones: large, female cones that produce naked seeds, and smaller male cones on separate plants. Palms do not. **24** Angiosperms are successful because of flowers and fruit. These structures protect reproduction from variability in the environment. **25** Using animal pollinators promotes cross-pollination and increases genetic diversity. The

odds that the pollen will reach another flower are greatly increased compared with the randomness of wind pollination. **26** Biodiversity is the variation in all forms of life. It can refer to variation within a species, within an ecosystem, or on an entire planet. It is important because it ensures a resource for new food crops and medicines. Plant life balances the ecosystems, protects watersheds, mitigates erosion, moderates climate, and provides shelter for many animal species.

Chapter 27

1 Figure 27.5 The animal might develop two heads and no tail. **2** Figure 27.6 C **3** Figure 27.9 D **4** B **5** C **6** D **7** C **8** B **9** A **10** C **11** B **12** D **13** D **14** B **15** A **16** C **17**B **18** D **19** The development of specialized tissues affords more complex animal anatomy and physiology because differentiated tissue types can perform unique functions and work together in tandem to allow the animal to perform more functions. For example, specialized muscle tissue allows directed and efficient movement, and specialized nervous tissue allows for multiple sensory modalities as well as the ability to respond to various sensory information; these functions are not necessarily available to other non-animal organisms. **20** Humans are multicellular organisms. They also contain differentiated tissues, such as epithelial, muscle, and nervous tissue, as well as specialized organs and organ systems. As heterotrophs, humans cannot produce their own nutrients and must obtain them by ingesting other organisms, such as plants, fungi, and animals. Humans undergo sexual reproduction, as well as the same embryonic developmental stages as other animals, which eventually lead to a fixed and motile body plan controlled in large part by *Hox* genes. **21** Altered expression of homeotic genes can lead to major changes in the morphology of the individual. *Hox* genes can affect the spatial arrangements of organs and body parts. If a *Hox* gene was mutated or duplicated, it could affect where a leg might be on a fruit fly or how far apart a person's fingers are. **22** Humans have body plans that are bilaterally symmetrical and are characterized by the development of three germ layers, making them triploblasts. Humans have true coeloms and are thus eucoelomates. As deuterostomes, humans are characterized by radial and indeterminate cleavage. **23** The evolution of bilateral symmetry led to designated head and tail body regions, and promoted more efficient mobility for animals. This improved mobility allowed for more skillful seeking of resources and prey escaping from predators. The appearance of the coelom in coelomates provides many internal organs with shock absorption, making them less prone to physical damage from bodily assault. A coelom also gives the body greater flexibility, which promotes more efficient movement. The relatively loose placement of organs within the coelom allows them to develop and grow with some spatial freedom, which promoted the evolution of optimal organ arrangement. The coelom also provides space for a circulatory system, which is an advantageous way to distribute body fluids and gases. **24** Two new clades that comprise the two major groups of protostomes are called the lophotrochozoans and the ecdysozoans. The formation of these two clades came about through molecular research from DNA and protein data. Also, the novel phylum of worm called Acoelomorpha was determined due to molecular data that distinguished them from other flatworms. **25** In many cases, morphological similarities between animals may be only superficial similarities and may not indicate a true evolutionary relationship. One of the reasons for this is that certain morphological traits can evolve along very different evolutionary branches of animals for similar ecological reasons. **26** One theory states that environmental factors led to the Cambrian explosion. For example, the rise in atmospheric oxygen and oceanic calcium levels helped to provide the right environmental conditions to allow such a rapid evolution of new animal phyla. Another theory states that ecological factors such as competitive pressures and predator-prey relationships reached a threshold that supported the rapid animal evolution that took place during the Cambrian period. **27** It is true that multiple mass extinction events have taken place since the Cambrian period, when most currently existing animal phyla appeared, and the majority of animal species were commonly wiped out during these events. However, a small number of animal species representing each phylum were usually able to survive each extinction event, allowing the phylum to continue to evolve rather than become altogether extinct.

Chapter 28

1 Figure 28.3 B **2** Figure 28.20 D **3** Figure 28.36 C **4** B **5** D **6** D **7** C **8** B **9** A **10** C **11** B **12** D **13** C **14** A **15** B **16** D **17** C **18** Pinacocytes are epithelial-like cells, form the outermost layer of sponges, and enclose a jelly-like substance called mesohyl. In some sponges, porocytes form ostia, single tube-shaped cells that act as valves to regulate the flow of water into the spongocoel. Choanocytes ("collar cells") are present at various locations, depending on the type of sponge, but they always line some space through which water flows and are used in feeding. **19** The sponges draw water carrying food particles into the spongocoel using the beating of flagella on the choanocytes. The food particles are caught by the collar of the choanocyte and are brought into the cell by phagocytosis. Digestion of the food particle takes place inside the cell. The difference between this and the mechanisms of other animals is that digestion takes place within cells rather than outside of cells. It means that the organism can feed only on particles smaller than the cells themselves. **20** Nematocysts are "stinging cells" designed to paralyze prey. The nematocysts contain a neurotoxin that renders prey immobile. **21** Poriferans do not possess true tissues, while cnidarians do have tissues. Because of this difference, poriferans do not have a nervous system or muscles for locomotion, which cnidarians have. **22** Mollusks have a large muscular foot that may be modified in various ways, such

as into tentacles, but it functions in locomotion. They have a mantle, a structure of tissue that covers and encloses the dorsal portion of the animal, and secretes the shell when it is present. The mantle encloses the mantle cavity, which houses the gills (when present), excretory pores, anus, and gonadopores. The coelom of mollusks is restricted to the region around the systemic heart. The main body cavity is a hemocoel. Many mollusks have a radula near the mouth that is used for scraping food. **23** Mollusks have a shell, even if it is a reduced shell. Nemertines do not have a shell. Nemertines have a proboscis; mollusks do not. Nemertines have a closed circulatory system, whereas Mollusks have an open circulatory system. **24** It is a true animal with at least rudiments of the physiological systems—feeding, nervous, muscle, and reproductive—found in "higher animals" like mice and humans. It is so small that large numbers can be raised in Petri dishes. It reproduces rapidly. It is transparent so that every cell in the living animal can be seen under the microscope. Before it dies (after 2–3 weeks), it shows signs of aging and thus may provide general clues as to the aging process. **25** There are nematodes with separate sexes and hermaphrodites in addition to species that reproduce parthenogentically. The nematode *Caenorhabditis elegans* has a self-fertilizing hermaphrodite sex and a pure male sex. **26** The Arthropoda include the Hexapoda, which are mandibulates with six legs, the Myriapoda, which are mandibulates with many legs and include the centipedes and millipedes, the Crustacea, which are mostly marine mandibulates, and the Chelicerata, which include the spiders and scorpions and their kin. **27** Arthropods have an exoskeleton, which is missing in annelids. Arthropod segmentation is more specialized with major organs concentrated in body tagma. Annelid segmentation is usually more uniform with the intestine extending through most segments. **28** The Asteroidea are the sea stars, the Echinoidea are the sea urchins and sand dollars, the Ophiuroidea are the brittle stars, the Crinoidea are the sea lilies and feather stars, the Holothuroidea are the sea cucumbers.

Chapter 29

1 **Figure 29.3** A **2** **Figure 29.20** D **3** **Figure 29.22** The ancestor of modern Testudines may at one time have had a second opening in the skull, but over time this might have been lost. **4** B **5** A **6** C **7** B **8** D **9** A **10** C **11** D **12** B **13** D **14** A **15** D **16** A **17** A **18** The characteristic features of the phylum Chordata are a notochord, a dorsal hollow nerve cord, pharyngeal slits, and a post-anal tail. **19** Comparison of hagfishes with lampreys shows that the cranium evolved first in early vertebrates, as it is seen in hagfishes, which evolved earlier than lampreys. This was followed by evolution of the vertebral column, a primitive form of which is seen in lampreys and not in hagfishes. **20** Evolution of the jaw and paired fins permitted gnathostomes to diversify from the sedentary suspension feeding of agnathans to a mobile predatory lifestyle. The ability of gnathostomes to utilize new nutrient sources may be one reason why the gnathostomes replaced most agnathans. **21** A moist environment is required, as frog eggs lack a shell and dehydrate quickly in dry environments. **22** The larval stage of frogs is the tadpole, which is usually a filter-feeding herbivore. Tadpoles usually have gills, a lateral line system, long-finned tails, and lack limbs. In the adult form, the gills and lateral line system disappear, and four limbs develop. The jaws grow larger, suitable for carnivorous feeding, and the digestive system transforms into the typical short gut of a predator. An eardrum and air-breathing lungs also develop. **23** The chorion facilitates the exchange of oxygen and carbon dioxide gases between the embryo and the surrounding air. The amnion protects the embryo from mechanical shock and prevents dehydration. The allantois stores nitrogenous wastes produced by the embryo and facilitates respiration. **24** Lizards differ from snakes by having eyelids, external ears, and less kinematic skulls. **25** This is suggested by similarities observed between theropod fossils and birds, specifically in the design of the hip and wrist bones, as well as the presence of a furcula, or wishbone, formed by the fusing of the clavicles. **26** The sternum of birds is larger than that of other vertebrates, which accommodates the force required for flapping. Another skeletal modification is the fusion of the clavicles, forming the furcula or wishbone. The furcula is flexible enough to bend during flapping and provides support to the shoulder girdle during flapping. Birds also have pneumatic bones that are hollow rather than filled with tissue. **27** The lower jaw of mammals consists of only one bone, the dentary. The dentary bone joins the skull at the squamosal bone. Mammals have three bones of the middle ear. The adductor muscle that closes the jaw is composed of two muscles in mammals. Most mammals have heterodont teeth. **28** In some mammals, the cerebral cortex is highly folded, allowing for greater surface area than a smooth cortex. The optic lobes are divided into two parts in mammals. Eutherian mammals also possess a specialized structure that links the two cerebral hemispheres, called the corpus callosum. **29** Archaic *Homo sapiens* differed from modern humans by having a thick skull and a prominent brow ridge, and lacking a prominent chin. **30** The immediate ancestors of humans were *Australopithecus*. All people past and present, along with the australopithecines, are hominins. We share the adaptation of being habitually bipedal. The earliest australopithecines very likely did not evolve until 5 million years ago. The primate fossil record for this crucial transitional period leading to australopithecines is still sketchy and somewhat confusing. By about 2.5 million years ago, there were at least two evolutionary lines of hominins descended from early australopithecines.

Chapter 30

1 **Figure 30.7** A and B. The cortex, pith, and epidermis are made of parenchyma cells. **2** **Figure 30.32** Yes, you can equalize the water level by adding the solute to the left side of the tube such that water moves

toward the left until the water levels are equal. **3** Figure 30.34 B. **4** C **5** B **6** C **7** D **8** A **9** C **10** B **11** B **12** A **13** C **14** B **15** A **16** C **17** D **18** B **19** A **20** D **21** C **22** C **23** B **24** C **25** A **26** C **27** Lawn grasses and other monocots have an intercalary meristem, which is a region of meristematic tissue at the base of the leaf blade. This is beneficial to the plant because it can continue to grow even when the tip of the plant is removed by grazing or mowing. **28** Vascular tissue transports water, minerals, and sugars throughout the plant. Vascular tissue is made up of xylem tissue and phloem tissue. Xylem tissue transports water and nutrients from the roots upward. Phloem tissue carries sugars from the sites of photosynthesis to the rest of the plant. **29** Stomata allow gases to enter and exit the plant. Guard cells regulate the opening and closing of stomata. If these cells did not function correctly, a plant could not get the carbon dioxide needed for photosynthesis, nor could it release the oxygen produced by photosynthesis. **30** Xylem is made up tracheids and vessel elements, which are cells that transport water and dissolved minerals and that are dead at maturity. Phloem is made up of sieve-tube cells and companion cells, which transport carbohydrates and are alive at maturity. **31** In woody plants, the cork cambium is the outermost lateral meristem; it produces new cells towards the interior, which enables the plant to increase in girth. The cork cambium also produces cork cells towards the exterior, which protect the plant from physical damage while reducing water loss. **32** In woody stems, lenticels allow internal cells to exchange gases with the outside atmosphere. **33** Annual rings can also indicate the climate conditions that prevailed during each growing season. **34** Answers will vary. Rhizomes, stolons, and runners can give rise to new plants. Corms, tubers, and bulbs can also produce new plants and can store food. Tendrils help a plant to climb, while thorns discourage herbivores. **35** A tap root system has a single main root that grows down. A fibrous root system forms a dense network of roots that is closer to the soil surface. An example of a tap root system is a carrot. Grasses such as wheat, rice, and corn are examples of fibrous root systems. Fibrous root systems are found in monocots; tap root systems are found in dicots. **36** The root would not be able to produce lateral roots. **37** Monocots have leaves with parallel venation, and dicots have leaves with reticulate, net-like venation. **38** Conifers such as spruce, fir, and pine have needle-shaped leaves with sunken stomata, helping to reduce water loss. **39** The process of bulk flow moves water up the xylem and moves photosynthates (solutes) up and down the phloem. **40** A long-day plant needs a higher proportion of the Pfr form to Pr form of phytochrome. The plant requires long periods of illumination with light enriched in the red range of the spectrum. **41** Gravitropism will allow roots to dig deep into the soil to find water and minerals, whereas the seedling will grow towards light to enable photosynthesis. **42** Refrigeration slows chemical reactions, including fruit maturation. Ventilation removes the ethylene gas that speeds up fruit ripening. **43** To prevent further entry of pathogens, stomata close, even if they restrict entry of CO_2. Some pathogens secrete virulence factors that inhibit the closing of stomata. Abscisic acid is the stress hormone responsible for inducing closing of stomata.

Chapter 31

1 Figure 31.5 The air content of the soil decreases. **2** Figure 31.6 The A horizon is the topsoil, and the B horizon is subsoil. **3** Figure 31.9 Soybeans are able to fix nitrogen in their roots, which are not harvested at the end of the growing season. The belowground nitrogen can be used in the next season by the corn. **4** C **5** B **6** A **7** B **8** D **9** A **10** B **11** B **12** B **13** A **14** A **15** A **16** Deficiencies in these nutrients could result in stunted growth, slow growth, and chlorosis. **17** van Helmont showed that plants do not consume soil, which is correct. He also thought that plant growth and increased weight resulted from the intake of water, a conclusion that has since been disproven. **18** Answers may vary. Essential macronutrients include carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur. Essential micronutrients include iron, manganese, boron, molybdenum, copper, zinc, chlorine, nickel, cobalt, sodium, and silicon. **19** A mineral soil forms from the weathering of rocks; it is inorganic material. An organic soil is formed from sedimentation; it mostly consists of humus. **20** Parent material, climate, topography, biological factors, and time affect soil formation. Parent material is the material in which soils form. Climate describes how temperature, moisture, and wind cause different patterns of weathering, influencing the characteristics of the soil. Topography affects the characteristics and fertility of a soil. Biological factors include the presence of living organisms that greatly affect soil formation. Processes such as freezing and thawing may produce cracks in rocks; plant roots can penetrate these crevices and produce more fragmentation. Time affects soil because soil develops over long periods. **21** Topography affects water runoff, which strips away parent material and affects plant growth. Steeps soils are more prone to erosion and may be thinner than soils that are on level surfaces. **22** Because it is natural and does not require use of a nonrenewable resource, such as natural gas. **23** Photosynthesis harvests and stores energy, whereas biological nitrogen fixation requires energy. **24** A nodule results from the symbiosis between a plant and bacterium. Within nodules, the process of nitrogen fixation allows the plant to obtain nitrogen from the air.

Chapter 32

1 Figure 32.3 Pollen (or sperm); carpellate; staminate. **2** Figure 32.8 B: The pollen tube will form but will not be guided toward the egg. **3** Figure 32.20 B **4** B **5** D **6** A **7** A **8** B **9** B **10** D **11** C **12** A **13** C **14** D **15** C **16** Inside the flower are the reproductive organs of the plant. The stamen is the male reproductive organ. Pollen is produced in the stamen. The carpel is the female reproductive organ. The ovary is the swollen

base of the carpel where ovules are found. Not all flowers have every one of the four parts. **17** Plants have two distinct phases in their lifecycle: the gametophyte stage and the sporophyte stage. In the gametophyte stage, when reproductive cells undergo meiosis and produce haploid cells called spores, the gametophyte stage begins. Spores divide by cell division to form plant structures of an entirely new plant. The cells in these structures or plants are haploid. Some of these cells undergo cell division and form sex cells. Fertilization, the joining of haploid sex cells, begins the sporophyte stage. Cells formed in this stage have the diploid number of chromosomes. Meiosis in some of these cells forms spores, and the cycle begins again: a process known as alternation of generations. **18** A typical flower has four main parts, or whorls: the calyx, corolla, androecium, and gynoecium. The outermost whorl of the flower has green, leafy structures known as sepals, which are collectively called the calyx. It helps to protect the unopened bud. The second whorl is made up of brightly colored petals that are known collectively as the corolla. The third whorl is the male reproductive structure known as the androecium. The androecium has stamens, which have anthers on a stalk or filament. Pollen grains are borne on the anthers. The gynoecium is the female reproductive structure. The carpel is the individual structure of the gynoecium and has a stigma, the stalk or style, and the ovary. **19** If all four whorls of a flower are present, it is a complete flower. If any of the four parts is missing, it is known as incomplete. Flowers that contain both an androecium and gynoecium are called androgynous or hermaphrodites. Those that contain only an androecium are known as staminate flowers, and those that have only carpels are known as carpellate. If both male and female flowers are borne on the same plant, it is called monoecious, while plants with male and female flowers on separate plants are termed dioecious. **20** Many seeds enter a period of inactivity or extremely low metabolic activity, a process known as dormancy. Dormancy allows seeds to tide over unfavorable conditions and germinate on return to favorable conditions. Favorable conditions could be as diverse as moisture, light, cold, fire, or chemical treatments. After heavy rains, many new seedlings emerge. Forest fires also lead to the emergence of new seedlings. **21** Some fruits have built-in mechanisms that allow them to disperse seeds by themselves, but others require the assistance of agents like wind, water, and animals. Fruit that are dispersed by the wind are light in weight and often have wing-like appendages that allow them to be carried by the wind; other have structures resembling a parachute that keep them afloat in the wind. Some fruits, such as those of dandelions, have hairy, weightless structures that allow them to float in the wind. Fruits dispersed by water are light and buoyant, giving them the ability to float; coconuts are one example. Animals and birds eat fruits and disperse their seeds by leaving droppings at distant locations. Other animals bury fruit that may later germinate. Some fruits stick to animals' bodies and are carried to new locations. People also contribute to seed dispersal when they carry fruits to new places. **22** Asexual reproduction does not require the expenditure of the plant's resources and energy that would be involved in producing a flower, attracting pollinators, or dispersing seeds. Asexual reproduction results in plants that are genetically identical to the parent plant, since there is no mixing of male and female gametes, resulting in better survival. The cuttings or buds taken from an adult plant produce progeny that mature faster and are sturdier than a seedling grown from a seed. **23** Asexual reproduction in plants can take place by natural methods or artificial methods. Natural methods include strategies used by the plant to propagate itself. Artificial methods include grafting, cutting, layering, and micropropagation. **24** Plant species that complete their life cycle in one season are known as annuals. Biennials complete their life cycle in two seasons. In the first season, the plant has a vegetative phase, whereas in the next season, it completes its reproductive phase. Perennials, such as the magnolia, complete their life cycle in two years or more. **25** Monocarpic plants flower only once during their lifetime. During the vegetative period of their lifecycle, these plants accumulate a great deal of food material that will be required during their once-in-a-lifetime flowering and setting of seed after fertilization. Soon after flowering, these plants die. Polycarpic plants flower several times during their life span; therefore, not all nutrients are channelled towards flowering.

Chapter 33

1 Figure 33.11 A **2** Figure 33.21 Both processes are the result of negative feedback loops. Negative feedback loops, which tend to keep a system at equilibrium, are more common than positive feedback loops. **3** Figure 33.22 Pyrogens increase body temperature by causing the blood vessels to constrict, inducing shivering, and stopping sweat glands from secreting fluid. **4** A **5** B **6** C **7** B **8** D **9** B **10** C **11** B **12** D **13** B **14** D **15** C **16** A **17** B **18** B **19** B **20** C **21** A **22** D **23** B **24** Diffusion is effective over a very short distance. If a cell exceeds this distance in its size, the center of the cell cannot get adequate nutrients nor can it expel enough waste to survive. To compensate for this, cells can loosely adhere to each other in a liquid medium, or develop into multi-celled organisms that use circulatory and respiratory systems to deliver nutrients and remove wastes. **25** Basal Metabolic Rate is an expression of the metabolic processes that occur to maintain an individual's functioning and body temperature. Smaller bodied animals have a relatively large surface area compared to a much larger animal. The large animal's large surface area leads to increased heat loss that the animal must compensate for, resulting in a higher BMR. A small animal, having less relative surface area, does not lose as much heat and has a correspondingly lower BMR. **26** Squamous epithelia can be either simple or stratified. As a single layer of cells, it presents a very thin epithelia that minimally inhibits diffusion. As a stratified epithelia, the surface cells can be sloughed off and the cells in deeper layers protect the underlying tissues from damage. **27** Both contain cells other than the traditional fibroblast. Both have cells that lodge in spaces within the tissue called lacunae. Both collagen and elastic fibers are found in bone and cartilage. Both tissues participate in vertebrate skeletal development and formation. **28** An adjustment

to a change in the internal or external environment requires a change in the direction of the stimulus. A negative feedback loop accomplishes this, while a positive feedback loop would continue the stimulus and result in harm to the animal. **29** Mammalian enzymes increase activity to the point of denaturation, increasing the chemical activity of the cells involved. Bacterial enzymes have a specific temperature for their most efficient activity and are inhibited at either higher or lower temperatures. Fever results in an increase in the destruction of the invading bacteria by increasing the effectiveness of body defenses and an inhibiting bacterial metabolism. **30** Diabetes is often associated with a lack in production of insulin. Without insulin, blood glucose levels go up after a meal, but never go back down to normal levels.

Chapter 34

1 Figure 34.11 B **2** Figure 34.12 C **3** Figure 34.19 C **4** D **5** B **6** C **7** C **8** A **9** D **10** A **11** C **12** A **13** B **14** C **15** B **16** Animals with a polygastric digestive system have a multi-chambered stomach. The four compartments of the stomach are called the rumen, reticulum, omasum, and abomasum. These chambers contain many microbes that break down the cellulose and ferment the ingested food. The abomasum is the "true" stomach and is the equivalent of a monogastric stomach chamber where gastric juices are secreted. The four-compartment gastric chamber provides larger space and the microbial support necessary for ruminants to digest plant material. **17** Birds have a stomach chamber called a gizzard. Here, the food is stored, soaked, and ground into finer particles, often using pebbles. Once this process is complete, the digestive juices take over in the proventriculus and continue the digestive process. **18** Accessory organs play an important role in producing and delivering digestive juices to the intestine during digestion and absorption. Specifically, the salivary glands, liver, pancreas, and gallbladder play important roles. Malfunction of any of these organs can lead to disease states. **19** The villi and microvilli are folds on the surface of the small intestine. These folds increase the surface area of the intestine and provide more area for the absorption of nutrients. **20** Essential nutrients are those nutrients that must be obtained from the diet because they cannot be produced by the body. Vitamins and minerals are examples of essential nutrients. **21** Minerals—such as potassium, sodium, and calcium—are required for the functioning of many cellular processes, including muscle contraction and nerve conduction. While minerals are required in trace amounts, not having minerals in the diet can be potentially harmful. **22** In the United States, obesity, particularly childhood obesity, is a growing concern. Some of the contributors to this situation include sedentary lifestyles and consuming more processed foods and less fruits and vegetables. As a result, even young children who are obese can face health concerns. **23** Malnutrition, often in the form of not getting enough calories or not enough of the essential nutrients, can have severe consequences. Many malnourished children have vision and dental problems, and over the years may develop many serious health problems. **24** Lipids add flavor to food and promote a sense of satiety or fullness. Fatty foods are sources of high energy; one gram of lipid contains nine calories. Lipids are also required in the diet to aid the absorption of lipid-soluble vitamins and for the production of lipid-soluble hormones. **25** Hormones control the different digestive enzymes that are secreted in the stomach and the intestine during the process of digestion and absorption. For example, the hormone gastrin stimulates stomach acid secretion in response to food intake. The hormone somatostatin stops the release of stomach acid. **26** There are many cases where loss of hormonal regulation can lead to illnesses. For example, the bilirubin produced by the breakdown of red blood cells is converted to bile by the liver. When there is malfunction of this process, there is excess bilirubin in the blood and bile levels are low. As a result, the body struggles with dealing with fatty food. This is why a patient suffering from jaundice is asked to eat a diet with almost zero fat.

Chapter 35

1 Figure 35.3 B **2** Figure 35.11 Potassium channel blockers slow the repolarization phase, but have no effect on depolarization. **3** Figure 35.26 D **4** C **5** B **6** B **7** B **8** B **9** C **10** D **11** B **12** B **13** C **14** B **15** A **16** B **17** C **18** B **19** Neurons contain organelles common to all cells, such as a nucleus and mitochondria. They are unique because they contain dendrites, which can receive signals from other neurons, and axons that can send these signals to other cells. **20** Myelin provides insulation for signals traveling along axons. Without myelin, signal transmission can slow down and degrade over time. This would slow down neuronal communication across the nervous system and affect all downstream functions. **21** Myelin prevents the leak of current from the axon. Nodes of Ranvier allow the action potential to be regenerated at specific points along the axon. They also save energy for the cell since voltage-gated ion channels and sodium-potassium transporters are not needed along myelinated portions of the axon. **22** An action potential travels along an axon until it depolarizes the membrane at an axon terminal. Depolarization of the membrane causes voltage-gated Ca^{2+} channels to open and Ca^{2+} to enter the cell. The intracellular calcium influx causes synaptic vesicles containing neurotransmitter to fuse with the presynaptic membrane. The neurotransmitter diffuses across the synaptic cleft and binds to receptors on the postsynaptic membrane. Depending on the specific neurotransmitter and postsynaptic receptor, this action can cause positive (excitatory postsynaptic potential) or negative (inhibitory postsynaptic potential) ions to enter the cell. **23** To determine the function of a specific brain area, scientists can look at patients who have damage in that brain area and see what symptoms they exhibit. Researchers can disable the brain structure temporarily using transcranial magnetic stimulation. They can disable or remove the area in an animal model. fMRI can be used to correlate specific functions with

increased blood flow to brain regions. **24** The spinal cord transmits sensory information from the body to the brain and motor commands from the brain to the body through its connections with peripheral nerves. It also controls motor reflexes. **25** The sympathetic nervous system prepares the body for "fight or flight," whereas the parasympathetic nervous system allows the body to "rest and digest." Sympathetic neurons release norepinephrine onto target organs; parasympathetic neurons release acetylcholine. Sympathetic neuron cell bodies are located in sympathetic ganglia. Parasympathetic neuron cell bodies are located in the brainstem and sacral spinal cord. Activation of the sympathetic nervous system increases heart rate and blood pressure and decreases digestion and blood flow to the skin. Activation of the parasympathetic nervous system decreases heart rate and blood pressure and increases digestion and blood flow to the skin. **26** The sensory-somatic nervous system transmits sensory information from the skin, muscles, and sensory organs to the CNS. It also sends motor commands from the CNS to the muscles, causing them to contract. **27** Symptoms of Alzheimer's disease include disruptive memory loss, confusion about time or place, difficulties planning or executing tasks, poor judgment, and personality changes. **28** Possible treatments for patients with major depression include psychotherapy and prescription medications. MAO inhibitor drugs inhibit the breakdown of certain neurotransmitters (including dopamine, serotonin, norepinephrine) in the synaptic cleft. SSRI medications inhibit the reuptake of serotonin into the presynaptic neuron.

Chapter 36

1 Figure 36.5 D **2** Figure 36.14 B **3** Figure 36.17 A **4** B **5** D **6** A **7** B **8** A **9** D **10** A **11** A **12** B **13** D **14** A **15** B **16** B **17** C **18** D **19** Transmission of sensory information from the receptor to the central nervous system will be impaired, and thus, perception of stimuli, which occurs in the brain, will be halted. **20** The just-noticeable difference is a fraction of the overall magnitude of the stimulus and seems to be a relatively fixed proportion (such as 10 percent) whether the stimulus is large (such as a very heavy object) or small (such as a very light object). **21** The cortical areas serving skin that is densely innervated likely are larger than those serving skin that is less densely innervated. **22** Pheromones may not be consciously perceived, and pheromones can have direct physiological and behavioral effects on their recipients. **23** The animal might not be able to recognize the differences in food sources and thus might not be able to discriminate between spoiled food and safe food or between foods that contain necessary nutrients, such as proteins, and foods that do not. **24** The sound would slow down, because it is transmitted through the particles (gas) and there are fewer particles (lower density) at higher altitudes. **25** Because vestibular sensation relies on gravity's effects on tiny crystals in the inner ear, a situation of reduced gravity would likely impair vestibular sensation. **26** The pineal gland could use length-of-day information to determine the time of year, for example. Day length is shorter in the winter than it is in the summer. For many animals and plants, photoperiod cues them to reproduce at a certain time of year. **27** The photoreceptors tonically inhibit the bipolar cells, and stimulation of the receptors turns this inhibition off, activating the bipolar cells.

Chapter 37

1 Figure 37.5 Proteins unfold, or denature, at higher temperatures. **2** Figure 37.11 B **3** Figure 37.14 Patient A has symptoms associated with decreased metabolism, and may be suffering from hypothyroidism. Patient B has symptoms associated with increased metabolism, and may be suffering from hyperthyroidism. **4** C **5** A **6** D **7** D **8** A **9** B **10** C **11** D **12** A **13** B **14** C **15** A **16** Although there are many different hormones in the human body, they can be divided into three classes based on their chemical structure: lipid-derived, amino acid-derived, and peptide hormones. One of the key distinguishing features of the lipid-derived hormones is that they can diffuse across plasma membranes whereas the amino acid-derived and peptide hormones cannot. **17** Secreted peptides such as insulin are stored within vesicles in the cells that synthesize them. They are then released in response to stimuli such as high blood glucose levels in the case of insulin. **18** The number of receptors that respond to a hormone can change, resulting in increased or decreased cell sensitivity. The number of receptors can increase in response to rising hormone levels, called up-regulation, making the cell more sensitive to the hormone and allowing for more cellular activity. The number of receptors can also decrease in response to rising hormone levels, called down-regulation, leading to reduced cellular activity. **19** Depending on the location of the protein receptor on the target cell and the chemical structure of the hormone, hormones can mediate changes directly by binding to intracellular receptors and modulating gene transcription, or indirectly by binding to cell surface receptors and stimulating signaling pathways. **20** In addition to producing FSH and LH, the anterior pituitary also produces the hormone prolactin (PRL) in females. Prolactin stimulates the production of milk by the mammary glands following childbirth. Prolactin levels are regulated by the hypothalamic hormones prolactin-releasing hormone (PRH) and prolactin-inhibiting hormone (PIH) which is now known to be dopamine. PRH stimulates the release of prolactin and PIH inhibits it. The posterior pituitary releases the hormone oxytocin, which stimulates contractions during childbirth. The uterine smooth muscles are not very sensitive to oxytocin until late in pregnancy when the number of oxytocin receptors in the uterus peaks. Stretching of tissues in the uterus and vagina stimulates oxytocin release in childbirth. Contractions increase in intensity as blood levels of oxytocin rise until the birth is complete. **21** Hormonal regulation is required for the growth and replication of most cells in the body. Growth hormone (GH), produced by the anterior pituitary, accelerates the rate of protein synthesis, particularly

in skeletal muscles and bones. Growth hormone has direct and indirect mechanisms of action. The direct actions of GH include: 1) stimulation of fat breakdown (lipolysis) and release into the blood by adipocytes. This results in a switch by most tissues from utilizing glucose as an energy source to utilizing fatty acids. This process is called a glucose-sparing effect. 2) In the liver, GH stimulates glycogen breakdown, which is then released into the blood as glucose. Blood glucose levels increase as most tissues are utilizing fatty acids instead of glucose for their energy needs. The GH mediated increase in blood glucose levels is called a diabetogenic effect because it is similar to the high blood glucose levels seen in diabetes mellitus. **22** Hormone production and release are primarily controlled by negative feedback. In negative feedback systems, a stimulus causes the release of a substance whose effects then inhibit further release. In this way, the concentration of hormones in blood is maintained within a narrow range. For example, the anterior pituitary signals the thyroid to release thyroid hormones. Increasing levels of these hormones in the blood then feed back to the hypothalamus and anterior pituitary to inhibit further signaling to the thyroid gland. **23** The term humoral is derived from the term humor, which refers to bodily fluids such as blood. Humoral stimuli refer to the control of hormone release in response to changes in extracellular fluids such as blood or the ion concentration in the blood. For example, a rise in blood glucose levels triggers the pancreatic release of insulin. Insulin causes blood glucose levels to drop, which signals the pancreas to stop producing insulin in a negative feedback loop. Hormonal stimuli refer to the release of a hormone in response to another hormone. A number of endocrine glands release hormones when stimulated by hormones released by other endocrine organs. For example, the hypothalamus produces hormones that stimulate the anterior pituitary. The anterior pituitary in turn releases hormones that regulate hormone production by other endocrine glands. For example, the anterior pituitary releases thyroid-stimulating hormone, which stimulates the thyroid gland to produce the hormones T_3 and T_4. As blood concentrations of T_3 and T_4 rise they inhibit both the pituitary and the hypothalamus in a negative feedback loop. **24** The main mineralocorticoid is aldosterone, which regulates the concentration of ions in urine, sweat, and saliva. Aldosterone release from the adrenal cortex is stimulated by a decrease in blood concentrations of sodium ions, blood volume, or blood pressure, or an increase in blood potassium levels. **25** The adrenal medulla contains two types of secretory cells, one that produces epinephrine (adrenaline) and another that produces norepinephrine (noradrenaline). Epinephrine is the primary adrenal medulla hormone accounting for 75–80 percent of its secretions. Epinephrine and norepinephrine increase heart rate, breathing rate, cardiac muscle contractions, and blood glucose levels. They also accelerate the breakdown of glucose in skeletal muscles and stored fats in adipose tissue. The release of epinephrine and norepinephrine is stimulated by neural impulses from the sympathetic nervous system. These neural impulses originate from the hypothalamus in response to stress to prepare the body for the fight-or-flight response.

Chapter 38

1 **Figure 38.19**B **2** **Figure 38.37** B **3** **Figure 38.38** In the presence of Sarin, acetycholine is not removed from the synapse, resulting in continuous stimulation of the muscle plasma membrane. At first, muscle activity is intense and uncontrolled, but the ion gradients dissipate, so electrical signals in the T-tubules are no longer possible. The result is paralysis, leading to death by asphyxiation. **4** A **5** C **6** D **7** C **8** B **9** C **10** A **11** C **12** B **13** D **14** C **15** A **16** D **17** B **18** D **19** D **20** The female pelvis is tilted forward and is wider, lighter, and shallower than the male pelvis. It is also has a pubic angle that is broader than the male pelvis. **21** The pelvic girdle is securely attached to the body by strong ligaments, unlike the pectoral girdle, which is sparingly attached to the ribcage. The sockets of the pelvic girdle are deep, allowing the femur to be more stable than the pectoral girdle, which has shallow sockets for the scapula. Most tetrapods have 75 percent of their weight on the front legs because the head and neck are so heavy; the advantage of the shoulder joint is more degrees of freedom in movement. **22** Compact bone tissue forms the hard external layer of all bones and consists of osteons. Compact bone tissue is prominent in areas of bone at which stresses are applied in only a few directions. Spongy bone tissue forms the inner layer of all bones and consists of trabeculae. Spongy bone is prominent in areas of bones that are not heavily stressed or at which stresses arrive from many directions. **23** Osteocytes function in the exchange of nutrients and wastes with the blood. They also maintain normal bone structure by recycling the mineral salts in the bony matrix. Osteoclasts remove bone tissue by releasing lysosomal enzymes and acids that dissolve the bony matrix. Osteoblasts are bone cells that are responsible for bone formation. **24** The hip joint is flexed and the knees are extended. **25** Elevation is the movement of a bone upward, such as when the shoulders are shrugged, lifting the scapulae. Depression is the downward movement of a bone, such as after the shoulders are shrugged and the scapulae return to their normal position from an elevated position. **26** Because ATP is required for myosin to release from actin, muscles would remain rigidly contracted until more ATP was available for the myosin cross-bridge release. This is why dead vertebrates undergo rigor mortis. **27** The cross-sectional area, the length of the muscle fiber at rest, and the frequency of neural stimulation. **28** Neurons will not be able to release neurotransmitter without calcium. Skeletal muscles have calcium stored and don't need any from the outside.

Chapter 39

1 **Figure 39.7** B **2** **Figure 39.13** C **3** **Figure 39.20** The blood pH will drop and hemoglobin affinity for oxygen will decrease. **4** A **5** C **6** B **7** D **8** D **9** D **10** B **11** B **12** D **13** A **14** C **15** D **16** The main

bronchus is the conduit in the lung that funnels air to the airways where gas exchange occurs. The main bronchus attaches the lungs to the very end of the trachea where it bifurcates. The trachea is the cartilaginous structure that extends from the pharynx to the primary bronchi. It serves to funnel air to the lungs. The alveoli are the sites of gas exchange; they are located at the terminal regions of the lung and are attached to the respiratory bronchioles. The acinus is the structure in the lung where gas exchange occurs. **17** The sac-like structure of the alveoli increases their surface area. In addition, the alveoli are made of thin-walled parenchymal cells. These features allow gases to easily diffuse across the cells. **18** FEV1/FVC measures the forced expiratory volume in one second in relation to the total forced vital capacity (the total amount of air that is exhaled from the lung from a maximal inhalation). This ratio changes with alterations in lung function that arise from diseases such as fibrosis, asthma, and COPD. **19** If all the air in the lung were exhaled, then opening the alveoli for the next inspiration would be very difficult. This is because the tissues would stick together. **20** Oxygen moves from the lung to the bloodstream to the tissues according to the pressure gradient. This is measured as the partial pressure of oxygen. If the amount of oxygen drops in the inspired air, there would be reduced partial pressure. This would decrease the driving force that moves the oxygen into the blood and into the tissues. P_{O_2} is also reduced at high elevations: P_{O_2} at high elevations is lower than at sea level because the total atmospheric pressure is less than atmospheric pressure at sea level. **21** A doctor can detect a restrictive disease using spirometry. By detecting the rate at which air can be expelled from the lung, a diagnosis of fibrosis or another restrictive disease can be made. **22** Increased airway resistance increases the volume and pressure in the lung; therefore, the intrapleural pressure would be less negative and breathing would be more difficult. **23** A puncture to the thoracic cavity would equalize the pressure inside the thoracic cavity to the outside environment. For the lung to function properly, the intrapleural pressure must be negative. This is caused by the contraction of the diaphragm pulling the lungs down and drawing air into the lungs. **24** The lung is particularly susceptible to changes in the magnitude and direction of gravitational forces. When someone is standing or sitting upright, the pleural pressure gradient leads to increased ventilation further down in the lung. **25** Without carbonic anhydrase, carbon dioxide would not be hydrolyzed into carbonic acid or bicarbonate. Therefore, very little carbon dioxide (only 15 percent) would be transported in the blood away from the tissues. **26** Carbon monoxide has a higher affinity for hemoglobin than oxygen. This means that carbon monoxide will preferentially bind to hemoglobin over oxygen. Administration of 100 percent oxygen is an effective therapy because at that concentration, oxygen will displace the carbon monoxide from the hemoglobin.

Chapter 40

1 Figure 40.10 C **2** Figure 40.11 B **3** Figure 40.17 Blood in the legs is farthest away from the heart and has to flow up to reach it. **4** A **5** D **6** C **7** D **8** C **9** B **10** C **11** B **12** A **13** D **14** A **15** A **16** A closed circulatory system is a closed-loop system, in which blood is not free in a cavity. Blood is separate from the bodily interstitial fluid and contained within blood vessels. In this type of system, blood circulates unidirectionally from the heart around the systemic circulatory route, and then returns to the heart. **17** Systemic circulation flows through the systems of the body. The blood flows away from the heart to the brain, liver, kidneys, stomach, and other organs, the limbs, and the muscles of the body; it then returns to the heart. **18** Red blood cells are coated with proteins called antigens made of glycolipids and glycoproteins. When type A and type B blood are mixed, the blood agglutinates because of antibodies in the plasma that bind with the opposing antigen. Type O blood has no antigens. The Rh blood group has either the Rh antigen (Rh+) or no Rh antigen (Rh–). **19** Blood is important for regulation of the body's pH, temperature, and osmotic pressure, the circulation of nutrients and removal of wastes, the distribution of hormones from endocrine glands, the elimination of excess heat; it also contains components for the clotting of blood to prevent blood loss. Blood also transports clotting factors and disease-fighting agents. **20** Lymph capillaries take fluid from the blood to the lymph nodes. The lymph nodes filter the lymph by percolation through connective tissue filled with white blood cells. The white blood cells remove infectious agents, such as bacteria and viruses, to clean the lymph before it returns to the bloodstream. **21** The heart receives an electrical signal from the sinoatrial node triggering the cardiac muscle cells in the atria to contract. The signal pauses at the atrioventricular node before spreading to the walls of the ventricles so the blood is pumped through the body. This is the systolic phase. The heart then relaxes in the diastole and fills again with blood. **22** The capillaries basically exchange materials with their surroundings. Their walls are very thin and are made of one or two layers of cells, where gases, nutrients, and waste are diffused. They are distributed as beds, complex networks that link arteries as well as veins. **23** The heart rate increases, which increases the hydrostatic pressure against the artery walls. At the same time, the arterioles dilate in response to the increased exercise, which reduces peripheral resistance.

Chapter 41

1 Figure 41.5 C **2** Figure 41.6 A **3** Figure 41.8 Loop diuretics decrease the excretion of salt into the renal medulla, thereby reducing its osmolality. As a result, less water is excreted into the medulla by the descending limb, and more water is excreted as urine. **4** B **5** B **6** A **7** C **8** B **9** A **10** C **11** D **12** D **13** A **14** C **15** A **16** C **17** A **18** Excretion allows an organism to rid itself of waste molecules that could be toxic

if allowed to accumulate. It also allows the organism to keep the amount of water and dissolved solutes in balance. **19** Electrolyte ions often require special mechanisms to cross the semi-permeable membranes in the body. Active transport is the movement against a concentration gradient. **20** The loop of Henle is part of the renal tubule that loops into the renal medulla. In the loop of Henle, the filtrate exchanges solutes and water with the renal medulla and the vasa recta (the peritubular capillary network). The vasa recta acts as the countercurrent exchanger. The kidneys maintain the osmolality of the rest of the body at a constant 300 mOsm by concentrating the filtrate as it passes through the loop of Henle. **21** Externally, the kidneys are surrounded by three layers. The outermost layer is a tough connective tissue layer called the renal fascia. The second layer is called the perirenal fat capsule, which helps anchor the kidneys in place. The third and innermost layer is the renal capsule. Internally, the kidney has three regions—an outer cortex, a medulla in the middle, and the renal pelvis in the region called the hilum of the kidney, which is the concave part of the "bean" shape. **22** The removal of wastes, which could otherwise be toxic to an organism, is extremely important for survival. Having organs that specialize in this process and that operate separately from other organs provides a measure of safety for the organism. **23** (1) Microorganisms engulf food by endocytosis—the formation of vacuoles by involution of the cell membrane within the cells. The same vacuoles interact and exchange metabolites with the intracellular environment. Cellular wastes are excreted by exocytosis when the vacuoles merge with the cell membrane and excrete wastes into the environment. (2) Flatworms have an excretory system that consists of two tubules. The cells in the tubules are called flame cells; they have a cluster of cilia that propel waste matter down the tubules and out of the body. (3) Annelids have nephridia which have a tubule with cilia. Excretion occurs through a pore called the nephridiopore. Annelids have a system for tubular reabsorption by a capillary network before excretion. (4) Malpighian tubules are found in some species of arthropods. They are usually found in pairs, and the number of tubules varies with the species of insect. Malpighian tubules are convoluted, which increases their surface area, and they are lined with microvilli for reabsorption and maintenance of osmotic balance. Metabolic wastes like uric acid freely diffuse into the tubules. Potassium ion pumps line the tubules, which actively transport out K^+ ions, and water follows to form urine. Water and electrolytes are reabsorbed when these organisms are faced with low-water environments, and uric acid is excreted as a thick paste or powder. By not dissolving wastes in water, these organisms conserve water. **24** It is believed that the urea cycle evolved to adapt to a changing environment when terrestrial life forms evolved. Arid conditions probably led to the evolution of the uric acid pathway as a means of conserving water. **25** The urea cycle is the primary mechanism by which mammals convert ammonia to urea. Urea is made in the liver and excreted in urine. The urea cycle utilizes five intermediate steps, catalyzed by five different enzymes, to convert ammonia to urea. Birds, reptiles, and insects, on the other hand, convert toxic ammonia to uric acid instead of urea. Conversion of ammonia to uric acid requires more energy and is much more complex than conversion of ammonia to urea. **26** Hormones are small molecules that act as messengers within the body. Different regions of the nephron bear specialized cells, which have receptors to respond to chemical messengers and hormones. The hormones carry messages to the kidney. These hormonal cues help the kidneys synchronize the osmotic needs of the body. Hormones like epinephrine, norepinephrine, renin-angiotensin, aldosterone, anti-diuretic hormone, and atrial natriuretic peptide help regulate the needs of the body as well as the communication between the different organ systems. **27** The renin-angiotensin-aldosterone system acts through several steps to produce angiotensin II, which acts to stabilize blood pressure and volume. Thus, the kidneys control blood pressure and volume directly. Renin acts on angiotensinogen, which is made in the liver and converts it to angiotensin I. ACE (angiotensin converting enzyme) converts angiotensin I to angiotensin II. Angiotensin II raises blood pressure by constricting blood vessels. It triggers the release of aldosterone from the adrenal cortex, which in turn stimulates the renal tubules to reabsorb more sodium. Angiotensin II also triggers the release of anti-diuretic hormone from the hypothalamus, which leads to water retention. It acts directly on the nephrons and decreases GFR.

Chapter 42

1 **Figure 42.11** C **2** **Figure 42.14** MHC receptors differ from person to person. Thus, MHC receptors on an incompatible donor are considered "non-self" and are rejected by the immune system. **3** **Figure 42.16** If the blood of the mother and fetus mixes, memory cells that recognize the Rh antigen can form late in the first pregnancy. During subsequent pregnancies, these memory cells launch an immune attack on the fetal blood cells. Injection of anti-Rh antibody during the first pregnancy prevents the immune response from occurring. **4** D **5** B **6** A **7** C **8** D **9** B **10** B **11** C **12** D **13** A **14** C **15** A **16** C **17** B **18** D **19** B **20** C **21** D **22** If the MHC I molecules expressed on donor cells differ from the MHC I molecules expressed on recipient cells, NK cells may identify the donor cells as "non-self" and produce perforin and granzymes to induce the donor cells to undergo apoptosis, which would destroy the transplanted organ. **23** The entire complement system would probably be affected even when only a few members were mutated such that they could no longer bind. Because the complement involves the binding of activated proteins in a specific sequence, when one or more proteins in the sequence are absent, the subsequent proteins would be incapable of binding to elicit the complement's pathogen-destructive effects. **24** An antigen is a molecule that reacts with some component of the immune response (antibody, B cell receptor, T cell receptor). An epitope is the region on the antigen through which binding with the immune component actually occurs. **25** A naïve T or B cell is one that has not been activated by binding to the appropriate epitope. Naïve T and B cells cannot produce

responses. **26** The T_H1 response involves the secretion of cytokines to stimulate macrophages and CTLs and improve their destruction of intracellular pathogens and tumor cells. It is associated with inflammation. The T_H2 response is involved in the stimulation of B cells into plasma cells that synthesize and secrete antibodies. **27** The diversity of TCRs allows the immune system to have millions of different T cells, and thereby to be specific in distinguishing antigens. This diversity arises from mutation and recombination in the genes that encode the variable regions of TCRs. **28** T cells bind antigens that have been digested and embedded in MHC molecules by APCs. In contrast, B cells function themselves as APCs to bind intact, unprocessed antigens. **29** Upon reinfection, the memory cells will immediately differentiate into plasma cells and CTLs without input from APCs or T_H cells. In contrast, the adaptive immune response to the initial infection requires time for naïve B and T cells with the appropriate antigen specificities to be identified and activated. **30** Cross reactivity of antibodies can be beneficial when it allows an individual's immune system to respond to an array of similar pathogens after being exposed to just one of them. A potential cost of cross reactivity is an antibody response to parts of the body (self) in addition to the appropriate antigen.

Chapter 43

1 **Figure 43.8** D **2** **Figure 43.15** C **3** **Figure 43.17** B **4** A **5** B **6** D **7** A **8** A **9** C **10** A **11** C **12** C **13** A **14** A **15** D **16** A **17** A **18** C **19** B **20** D **21** B **22** A **23** D **24** B **25** A **26** B **27** B **28** D **29** A **30** D **31** Sexual reproduction produces a new combination of genes in the offspring that may better enable them to survive changes in the environment and assist in the survival of the species. **32** The presence of the W chromosome in birds determines femaleness and the presence of the Y chromosome in mammals determines maleness. The absence of those chromosomes and the homogeneity of the offspring (ZZ or XX) leads to the development of the other sex. **33** External fertilization can create large numbers of offspring without requiring specialized delivery or reproductive support organs. Offspring develop and mature quickly compared to internally fertilizing species. A disadvantage is that the offspring are out in the environment and predation can account for large loss of offspring. The embryos are susceptible to changes in the environment, which further depletes their numbers. Internally fertilizing species control their environment and protect their offspring from predators but must have specialized organs to complete these tasks and usually produce fewer embryos. **34** Paired external fertilization allows the female to select the male for mating. It also has a greater chance of fertilization taking place, whereas spawning just puts a large number of sperm and eggs together and random interactions result in the fertilization. **35** In phase one (excitement), vasodilation leads to vasocongestion and enlargement of erectile tissues. Vaginal secretions are released to lubricate the vagina during intercourse. In phase two (plateau), stimulation continues, the outer third of the vaginal wall enlarges with blood, and breathing and heart rate increase. In phase three (orgasm), rhythmic, involuntary contractions of muscles occur. In the male, reproductive accessory glands and tubules constrict, depositing semen in the urethra; then, the urethra contracts, expelling the semen through the penis. In women, the uterus and vaginal muscles contract in waves that may last slightly less than a second each. In phase four (resolution), the processes listed in the first three phases reverse themselves and return to their normal state. Men experience a refractory period in which they cannot maintain an erection or ejaculate for a period of time ranging from minutes to hours. Women do not experience a refractory period. **36** Stem cells are laid down in the male during gestation and lie dormant until adolescence. Stem cells in the female increase to one to two million and enter the first meiotic division and are arrested in prophase. At adolescence, spermatogenesis begins and continues until death, producing the maximum number of sperm with each meiotic division. Oogenesis continues again at adolescence in batches of oogonia with each menstrual cycle. These oogonia finish the first meiotic division, producing a primary oocyte with most of the cytoplasm and its contents, and a second cell called a polar body containing 23 chromosomes. The second meiotic division results in a secondary oocyte and a second oocyte. At ovulation, a mature haploid egg is released. If this egg is fertilized, it finishes the second meiotic division, including the chromosomes donated by the sperm in the finished cell. This is a diploid, fertilized egg. **37** Negative feedback in the male system is supplied through two hormones: inhibin and testosterone. Inhibin is produced by Sertoli cells when the sperm count exceeds set limits. The hormone inhibits GnRH and FSH, decreasing the activity of the Sertoli cells. Increased levels of testosterone affect the release of both GnRH and LH, decreasing the activity of the Leydig cells, resulting in decreased testosterone and sperm production. **38** Low levels of progesterone allow the hypothalamus to send GnRH to the anterior pituitary and cause the release of FSH and LH. FSH stimulates follicles on the ovary to grow and prepare the eggs for ovulation. As the follicles increase in size, they begin to release estrogen and a low level of progesterone into the blood. The level of estrogen rises to a peak, causing a spike in the concentration of LH. This causes the most mature follicle to rupture and ovulation occurs. **39** The first trimester lays down the basic structures of the body, including the limb buds, heart, eyes, and the liver. The second trimester continues the development of all of the organs and systems established during the first trimester. The placenta takes over the production of estrogen and high levels of progesterone and handles the nutrient and waste requirements of the fetus. The third trimester exhibits the greatest growth of the fetus, culminating in labor and delivery. **40** Stage one of labor results in the thinning of the cervix and the dilation of the cervical opening. Stage two delivers the baby, and stage three delivers the placenta. **41** Multiple sperm can fuse with the egg, resulting in polyspermy. The resulting embryo is not genetically viable and dies within a few days. **42** Mammalian eggs do not need a lot of yolk because the developing fetus obtains nutrients from the mother. Other species, in which the fetus

develops outside of the mother's body, such as occurs with birds, require a lot of yolk in the egg to nourish the embryo during development. **43** Organs form from the germ layers through the process of differentiation. During differentiation, the embryonic stem cells express a specific set of genes that will determine their ultimate fate as a cell type. For example, some cells in the ectoderm will express the genes specific to skin cells. As a result, these cells will differentiate into epidermal cells. The process of differentiation is regulated by cellular signaling cascades. **44** Animal bodies have lateral-medial (left-right), dorsal-ventral (back-belly), and anterior-posterior (head-feet) axes. The dorsal cells are genetically programmed to form the notochord and define the axis. There are many genes responsible for axis formation. Mutations in these genes lead to the loss of symmetry required for organism development.

Chapter 44

1 Figure 44.10 Tropical lakes don't freeze, so they don't undergo spring turnover in the same way temperate lakes do. However, stratification does occur, as well as seasonal turnover. **2** Figure 44.12 C. Boreal forests are not dominated by deciduous trees. **3** Figure 44.21 C. Photosynthetic organisms would be found in the photic, abyssal, neritic, and oceanic zones. **4** B **5** D **6** D **7** C **8** D **9** C **10** D **11** B **12** C **13** B **14** Ecologists working in organismal or population ecology might ask similar questions about how the biotic and abiotic conditions affect particular organisms and, thus, might find collaboration to be mutually beneficial. Levels of ecology such as community ecology or ecosystem ecology might pose greater challenges for collaboration because these areas are very broad and may include many different environmental components. **15** It is beneficial to consider a population to be all of the individuals living in the same area at the same time because it allows the ecologist to identify and study all of the abiotic and biotic factors that may affect the members of the population. However, this definition of a population could be considered a drawback if it prohibits the ecologist from studying a population's individuals that may be transitory, but still influential. Some species with members that have a wide geographic range might not be considered to be a population, but could still have many of the qualities of a population. **16** Ocean upwelling is a continual process that occurs year-round. Spring and fall turnover in freshwater lakes and ponds, however, is a seasonal process that occurs due to temperature changes in the water that take place during springtime warming and autumn cooling. Both ocean upwelling and spring and fall turnover enable nutrients in the organic materials at the bottom of the body of water to be recycled and reused by living things. **17** Areas that have been geographically isolated for very long periods of time allow unique species to evolve; these species are distinctly different from those of surrounding areas and remain so, since geographic isolation keeps them separated from other species. **18** Fire is less common in desert biomes than in temperate grasslands because deserts have low net primary productivity and, thus, very little plant biomass to fuel a fire. **19** Both the subtropical desert and the arctic tundra have a low supply of water. In the desert, this is due to extremely low precipitation, and in the arctic tundra, much of the water is unavailable to plants because it is frozen. Both the subtropical desert and the arctic tundra have low net primary productivity. **20** Bogs are low in oxygen and high in organic acids. The low oxygen content and the low pH both slow the rate of decomposition. **21** Organisms living in the intertidal zone must tolerate periodic exposure to air and sunlight and must be able to be periodically dry. They also must be able to endure the pounding waves; for this reason, some shoreline organisms have hard exoskeletons that provide protection while also reducing the likelihood of drying out. **22** Natural processes such as the Milankovitch cycles, variation in solar intensity, and volcanic eruptions can cause periodic, intermittent changes in global climate. Human activity, in the form of emissions from the burning of fossil fuels, has caused a progressive rise in the levels of atmospheric carbon dioxide. **23** If carbon emissions continue to rise, the global temperature will continue to rise; thus, ocean waters will cause the rising of sea levels at the coastlines. Continued melting of glaciers and reduced spring and summer meltwaters may cause summertime water shortages. Changes in seasonal temperatures may alter lifecycles and interrupt breeding patterns in many species of plants and animals.

Chapter 45

1 Figure 45.2 Smaller animals require less food and other resources, so the environment can support more of them. **2** Figure 45.10**b** A **3** Figure 45.16 Stage 4 represents a population that is decreasing. **4** C **5** D **6** A **7** A **8** B **9** D **10** A **11** C **12** B **13** A **14** B **15** D **16** D **17** B **18** B **19** D **20** B **21** C **22** D **23** C **24** B **25** The researcher would mark a certain number of penguins with a tag, release them back into the population, and, at a later time, recapture penguins to see what percentage of the recaptured penguins was tagged. This percentage would allow an estimation of the size of the penguin population. **26** Parental care is not feasible for organisms having many offspring because they do not have the energy available to take care of offspring. Most of their energy budget is used in the formation of seeds or offspring, so there is little left for parental care. Also, the sheer number of offspring would make individual parental care impossible. **27** In the first part of the curve, when few individuals of the species are present and resources are plentiful, growth is exponential, similar to a J-shaped curve. Later, growth slows due to the species using up resources. Finally, the population levels off at the carrying capacity of the environment, and it is relatively stable over time. **28** If a natural disaster such as a fire happened in the winter, when populations are low, it would have a greater effect on the overall population and its recovery than if the same disaster occurred during the summer,

when population levels are high. **29** Rapidly growing countries have a large segment of the population at a reproductive age or younger. Slower growing populations have a lower percentage of these individuals, and countries with zero population growth have an even lower percentage. On the other hand, a high proportion of older individuals is seen mostly in countries with zero growth, and a low proportion is most common in rapidly growing countries. **30** The competitive exclusion principle states that no two species competing for the same resources at the same time and place can coexist over time. Thus, one of the competing species will eventually dominate. On the other hand, if the species evolve such that they use resources from different parts of the habitat or at different times of day, the two species can exist together indefinitely. **31** Dogs salivated in response to food. This was the unconditioned stimulus and response. Dogs exposed to food had a bell rung repeatedly at the same time, eventually learning to associate the bell with food. Over time, the dogs would salivate when the bell was rung, even in the absence of food. Thus, the bell became the conditioned stimulus, and the salivation in response to the bell became the conditioned response.

Chapter 46

1 **Figure 46.8** According to the first law of thermodynamics, energy can neither be created nor destroyed. Eventually, all energy consumed by living systems is lost as heat or used for respiration, and the total energy output of the system must equal the energy that went into it. **2** **Figure 46.10** Pyramids of organisms may be inverted or diamond-shaped because a large organism, such as a tree, can sustain many smaller organisms. Likewise, a low biomass of organisms can sustain a larger biomass at the next trophic level because the organisms reproduce rapidly and thus supply continuous nourishment. Energy pyramids, however, must always be upright because of the laws of thermodynamics. The first law of thermodynamics states that energy can neither be created nor destroyed; thus, each trophic level must acquire energy from the trophic level below. The second law of thermodynamics states that, during the transfer of energy, some energy is always lost as heat; thus, less energy is available at each higher trophic level. **3** **Figure 46.17** C: Nitrification by bacteria converts nitrates (NO_3^-) to nitrites (NO_2^-). **4** D **5** C **6** B **7** D **8** A **9** C **10** D **11** B **12** D **13** C **14** B **15** C **16** A **17** D **18** A **19** B **20** C **21** Food webs show interacting groups of different species and their many interconnections with each other and the environment. Food chains are linear aspects of food webs that describe the succession of organisms consuming one another at defined trophic levels. Food webs are a more accurate representation of the structure and dynamics of an ecosystem. Food chains are easier to model and use for experimental studies. **22** Freshwater ecosystems are the rarest, but have great diversity of freshwater fish and other aquatic life. Ocean ecosystems are the most common and are responsible for much of the photosynthesis that occurs on Earth. Terrestrial ecosystems are very diverse; they are grouped based on their species and environment (biome), which includes forests, deserts, and tundras. **23** Grazing food webs have a primary producer at their base, which is either a plant for terrestrial ecosystems or a phytoplankton for aquatic ecosystems. The producers pass their energy to the various trophic levels of consumers. At the base of detrital food webs are the decomposers, which pass this energy to a variety of other consumers. Detrital food webs are important for the health of many grazing food webs because they eliminate dead and decaying organic material, thus, clearing space for new organisms and removing potential causes of disease. By breaking down dead organic matter, decomposers also make mineral nutrients available to primary producers; this process is a vital link in nutrient cycling. **24** Pyramids of numbers display the number of individual organisms on each trophic level. These pyramids can be either upright or inverted, depending on the number of the organisms. Pyramids of biomass display the weight of organisms at each level. Inverted pyramids of biomass can occur when the primary producer has a high turnover rate. Pyramids of energy are usually upright and are the best representation of energy flow and ecosystem structure. **25** NPE measures the rate at which one trophic level can use and make biomass from what it attained in the previous level, taking into account respiration, defecation, and heat loss. Endotherms have high metabolism and generate a lot of body heat. Although this gives them advantages in their activity level in colder temperatures, these organisms are 10 times less efficient at harnessing the energy from the food they eat compared with cold-blooded animals, and thus have to eat more and more often. **26** Nitrogen fixation is the process of bringing nitrogen gas from the atmosphere and incorporating it into organic molecules. Most plants do not have this capability and must rely on free-living or symbiotic bacteria to do this. As nitrogen is often the limiting nutrient in the growth of crops, farmers make use of artificial fertilizers to provide a nitrogen source to the plants as they grow. **27** Many factors can kill life in a lake or ocean, such as eutrophication by nutrient-rich surface runoff, oil spills, toxic waste spills, changes in climate, and the dumping of garbage into the ocean. Eutrophication is a result of nutrient-rich runoff from land using artificial fertilizers high in nitrogen and phosphorus. These nutrients cause the rapid and excessive growth of microorganisms, which deplete local dissolved oxygen and kill many fish and other aquatic organisms. **28** Most of the water on Earth is salt water, which humans cannot drink unless the salt is removed. Some fresh water is locked in glaciers and polar ice caps, or is present in the atmosphere. The Earth's water supplies are threatened by pollution and exhaustion. The effort to supply fresh drinking water to the planet's ever-expanding human population is seen as a major challenge in this century.

Chapter 47

1 Figure 47.6 A. An abundance of fern spores from several species was found below the K-Pg boundary, but none was found above. **2** Figure 47.9 The ground is permanently frozen so the seeds will keep even if the electricity fails. **3** B **4** Figure 47.16 C **5** C **6** A **7** C **8** D **9** B **10** C **11** D **12** C **13** C **14** C **15** D **16** C **17** The hypothesized cause of the K–Pg extinction event is an asteroid impact. The first piece of evidence of the impact is a spike in iridium (an element that is rare on Earth, but common in meteors) in the geological layers that mark the K–Pg transition. The second piece of evidence is an impact crater off the Yucatán Peninsula that is the right size and age to have caused the extinction event. **18** Extinction rates are calculated based on the recorded extinction of species in the past 500 years. Adjustments are made for unobserved extinctions and undiscovered species. The second method is a calculation based on the amount of habitat destruction and species-area curves. **19** Crop plants are derived from wild plants, and genes from wild relatives are frequently brought into crop varieties by plant breeders to add valued characteristics to the crops. If the wild species are lost, then this genetic variation would no longer be available. **20** Secondary plant compounds are toxins produced by plants to kill predators trying to eat them; some of these compounds can be used as drugs. Animal toxins such as snake venom can also be used as drugs. (Alternate answer: antibiotics are compounds produced by bacteria and fungi which can be used to kill bacteria.) **21** Human population growth leads to unsustainable resource use, which causes habitat destruction to build new human settlements, create agricultural fields, and so on. Larger human populations have also led to unsustainable fishing and hunting of wild animal populations. Excessive use of fossil fuels also leads to global warming. **22** The frog is at risk from global warming shifting its preferred habitat up the mountain. In addition, it will be at risk from exotic species, either as a new predator or through the impact of transmitted diseases such as chytridiomycosis. It is also possible that habitat destruction will threaten the species. **23** Larger preserves will contain more species. Preserves should have a buffer around them to protect species from edge effects. Preserves that are round or square are better than preserves with many thin arms. **24** When a keystone species is removed many species will disappear from the ecosystem.

3' UTR 3' untranslated region; region just downstream of the protein-coding region in an RNA molecule that is not translated

5' cap a methylated guanosine triphosphate (GTP) molecule that is attached to the 5' end of a messenger RNA to protect the end from degradation

5' UTR 5' untranslated region; region just upstream of the protein-coding region in an RNA molecule that is not translated

7-methylguanosine cap modification added to the 5' end of pre-mRNAs to protect mRNA from degradation and assist translation

A horizon consists of a mixture of organic material with inorganic products of weathering

abduction when a bone moves away from the midline of the body

abiotic nonliving components of the environment

aboveground biomass total mass of aboveground living plants per area

abscisic acid (ABA) plant hormone that induces dormancy in seeds and other organs

abscission physiological process that leads to the fall of a plant organ (such as leaf or petal drop)

absorption spectrum range of wavelengths of electromagnetic radiation absorbed by a given substance

abstract opening section of a scientific paper that summarizes the research and conclusions

abyssal zone deepest part of the ocean at depths of 4000 m or greater

Acanthostega one of the earliest known tetrapods

accessory fruit fruit derived from tissues other than the ovary

acclimatization alteration in a body system in response to environmental change

acellular lacking cells

acetyl CoA combination of an acetyl group derived from pyruvic acid and coenzyme A, which is made from pantothenic acid (a B-group vitamin)

cetylcholine neurotransmitter released by neurons in the central nervous system and peripheral nervous system

acetylcholinesterase (AChE) enzyme that breaks down ACh into acetyl and choline

acid molecule that donates hydrogen ions and increases the concentration of hydrogen ions in a solution

acid rain corrosive rain caused by rainwater falling to the ground through sulfur dioxide gas, turning it into weak sulfuric acid; can damage structures and ecosystems

acidophile organism with optimal growth pH of three or below

acoelomate animal without a body cavity

acromegaly condition caused by overproduction of GH in adults

acrosomal reaction series of biochemical reactions that the sperm uses to break through the zona pellucida

actin globular contractile protein that interacts with myosin for muscle contraction

Actinopterygii ray-finned fishes

action potential self-propagating momentary change in the electrical potential of a neuron (or muscle) membrane

activation energy energy necessary for reactions to occur

activator protein that binds to prokaryotic operators to increase transcription

active site specific region of the enzyme to which the substrate binds

active transport method of transporting material that requires energy

acute disease disease where the symptoms rise and fall within a short period of time

adaptation heritable trait or behavior in an organism that aids in its survival and reproduction in its present environment

adaptive evolution increase in frequency of beneficial alleles and decrease in deleterious alleles due to selection

adaptive immunity immunity that has memory and occurs after exposure to an antigen either from a pathogen or a vaccination

adaptive radiation rapid branching through speciation of a phylogenetic tree into many closely related species

adaptive radiation speciation when one species radiates out to form several other species

Addison's disease disorder caused by the hyposecretion of corticosteroids

adduction movement of the limbs inward after abduction

adenylate cyclase an enzyme that catalyzes the conversion of ATP to cyclic AMP

adhesion attraction between water molecules and other molecules

adrenal cortex outer portion of adrenal glands that produces corticosteroids

adrenal gland endocrine glands associated with the kidneys

adrenal medulla inner portion of adrenal glands that produces epinephrine and norepinephrine

adrenocorticotropic hormone (ACTH) hormone released by the anterior pituitary, which stimulates the adrenal cortex to release corticosteroids during the long-term stress response

adventitious describes an organ that grows in an unusual place, such as a roots growing from the side of a stem

adventitious root aboveground root that arises from a plant part other than the radicle of the plant embryo

aerobic respiration process in which organisms convert energy in the presence of oxygen

afferent arteriole arteriole that branches from the cortical radiate artery and enters the glomerulus

affinity attraction of molecular complementarity between antigen and antibody molecules

age structure proportion of population members at specific age ranges

aggregate fruit fruit that develops from multiple carpels in the same flower

aggressive display visual display by a species member to discourage other members of the same species or different species

aldosterone steroid hormone produced by the adrenal cortex that stimulates the reabsorption of Na^+ from extracellular fluids and secretion of K^+.

aleurone single layer of cells just inside the seed coat that secretes enzymes upon germination

algal bloom rapid increase of algae in an aquatic system

alimentary canal tubular digestive system with a mouth and anus

aliphatic hydrocarbon hydrocarbon consisting of a linear chain of carbon atoms

alkaliphile organism with optimal growth pH of nine or above

allantois membrane of the egg that stores nitrogenous wastes produced by the embryo; also facilitates respiration

allele frequency (also, gene frequency) rate at which a specific allele appears within a population

allele gene variations that arise by mutation and exist at the same relative locations on homologous chromosomes

allergy immune reaction that results from immediate hypersensitivities in which an antibody-mediated immune response occurs within minutes of exposure to a harmless antigen

allopatric speciation speciation that occurs via geographic separation

allopolyploid polyploidy formed between two related, but separate species

allosteric inhibition inhibition by a binding event at a site different from the active site, which induces a conformational change and reduces the affinity of the enzyme for its substrate

alpha cell endocrine cell of the pancreatic islets that produces the hormone glucagon

alpha-helix structure (α-helix) type of secondary structure of proteins formed by folding of the polypeptide into a helix shape with hydrogen bonds stabilizing the structure

alteration change of the set point in a homeostatic system

alternation of generations life-cycle type in which the diploid and haploid stages alternate

alveolar duct duct that extends from the terminal bronchiole to the alveolar sac

alveolar P_{O_2}

alveolar sac structure consisting of two or more alveoli that share a common opening

alveolar ventilation how much air is in the alveoli

alveolus (plural: alveoli) (also, air sac) terminal region of the lung where gas exchange occurs

Alzheimer's disease neurodegenerative disorder characterized by problems with memory and thinking

amino acid monomer of a protein; has a central carbon or alpha carbon to which an amino group, a carboxyl group, a hydrogen, and an R group or side chain is attached; the R group is different for all 20 amino acids

amino acid-derived hormone hormone derived from amino acids

aminoacyl tRNA synthetase enzyme that "charges" tRNA molecules by catalyzing a bond between the tRNA and a corresponding amino acid

aminopeptidase protease that breaks down peptides to single amino acids; secreted by the brush border of small intestine

ammonia compound made of one nitrogen atom and three hydrogen atoms

ammonification process by which ammonia is released during the decomposition of nitrogen-containing organic compounds

ammonotelic describes an animal that excretes ammonia as the primary waste material

amnion membrane of the egg that protects the embryo from mechanical shock and prevents dehydration

amniote animal that produces a terrestrially adapted egg protected by amniotic membranes

amoebocyte sponge cell with multiple functions, including nutrient delivery, egg formation, sperm delivery, and cell differentiation

amphiarthrosis joint that allows slight movement; includes syndesmoses and symphyses

Amphibia frogs, salamanders, and caecilians

amphiphilic molecule possessing a polar or charged area and a nonpolar or uncharged area capable of interacting with both hydrophilic and hydrophobic environments

ampulla of Lorenzini sensory organ that allows sharks to detect electromagnetic fields produced by living things

amygdala structure within the limbic system that processes fear

anabolic (also, anabolism) pathways that require an input of energy to synthesize complex molecules from simpler ones

anaerobic cellular respiration process in which organisms convert energy for their use in the absence of oxygen

anaerobic process that does not use oxygen

anaerobic refers to organisms that grow without oxygen

analogy (also, homoplasy) characteristic that is similar between organisms by convergent evolution, not due to the same evolutionary path

analytical model ecosystem model that is created with mathematical formulas to predict the effects of environmental disturbances on ecosystem structure and dynamics

anaphase stage of mitosis during which sister chromatids are separated from each other

anapsid animal having no temporal fenestrae in the cranium

anatomical dead space (also, anatomical shunt) region of the lung that lacks proper ventilation/ perfusion due to an anatomical block

androecium sum of all the stamens in a flower

androgen male sex hormone such as testosterone

aneuploid individual with an error in chromosome number; includes deletions and duplications of chromosome segments

aneuploidy condition of a cell having an extra chromosome or missing a chromosome for its species

angina pain caused by partial blockage of the coronary arteries by the buildup of plaque and lack of oxygen to the heart muscle

angiotensin converting enzyme (ACE) enzyme that converts angiotensin I to angiotensin II

angiotensin I product in the renin-angiotensin-aldosterone pathway

angiotensin II molecule that affects different organs to increase blood pressure

angular movement produced when the angle between the bones of a joint changes

anion negative ion that is formed by an atom gaining one or more electrons

Annelida phylum of vermiform animals with metamerism

anoxic without oxygen

antenna protein pigment molecule that directly absorbs light and transfers the energy absorbed to other pigment molecules

anterior pituitary portion of the pituitary gland that produces six hormones; also called adenohypophysis

anther sac-like structure at the tip of the stamen in which pollen grains are produced

antheridium male gametangium

Anthophyta phylum to which angiosperms belong

anthropoid monkeys, apes, and humans

antibiotic biological substance that, in low concentration, is antagonistic to the growth of prokaryotes

antibiotic resistance ability of an organism to be unaffected by the actions of an antibiotic

antibody protein that is produced by plasma cells after stimulation by an antigen; also known as an immunoglobulin

anticodon three-nucleotide sequence in a tRNA molecule that corresponds to an mRNA codon

anti-diuretic hormone (ADH) hormone produced by the hypothalamus and released by the posterior pituitary that increases water reabsorption by the kidneys

antigen foreign or "non-self" protein that triggers the immune response

antigen-presenting cell (APC) immune cell that detects, engulfs, and informs the adaptive immune response about an infection by presenting the processed antigen on the cell surface

antioxidant agent that prevents cell destruction by reactive oxygen species

antipodals the three cells away from the micropyle

antiporter transporter that carries two ions or small molecules in different directions

Anura frogs

anus exit point for waste material

aorta major artery of the body that takes blood away from the heart

apex consumer organism at the top of the food chain

aphotic zone part of the ocean where no light penetrates

apical bud bud formed at the tip of the shoot

apical meristem meristematic tissue located at the tips of stems and roots; enables a plant to extend in length

apocrine gland scent gland that secretes substances that are used for chemical communication

Apoda caecilians

apodeme ingrowth of an animal's exoskeleton that functions as an attachment site for muscles

apomixis process by which seeds are produced without fertilization of sperm and egg

apoptosis programmed cell death

aposematic coloration warning coloration used as a defensive mechanism against predation appearance of a plant tumor

appendicular skeleton composed of the bones of the upper limbs, which function to grasp and manipulate objects, and the lower limbs, which permit locomotion

applied science form of science that aims to solve real-world problems

appositional growth increase in the diameter of bones by the addition of bone tissue at the surface of bones

aquaporin channel protein that allows water through the membrane at a very high rate

arachnoid mater spiderweb-like middle layer of the meninges that cover the central nervous system

arbuscular mycorrhiza mycorrhizal association in which the fungal hyphae enter the root cells and form extensive networks

Arbuscular mycorrhizae mycorrhizae commonly involving Glomeromycetes in which the fungal hyphae penetrate the cell walls of the plant root cells (but not the cell membranes)

Archaeopteryx transition species from dinosaur to bird from the Jurassic period

archegonium female gametangium

archenteron primitive gut cavity within the gastrula that opens outwards via the blastopore

archosaur modern crocodilian or bird, or an extinct pterosaur or dinosaur

arcuate artery artery that branches from the interlobar artery and arches over the base of the renal pyramids

aromatic hydrocarbon hydrocarbon consisting of closed rings of carbon atoms atom or chemical group that does not contain equal numbers of protons and electrons

arteriole small vessel that connects an artery to a capillary bed

artery blood vessel that takes blood away from the heart

Arthropoda phylum of animals with jointed appendages

articulation any place where two bones are joined

ascending limb part of the loop of Henle that ascends from the renal medulla to the renal cortex

ascocarp fruiting body of ascomycetes

Ascomycota (also, sac fungi) phylum of fungi that store spores in a sac called ascus

asexual reproduction form of reproduction that produces offspring that are genetically identical to the parent

assimilation biomass consumed and assimilated from the previous trophic level after accounting for the energy lost due to incomplete ingestion of food, energy used for respiration, and energy lost as waste

assortative mating when individuals tend to mate with those who are phenotypically similar to themselves

astrocyte glial cell in the central nervous system that provide nutrients, extracellular buffering, and structural support for neurons; also makes up the blood-brain barrier

asymmetrical describes animals with no axis of symmetry in their body pattern

asymptomatic disease disease where there are no symptoms and the individual is unaware of being infected unless lab tests are performed

atherosclerosis buildup of fatty plaques in the coronary arteries in the heart

atom smallest and most fundamental unit of matter

atom the smallest unit of matter that retains all of the chemical properties of an element

atomic mass calculated mean of the mass number for an element's isotopes

atomic number total number of protons in an atom

ATP adenosine triphosphate, the cell's energy currency

ATP synthase (also, F1F0 ATP synthase) membrane-embedded protein complex that adds a phosphate to ADP with energy from protons diffusing through it

atrial natriuretic peptide (ANP) hormone produced by the heart to reduce blood volume, pressure, and Na^+ concentration

atrioventricular valve one-way membranous flap of connective tissue between the atrium and the ventricle in the right side of the heart; also known as tricuspid valve

atrium (plural: atria) chamber of the heart that receives blood from the veins and sends blood to the ventricles

attention deficit hyperactivity disorder (ADHD) neurodevelopmental disorder characterized by difficulty maintaining attention and controlling impulses

attenuation weakening of a virus during vaccine development

audition sense of hearing

auditory ossicle (also, middle ear) transduces sounds from the air into vibrations in the fluid-filled cochlea

Australopithecus genus of hominins that evolved in eastern Africa approximately 4 million years ago

autism spectrum disorder (ASD) neurodevelopmental disorder characterized by impaired social interaction and communication abilities

autoantibody antibody that incorrectly marks "self" components as foreign and stimulates the immune response

autocrine signal signal that is sent and received by the same or similar nearby cells

autoimmune response inappropriate immune response to host cells or self-antigens

autoimmunity type of hypersensitivity to self antigens

autoinducer signaling molecule secreted by bacteria to communicate with other bacteria of its kind and others

autonomic nervous system part of the peripheral nervous system that controls bodily functions

autopolyploid polyploidy formed within a single species

autosome any of the non-sex chromosomes

autosomes any of the non-sex chromosomes

auxin plant hormone that influences cell elongation (in phototropism), gravitropism, apical dominance and root growth

avidity total binding strength of a multivalent antibody with antigen

axial skeleton forms the central axis of the body and includes the bones of the skull, the ossicles of the middle ear, the hyoid bone of the throat, the vertebral column, and the thoracic cage (ribcage)

axillary bud bud located in the axil: the stem area where the petiole connects to the stem

axon hillock electrically sensitive structure on the cell body of a neuron that integrates signals from multiple neuronal connections

axon terminal structure on the end of an axon that can form a synapse with another neuron

axon tube-like structure that propagates a signal from a neuron's cell body to axon terminals

AZT anti-HIV drug that inhibits the viral enzyme reverse transcriptase

B cell lymphocyte that matures in the bone marrow and differentiates into antibody-secreting plasma cells

B horizon soil layer that is an accumulation of mostly fine material that has moved downward

back mutation when a live virus vaccine reverts back to it disease-causing phenotype

bacteriophage virus that infects bacteria

balanced chemical equation statement of a chemical reaction with the number of each type of atom equalized for both the products and reactants

ball-and-socket joint joint with a rounded, ball-like end of one bone fitting into a cuplike socket of another bone

barcoding molecular biology technique in which one or more short gene sequences taken from a well-characterized portion of the genome is used to identify a species

bark tough, waterproof, outer epidermal layer of cork cells

basal angiosperms a group of plants that probably branched off before the separation of monocots and eudicots

basal ganglia interconnected collections of cells in the brain that are involved in movement and motivation; also known as basal nuclei

basal metabolic rate (BMR) metabolic rate at rest in endothermic animals

basal nuclei see basal ganglia

basal taxon branch on a phylogenetic tree that has not diverged significantly from the root ancestor

base molecule that donates hydroxide ions or otherwise binds excess hydrogen ions and decreases the concentration of hydrogen ions in a solution

basic science science that seeks to expand knowledge and understanding regardless of the short- term application of that knowledge

basidiocarp fruiting body that protrudes from the ground and bears the basidia

Basidiomycota (also, club fungi) phylum of fungi that produce club-shaped structures (basidia) that contain spores

basidium club-shaped fruiting body of basidiomycetes

basilar membrane stiff structure in the cochlea that indirectly anchors auditory receptors

basophil leukocyte that releases chemicals usually involved in the inflammatory response

Batesian mimicry type of mimicry where a non-harmful species takes on the warning colorations of a harmful one

bedrock solid rock that lies beneath the soil

behavior change in an organism's activities in response to a stimulus

behavioral biology study of the biology and evolution of behavior

behavioral isolation type of reproductive isolation that occurs when a specific behavior or lack of one prevents reproduction from taking place

benthic realm (also, benthic zone) part of the ocean that extends along the ocean bottom from the shoreline to the deepest parts of the ocean floor

beta cell endocrine cell of the pancreatic islets that produces the hormone insulin

beta-pleated sheet (*β*-pleated) secondary structure found in proteins in which "pleats" are formed by hydrogen bonding between atoms on the backbone of the polypeptide chain

bicarbonate (HCO_3^-)

bicarbonate buffer system system in the blood that absorbs carbon dioxide and regulates pH levels

bicuspid valve (also, mitral valve; left atrioventricular valve) one-way membranous flap between the atrium and the ventricle in the left side of the heart

bilateral symmetry type of symmetry in which there is only one plane of symmetry, so the left and right halves of an animal are mirror images

bile digestive juice produced by the liver; important for digestion of lipids

binary fission prokaryotic cell division process

binomial nomenclature system of two-part scientific names for an organism, which includes genus and species names

biochemistry study of the chemistry of biological organisms

biodiversity hotspot concept originated by Norman Myers to describe a geographical region with a large number of endemic species and a large percentage of degraded habitat

biodiversity variety of a biological system, typically conceived as the number of species, but also applying to genes, biochemistry, and ecosystems

bioenergetics study of energy flowing through living systems

biofilm microbial community that is held together by a gummy-textured matrix

biogeochemical cycle cycling of mineral nutrients through ecosystems and through the non-living world

biogeography study of the geographic distribution of living things and the abiotic factors that affect their distribution

biological carbon pump process by which inorganic carbon is fixed by photosynthetic species that then die and fall to the sea floor where they cannot be reached by saprobes and their carbon dioxide consumption cannot be returned to the atmosphere

biological macromolecule large molecule necessary for life that is built from smaller organic molecules

biological nitrogen fixation conversion of atmospheric nitrogen into ammonia exclusively carried out by prokaryotes

biology the study of living organisms and their interactions with one another and their environments

bioluminescence generation and emission of light by an organism, as in dinoflagellates

biomagnification increasing concentrations of persistent, toxic substances in organisms at each trophic level, from the primary producers to the apex consumers

biomarker individual protein that is uniquely produced in a diseased state

biomass total weight, at the time of measurement, of living or previously living organisms in a unit area within a trophic level

biome ecological community of plants, animals, and other organisms that is adapted to a characteristic set of environmental conditions

bioremediation use of microbial metabolism to remove pollutants

biosphere collection of all the ecosystems on Earth

biotechnology any technological application that uses living organisms, biological systems, or their derivatives to produce or modify other products

biotechnology use of biological agents for technological advancement

biotic living components of the environment

biotic potential (r_{max}) maximal potential growth rate of a species

bipolar neuron neuron with two processes from the cell body, typically in opposite directions

biramous referring to two branches per appendage

birth rate (*B*) number of births within a population at a specific point in time

Black Death devastating pandemic that is believed to have been an outbreak of bubonic plague caused by the bacterium *Yersinia pestis*

blastocyst structure formed when cells in the mammalian blastula separate into an inner and outer layer

blastopore indentation formed during gastrulation, evident in the gastrula stage

blastula 16–32 cell stage of development of an animal embryo

blending theory of inheritance hypothetical inheritance pattern in which parental traits are blended together in the offspring to produce an intermediate physical appearance

blood pressure (BP) pressure of blood in the arteries that helps to push blood through the body

blood urea nitrogen (BUN) estimate of urea in the blood and an indicator of kidney function

body plan morphology or constant shape of an organism

bolus mass of food resulting from chewing action and wetting by saliva

bone (also, osseous tissue) connective tissue that constitutes the endoskeleton

bone remodeling replacement of old bone tissue by new bone tissue

botany study of plants

bottleneck effect magnification of genetic drift as a result of natural events or catastrophes

botulism disease produce by the toxin of the anaerobic bacterium *Clostridium botulinum*

Bowman's capsule structure that encloses the glomerulus

brachiation movement through trees branches via suspension from the arms

brainstem portion of the brain that connects with the spinal cord; controls basic nervous system functions like breathing, heart rate, and swallowing

branch point node on a phylogenetic tree where a single lineage splits into distinct new ones

bronchiole airway that extends from the main tertiary bronchi to the alveolar sac

bronchus (plural: bronchi) smaller branch of cartilaginous tissue that stems off of the trachea; air is funneled through the bronchi to the region where gas exchange occurs in alveoli

brumation period of much reduced metabolism and torpor that occurs in any ectotherm in cold weather

budding form of asexual reproduction that results from the outgrowth of a part of a cell leading to a separation from the original animal into two individuals

budding method of exit from the cell used in certain animal viruses, where virions leave the cell individually by capturing a piece of the host plasma membrane

buffer substance that prevents a change in pH by absorbing or releasing hydrogen or hydroxide ions

bulb modified underground stem that consists of a large bud surrounded by numerous leaf scales

bulbourethral gland secretion that cleanses the urethra prior to ejaculation

bush meat wild-caught animal used as food (typically mammals, birds, and reptiles); usually referring to hunting in the tropics of sub-Saharan Africa, Asia, and the Americas

C horizon layer of soil that contains the parent material, and the organic and inorganic material that is broken down to form soil; also known as the soil base

CAAT box (GGCCAATCT) essential eukaryotic promoter sequence involved in binding transcription factors

caecilian legless amphibian that belongs to the clade Apoda

calcification process of deposition of mineral salts in the collagen fiber matrix that crystallizes and hardens the tissue

calcitonin hormone produced by the parafollicular cells of the thyroid gland that functions to lower blood Ca^{2+} levels and promote bone growth

calorie amount of heat required to change the temperature of one gram of water by one degree Celsius

Calvin cycle light-independent reactions of photosynthesis that convert carbon dioxide from the atmosphere into carbohydrates using the energy and reducing power of ATP and NADPH

calyx structure that connects the renal pelvis to the renal medulla

calyx whorl of sepals

Cambrian explosion time during the Cambrian period (542–488 million years ago) when most of the animal phyla in existence today evolved

camouflage avoid detection by blending in with the background.

CA-MRSA MRSA acquired in the community rather than in a hospital setting

canaliculus microchannel that connects the lacunae and aids diffusion between cells

candela (cd) unit of measurement of luminous intensity (brightness)

canopy branches and foliage of trees that form a layer of overhead coverage in a forest

capillary action occurs because water molecules are attracted to charges on the inner surfaces of narrow tubular structures such as glass tubes, drawing the water molecules to the sides of the tubes

capillary bed large number of capillaries that converge to take blood to a particular organ or tissue

capillary smallest blood vessel that allows the passage of individual blood cells and the site of diffusion of oxygen and nutrient exchange

capsid protein coating of the viral core

capsomere protein subunit that makes up the capsid

capsule case of the sporangium in mosses

capsule external structure that enables a prokaryote to attach to surfaces and protects it from dehydration

captacula tentacle-like projection that is present in tusks shells to catch prey

carbaminohemoglobin molecule that forms when carbon dioxide binds to hemoglobin

carbohydrate biological macromolecule in which the ratio of carbon to hydrogen and to oxygen is 1:2:1; carbohydrates serve as energy sources and structural support in cells and form the a cellular exoskeleton of arthropods

carbon fixation process of converting inorganic CO_2 gas into organic compounds

carbonic anhydrase (CA) enzyme that catalyzes carbon dioxide and water into carbonic acid

carboxypeptidase protease that breaks down peptides to single amino acids; secreted by the brush border of the small intestine

cardiac cycle filling and emptying the heart of blood by electrical signals that cause the heart muscles to contract and relax

cardiac muscle tissue muscle tissue found only in the heart; cardiac contractions pump blood throughout the body and maintain blood pressure

cardiac output the volume of blood pumped by the heart in one minute as a product of heart rate multiplied by stroke volume

cardiomyocyte specialized heart muscle cell that is striated but contracts involuntarily like smooth muscle

carnivore animal that consumes animal flesh

carotenoid photosynthetic pigment that functions to dispose of excess energy

carpel single unit of the pistil

carpus eight bones that comprise the wrist

carrier protein membrane protein that moves a substance across the plasma membrane by changing its own shape

carrying capacity (*K*) number of individuals of a species that can be supported by the limited resources of a habitat

cartilage type of connective tissue with a large amount of ground substance matrix, cells called chondrocytes, and some amount of fibers

cartilaginous joint joint in which the bones are connected by cartilage

Casparian strip waxy coating that forces water to cross endodermal plasma membranes before entering the vascular cylinder, instead of moving between endodermal cells

catabolic (also, catabolism) pathways in which complex molecules are broken down into simpler ones

catabolite activator protein (CAP) protein that complexes with cAMP to bind to the promoter sequences of operons that control sugar processing when glucose is not available

Catarrhini clade of Old World monkeys

cation positive ion that is formed by an atom losing one or more electrons

caveolin protein that coats the cytoplasmic side of the plasma membrane and participates in the process of liquid update by potocytosis

cDNA library collection of cloned cDNA sequences

cell cycle checkpoint mechanism that monitors the preparedness of a eukaryotic cell to advance through the various cell cycle stages

cell cycle ordered sequence of events that a cell passes through between one cell division and the next

cell cycle ordered series of events involving cell growth and cell division that produces two new daughter cells

cell cycle regulatory protein that inhibits the cell cycle; its levels are controlled by p53

cell cycle regulatory protein that regulates cell growth and monitors DNA damage; it halts the progression of the cell cycle in cases of DNA damage and may induce apoptosis

cell necrosis cell death

cell plate structure formed during plant cell cytokinesis by Golgi vesicles, forming a temporary structure (phragmoplast) and fusing at the metaphase plate; ultimately leads to the formation of cell walls that separate the two daughter cells

cell theory see unified cell theory

cell wall rigid cell covering made of cellulose that protects the cell, provides structural support, and gives shape to the cell

cell-mediated immune response adaptive immune response that is carried out by T cells

cell-surface receptor cell-surface protein that transmits a signal from the exterior of the cell to the interior, even though the ligand does not enter the cell

cellular cloning production of identical cell populations by binary fission

cellulose polysaccharide that makes up the cell wall of plants; provides structural support to the cell

centimorgan (cM) (also, map unit) relative distance that corresponds to a recombination frequency of 0.01

Central Dogma states that genes specify the sequence of mRNAs, which in turn specify the sequence of proteins

central vacuole large plant cell organelle that regulates the cell's storage compartment, holds water, and plays a significant role in cell growth as the site of macromolecule degradation

centriole rod-like structure constructed of microtubules at the center of each animal cell centrosome

centromere region at which sister chromatids are bound together; a constricted area in condensed chromosomes

centrosome region in animal cells made of two centrioles

cephalic phase first phase of digestion, controlled by the neural response to the stimulus provided by food

Cephalochordata chordate clade whose members possess a notochord, dorsal hollow nerve cord, pharyngeal slits, and a post-anal tail in the adult stage

cephalothorax fused head and thorax in some species

cerebellum brain structure involved in posture, motor coordination, and learning new motor actions

cerebral cortex outermost sheet of brain tissue; involved in many higher-order functions

cerebrospinal fluid (CSF) clear liquid that surrounds the brain and spinal cord and fills the ventricles and central canal; acts as a shock absorber and circulates material throughout the brain and spinal cord.

chain termination method method of DNA sequencing using labeled dideoxynucleotides to terminate DNA replication; it is also called the dideoxy method or the Sanger method

channel protein membrane protein that allows a substance to pass through its hollow core across the plasma membrane

channel width of a river or stream from one bank to the other bank

chaperone (also, chaperonin) protein that helps nascent protein in the folding process

charophyte other term for green algae; considered the closest relative of land plants

chelicera modified first pair of appendages in subphylum Chelicerata

chemical bond interaction between two or more of the same or different atoms that results in the formation of molecules

chemical diversity variety of metabolic compounds in an ecosystem

chemical energy potential energy in chemical bonds that is released when those bonds are broken

chemical reaction process leading to the rearrangement of atoms in molecules

chemical reactivity the ability to combine and to chemically bond with each other

chemical synapse small space between axon terminals and dendrites of nerve cells where neurotransmitters function

chemiosmosis process in which there is a production of adenosine triphosphate (ATP) in cellular metabolism by the involvement of a proton gradient across a membrane

chemoautotroph organism capable of synthesizing its own food using energy from inorganic molecules

chemoautotroph organism that can build organic molecules using energy derived from inorganic chemicals instead of sunlight

chemotroph organism that obtains energy from chemical compounds

chiasmata (singular, *chiasma*) the structure that forms at the crossover points after genetic material is exchanged

chitin type of carbohydrate that forms the outer skeleton of all arthropods that include crustaceans and insects; it also forms the cell walls of fungi

chloride shift chloride shift exchange of chloride for bicarbonate into or out of the red blood cell

chlorophyll *a* form of chlorophyll that absorbs violet-blue and red light and consequently has a bluish-green color; the only pigment molecule that performs the photochemistry by getting excited and losing an electron to the electron transport chain

chlorophyll *b* accessory pigment that absorbs blue and red-orange light and consequently has a yellowish-green tint

chlorophyll green pigment that captures the light energy that drives the light reactions of photosynthesis

chloroplast organelle in which photosynthesis takes place

chloroplast plant cell organelle that carries out photosynthesis

choanocyte (also, collar cell) sponge cell that functions to generate a water current and to trap and ingest food particles via phagocytosis

cholecystokinin hormone that stimulates the contraction of the gallbladder to release bile

Chondrichthyes jawed fish with paired fins and a skeleton made of cartilage

chondrocyte cell found in cartilage

Chordata phylum of animals distinguished by their possession of a notochord, a dorsal, hollow nerve cord, pharyngeal slits, and a post-anal tail at some point in their development

Chordata phylum of animals distinguished by their possession of a notochord, a dorsal hollow nerve cord, pharyngeal slits, and a post-anal tail at some point during their development

chorion membrane of the egg that surrounds the embryo and yolk sac

choroid plexus spongy tissue within ventricles that produces cerebrospinal fluid

chromatid single DNA molecule of two strands of duplicated DNA and associated proteins held together at the centromere

chromatin protein-DNA complex that serves as the building material of chromosomes

chromophore molecule that absorbs light

Chromosomal Theory of Inheritance theory proposing that chromosomes are the vehicles of genes and that their behavior during meiosis is the physical basis of the inheritance patterns that Mendel observed

chromosome inversion detachment, 180° rotation, and reinsertion of a chromosome arm

chromosome structure within the nucleus that is made up of chromatin that contains DNA, the hereditary material

chronic infection describes when the virus persists in the body for a long period of time

chylomicron small lipid globule

chyme mixture of partially digested food and stomach juices

chymotrypsin pancreatic protease

chytridiomycosis disease of amphibians caused by the fungus *Batrachochytrium dendrobatidis;*

Chytridiomycota (also, chytrids) primitive phylum of fungi that live in water and produce gametes with flagella

cilium (plural = cilia) short, hair-like structure that extends from the plasma membrane in large numbers and is used to move an entire cell or move substances along the outer surface of the cell

cingulate gyrus helps regulate emotions and pain; thought to directly drive the body's conscious response to unpleasant experiences

circadian describes a time cycle about one day in length

circumduction movement of a limb in a circular motion.

***cis*-acting element** transcription factor binding sites within the promoter that regulate the transcription of a gene adjacent to it

citric acid cycle (also, Krebs cycle) series of enzyme-catalyzed chemical reactions of central importance in all living cells

cladistics system used to organize homologous traits to describe phylogenies

class division of phylum in the taxonomic classification system

classical conditioning association of a specific stimulus and response through conditioning

clathrates frozen chunks of ice and methane found at the bottom of the ocean

clathrin protein that coats the inward-facing surface of the plasma membrane and assists in the formation of specialized structures, like coated pits, for phagocytosis

clavicle S-shaped bone that positions the arms laterally

clay soil particles that are less than 0.002 mm in diameter

cleavage cell division of a fertilized egg (zygote) to form a multicellular embryo

cleavage furrow constriction formed by an actin ring during cytokinesis in animal cells that leads to cytoplasmic division

climate long-term, predictable atmospheric conditions present in a specific area

climax community final stage of succession, where a stable community is formed by a characteristic assortment of plant and animal species

cline gradual geographic variation across an ecological gradient

clitellum specialized band of fused segments, which aids in reproduction

clitoris sensory structure in females; stimulated during sexual arousal

cloaca common body opening for the digestive, excretory, and reproductive systems found in non-mammals, such as birds

clonal selection activation of B cells corresponding to one specific BCR variant and the dramatic proliferation of that variant

clone exact replica

closed circulatory system system in which the blood is separated from the bodily interstitial fluid and contained in blood vessels

club mosses earliest group of seedless vascular plants

Cnidaria phylum of animals that are diploblastic and have radial symmetry

cnidocyte specialized stinging cell found in Cnidaria

cochlea whorled structure that contains receptors for transduction of the mechanical wave into an electrical signal

codominance in a heterozygote, complete and simultaneous expression of both alleles for the same characteristic

codon three consecutive nucleotides in mRNA that specify the insertion of an amino acid or the release of a polypeptide chain during translation

coelom lined body cavity

coenocytic hypha single hypha that lacks septa and contains many nuclei

coenzyme small organic molecule, such as a vitamin or its derivative, which is required to enhance the activity of an enzyme

cofactor inorganic ion, such as iron and magnesium ions, required for optimal regulation of enzyme activity

cognitive learning knowledge and skills acquired by the manipulation of information in the mind

cohesin proteins that form a complex that seals sister chromatids together at their centromeres until anaphase II of meiosis

cohesion intermolecular forces between water molecules caused by the polar nature of water; responsible for surface tension

coleoptile covering of the shoot tip, found in germinating monocot seeds

coleorhiza covering of the root tip, found in germinating monocot seeds

colinear in terms of RNA and protein, three "units" of RNA (nucleotides) specify one "unit" of protein (amino acid) in a consecutive fashion

collenchyma cell elongated plant cell with unevenly thickened walls; provides structural support to the stem and leaves

colloid fluid inside the thyroid gland that contains the glycoprotein thyroglobulin

columnar epithelia epithelia made of cells taller than they are wide, specialized in absorption

commensalism relationship between species wherein one species benefits from the close, prolonged interaction, while the other species neither benefits nor is harmed

commensalism symbiotic relationship in which one member benefits while the other member is not affected

community set of populations inhabiting a particular area

compact bone forms the hard external layer of all bones

companion cell phloem cell that is connected to sieve-tube cells; has large amounts of ribosomes and mitochondrion

competitive exclusion principle no two species within a habitat can coexist when they compete for the same resources at the same place and time

competitive inhibition type of inhibition in which the inhibitor competes with the substrate molecule by binding to the active site of the enzyme

complement system array of approximately 20 soluble proteins of the innate immune system that enhance phagocytosis, bore holes in pathogens, and recruit lymphocytes; enhances the adaptive response when antibodies are produced

compliance measurement of the elasticity of the lung

compound leaf leaf in which the leaf blade is subdivided to form leaflets, all attached to the midrib

compound substance composed of molecules consisting of atoms of at least two different elements

concentration gradient area of high concentration adjacent to an area of low concentration

conceptual model (also, compartment models) ecosystem model that consists of flow charts that show the interactions of different compartments of the living and non-living components of the ecosystem

conclusion section of a scientific paper that summarizes the importance of the experimental findings

condensin proteins that help sister chromatids coil during prophase

conditioned behavior behavior that becomes associated with a specific stimulus through conditioning

condyloid joint oval-shaped end of one bone fitting into a similarly oval-shaped hollow of another bone

cone weakly photosensitive, chromatic, cone-shaped neuron in the fovea of the retina that detects bright light and is used in daytime color vision

conifer dominant phylum of gymnosperms with the most variety of trees

conispiral shell shape coiled around a horizontal axis

conjugation process by which prokaryotes move DNA from one individual to another using a pilus

connective tissue type of tissue made of cells, ground substance matrix, and fibers

consensus DNA sequence that is used by many species to perform the same or similar functions

conspecifics individuals that are members of the same species

contig larger sequence of DNA assembled from overlapping shorter sequences

continuous variation inheritance pattern in which a character shows a range of trait values with small gradations rather than large gaps between them

contour feather feather that creates an aerodynamic surface for efficient flight

contraception (also, birth control) various means used to prevent pregnancy

contractile vacuole vesicle that fills with water (as it enters the cell by osmosis) and then contracts to squeeze water from the cell; an osmoregulatory vesicle

control part of an experiment that does not change during the experiment

convergent evolution process by which groups of organisms independently evolve to similar forms

coral reef ocean ridges formed by marine invertebrates living in warm, shallow waters within the photic zone

core enzyme prokaryotic RNA polymerase consisting of α, α, β, and β' but missing σ; this complex performs elongation

corm rounded, fleshy underground stem that contains stored food

cornea transparent layer over the front of the eye that helps focus light waves

corolla collection of petals

corona wheel-like structure on the anterior portion of the rotifer that contains cilia and moves food and water toward the mouth

coronary artery vessel that supplies the heart tissue with blood

coronary vein vessel that takes blood away from the heart tissue back to the chambers in the heart

corpus callosum thick fiber bundle that connects the cerebral hemispheres

cortex (animal) outer layer of an organ like the kidney or adrenal gland

cortex ground tissue found between the vascular tissue and the epidermis in a stem or root

cortical nephron nephron that lies in the renal cortex

cortical radiate artery artery that radiates from the arcuate arteries into the renal cortex

corticosteroid hormone released by the adrenal cortex in response to long-term stress

cortisol glucocorticoid produced in response to stress

cotyledon fleshy part of seed that provides nutrition to the seed

cotyledon primitive leaf that develop in the zygote; monocots have one cotyledon, and dicots have two cotyledons

countercurrent exchanger peritubular capillary network that allows exchange of solutes and water from the renal tubules

countercurrent multiplier osmotic gradient in the renal medulla that is responsible for concentration of urine

courtship display visual display used to attract a mate

covalent bond type of strong bond formed between two of the same or different elements; forms when electrons are shared between atoms

coxal bone hip bone

cranial bone one of eight bones that form the cranial cavity that encloses the brain and serves as an attachment site for the muscles of the head and neck

cranial nerve sensory and/or motor nerve that emanates from the brain

Craniata clade composed of chordates that possess a cranium; includes Vertebrata together with hagfishes

cranium bony, cartilaginous, or fibrous structure surrounding the brain, jaw, and facial bones

Crocodilia crocodiles and alligators

crop cultivated plant

cross reactivity binding of an antibody to an epitope corresponding to an antigen that is different from the one the antibody was raised against

crossover exchange of genetic material between non-sister chromatids resulting in chromosomes that incorporate genes from both parents of the organism

cross-pollination transfer of pollen from the anther of one flower to the stigma of a different flower

Cryogenian period geologic period (850–630 million years ago) characterized by a very cold global climate

cryptochrome protein that absorbs light in the blue and ultraviolet regions of the light spectrum

cryptofauna invertebrates found within the calcium carbonate substrate of coral reefs

ctenidium specialized gill structure in mollusks

cuboidal epithelia epithelia made of cube-shaped cells, specialized in glandular functions

Cushing's disease disorder caused by the hypersecretion of glucocorticoids

cutaneous respiration gas exchange through the skin

cuticle (animal) the tough, external layer possessed by members of the invertebrate class Ecdysozoa that is periodically molted and replaced

cuticle waxy covering on the outside of the leaf and stem that prevents the loss of water

cuticle waxy protective layer on the leaf surface

cutting method of asexual reproduction where a portion of the stem contains notes and internodes is placed in moist soil and allowed to root

cyanobacteria bacteria that evolved from early phototrophs and oxygenated the atmosphere; also known as blue-green algae

cycad gymnosperm that grows in tropical climates and resembles a palm tree; member of the phylum Cycadophyta

cyclic AMP (cAMP) second messenger that is derived from ATP

cyclic AMP-dependent kinase (also, protein kinase A, or PKA) kinase that is activated by binding to cAMP

cyclin one of a group of proteins that act in conjunction with cyclin-dependent kinases to help regulate the cell cycle by phosphorylating key proteins; the concentrations of cyclins fluctuate throughout the cell cycle

cyclin-dependent kinase one of a group of protein kinases that helps to regulate the cell cycle when bound to cyclin; it functions to phosphorylate other proteins that are either activated or inactivated by phosphorylation

cypris larval stage in the early development of crustaceans

cytochrome complex group of reversibly oxidizable and reducible proteins that forms part of the electron transport chain between photosystem II and photosystem I

cytogenetic mapping technique that uses a microscope to create a map from stained chromosomes

cytokine chemical messenger that regulates cell differentiation, proliferation, gene expression, and cell trafficking to effect immune responses

cytokinesis division of the cytoplasm following mitosis that forms two daughter cells.

cytokinin plant hormone that promotes cell division

cytopathic causing cell damage

cytoplasm entire region between the plasma membrane and the nuclear envelope, consisting of organelles suspended in the gel-like cytosol, the cytoskeleton, and various chemicals

cytoplasmic streaming movement of cytoplasm into an extended pseudopod such that the entire cell is transported to the site of the pseudopod

cytoskeleton network of protein fibers that collectively maintain the shape of the cell, secure some organelles in specific positions, allow cytoplasm and vesicles to move within the cell, and enable unicellular organisms to move independently

cytosol gel-like material of the cytoplasm in which cell structures are suspended

cytotoxic T lymphocyte (CTL) adaptive immune cell that directly kills infected cells via perforin and granzymes, and releases cytokines to enhance the immune response

dead space area in the lung that lacks proper ventilation or perfusion

dead zone area within an ecosystem in lakes and near the mouths of rivers where large areas of ecosystems are depleted of their normal flora and fauna; these zones can be caused by eutrophication, oil spills, dumping of toxic chemicals, and other human activities

death rate (*D*) number of deaths within a population at a specific point in time

decomposer organism that carries out the decomposition of dead organisms

deductive reasoning form of logical thinking that uses a general inclusive statement to forecast specific results

degeneracy (of the genetic code) describes that a given amino acid can be encoded by more than one nucleotide triplet; the code is degenerate, but not ambiguous

dehydration synthesis (also, condensation) reaction that links monomer molecules together, releasing a molecule of water for each bond formed

demographic-based population model modern model of population dynamics incorporating many features of the *r*- and *K*-selection theory

demography statistical study of changes in populations over time

denaturation loss of shape in a protein as a result of changes in temperature, pH, or exposure to chemicals

denature process that changes the natural properties of a substance

dendrite structure that extends away from the cell body to receive messages from other neurons

dendritic cell immune cell that processes antigen material and presents it on the surface of other cells to induce an immune response

denitrification transformation of nitrate from soil to gaseous nitrogen compounds such as N_2O, NO and N_2

density-dependent regulation regulation of population that is influenced by population density, such as crowding effects; usually involves biotic factors

density-independent regulation regulation of populations by factors that operate independent of population density, such as forest fires and volcanic eruptions; usually involves abiotic factors

dentary single bone that comprises the lower jaw of mammals

deoxynucleotide individual monomer (single unit) of DNA

deoxyribonucleic acid (DNA) double-helical molecule that carries the hereditary information of the cell

dephosphorylation removal of a phosphate group from a molecule

depolarization change in the membrane potential to a less negative value

depression movement downward of a bone, such as after the shoulders are shrugged and the scapulae return to their normal position from an elevated position; opposite of elevation

dermal tissue protective plant tissue covering the outermost part of the plant; controls gas exchange

descending limb part of the loop of Henle that descends from the renal cortex into the renal medulla

descriptive science (also, discovery science) form of science that aims to observe, explore, and investigate

desmosome linkages between adjacent epithelial cells that form when cadherins in the plasma membrane attach to intermediate filaments

determinate cleavage developmental tissue fate of each embryonic cell is already determined

detrital food web type of food web in which the primary consumers consist of decomposers; these are often associated with grazing food webs within the same ecosystem

Deuteromycota (also, imperfect fungi) phylum of fungi that do not have a known sexual reproductive cycle

deuterostome blastopore develops into the anus, with the second opening developing into the mouth

diabetes insipidus disorder caused by underproduction of ADH

diabetes mellitus disorder caused by low levels of insulin activity

diabetogenic effect effect of GH that causes blood glucose levels to rise similar to diabetes mellitus

diacylglycerol (DAG) cleavage product of PIP_2 that is used for signaling within the plasma membrane

diaphragm domed-shaped skeletal muscle located under lungs that separates the thoracic cavity from the abdominal cavity

diaphysis central shaft of bone, contains bone marrow in a marrow cavity

diapsid animal having two temporal fenestrae in the cranium

diarthrosis joint that allows for free movement of the joint; found in synovial joints

diastole relaxation phase of the cardiac cycle when the heart is relaxed and the ventricles are filling with blood

dicer enzyme that chops the pre-miRNA into the mature form of the miRNA

dicot (also, eudicot) related group of angiosperms whose embryos possess two cotyledons

dideoxynucleotide individual monomer of DNA that is missing a hydroxyl group (–OH)

diffusion passive process of transport of low-molecular weight material according to its concentration gradient

digestion mechanical and chemical break down of food into small organic fragments

digestive juice produced by the liver; important for digestion of lipids

dihybrid result of a cross between two true-breeding parents that express different traits for two characteristics

dimer chemical compound formed when two molecules join together

dimerization (of receptor proteins) interaction of two receptor proteins to form a functional complex called a dimer

dioecious describes a species in which the male and female reproductive organs are carried on separate specimens

dipeptidase protease that breaks down peptides to single amino acids; secreted by the brush border of small intestine

diphyodont refers to the possession of two sets of teeth in a lifetime

diploblast animal that develops from two germ layers

diploid cell, nucleus, or organism containing two sets of chromosomes ($2n$)

diploid-dominant life-cycle type in which the multicellular diploid stage is prevalent

diplontic diploid stage is the dominant stage

directional selection selection that favors phenotypes at one end of the spectrum of existing variation

disaccharide two sugar monomers that are linked together by a glycosidic bond

discontinuous variation inheritance pattern in which traits are distinct and are transmitted independently of one another

discussion section of a scientific paper in which the author interprets experimental results, describes how variables may be related, and attempts to explain the phenomenon in question

dispersal allopatric speciation that occurs when a few members of a species move to a new geographical area

dissociation release of an ion from a molecule such that the original molecule now consists of an ion and the charged remains of the original, such as when water dissociates into H^+ and OH^-

distal convoluted tubule (DCT) part of the renal tubule that is the most distant from the glomerulus

distraction display visual display used to distract predators away from a nesting site

divergent evolution process by which groups of organisms evolve in diverse directions from a common point

diversifying selection selection that favors two or more distinct phenotypes

DNA barcoding molecular genetic method for identifying a unique genetic sequence to associate with a species

DNA methylation epigenetic modification that leads to gene silencing; commonly found in cancer cells

DNA microarray method used to detect gene expression by analyzing an array of DNA fragments that are fixed to a glass slide or a silicon chip to identify active genes and identify sequences

dominant lethal inheritance pattern in which an allele is lethal both in the homozygote and the heterozygote; this allele can only be transmitted if the lethality phenotype occurs after reproductive age

dominant trait which confers the same physical appearance whether an individual has two copies of the trait or one copy of the dominant trait and one copy of the recessive trait

dormancy period of no growth and very slow metabolic processes

dorsal cavity body cavity on the posterior or back portion of an animal; includes the cranial and vertebral cavities

dorsal hollow nerve cord hollow, tubular structure derived from ectoderm, which is located dorsal to the notochord in chordates

dorsiflexion bending at the ankle such that the toes are lifted toward the knee

double circulation flow of blood in two circuits: the pulmonary circuit through the lungs and the systemic circuit through the organs and body

double fertilization two fertilization events in angiosperms; one sperm fuses with the egg, forming the zygote, whereas the other sperm fuses with the polar nuclei, forming endosperm

down feather feather specialized for insulation

down-regulation a decrease in the number of hormone receptors in response to increased hormone levels

downstream nucleotides following the initiation site in the direction of mRNA transcription; in general, sequences that are toward the 3' end relative to a site on the mRNA

duodenum first part of the small intestine where a large part of digestion of carbohydrates and fats occurs

dura mater tough outermost layer that covers the central nervous system

eccrine gland sweat gland

Ecdysozoa clade of protostomes that exhibit exoskeletal molting (ecdysis)

Echinodermata phylum of deuterostomes with spiny skin; exclusively marine organisms

ecological pyramid (also, Eltonian pyramid) graphical representation of different trophic levels in an ecosystem based of organism numbers, biomass, or energy content

ecology study of interaction between living things and their environment

ecosystem all the living things in a particular area together with the abiotic, nonliving parts of that environment

ecosystem community of living organisms and their interactions with their abiotic environment

ecosystem diversity variety of ecosystems

ecosystem dynamics study of the changes in ecosystem structure caused by changes in the environment or internal forces

ecosystem services human benefits and services provided by natural ecosystems

ectomycorrhiza mycorrhizal fungi that surround the roots with a mantle and have a Hartig net that extends into the roots between cells

Ectomycorrhizae mycorrhizae in which the fungal hyphae do not penetrate the root cells of the plant

ectotherm animal incapable of maintaining a relatively constant internal body temperature

Ediacaran period geological period (630–542 million years ago) when the oldest definite multicellular organisms with tissues evolved

effector cell lymphocyte that has differentiated, such as a B cell, plasma cell, or cytotoxic T lymphocyte

efferent arteriole arteriole that exits from the glomerulus

elastase pancreatic protease

elastic recoil property of the lung that drives the lung tissue inward

elastic work work conducted by the intercostal muscles, chest wall, and diaphragm

electrocardiogram (ECG) recording of the electrical impulses of the cardiac muscle

electrochemical gradient gradient produced by the combined forces of an electrical gradient and a chemical gradient

electrogenic pump pump that creates a charge imbalance

electrolyte ion necessary for nerve impulse conduction, muscle contractions and water balance

electrolyte solute that breaks down into ions when dissolved in water

electromagnetic spectrum range of all possible frequencies of radiation

electron configuration arrangement of electrons in an atom's electron shell (for example, $1s^2 2s^2 2p^6$)

electron microscope an instrument that magnifies an object using a beam of electrons passed and bent through a lens system to visualize a specimen

electron negatively charged subatomic particle that resides outside of the nucleus in the electron orbital; lacks functional mass and has a negative charge of –1 unit

electron orbital how electrons are spatially distributed surrounding the nucleus; the area where an electron is most likely to be found

electron transfer movement of electrons from one element to another; important in creation of ionic bonds

electron transport chain group of proteins between PSII and PSI that pass energized electrons and use the energy released by the electrons to move hydrogen ions against their concentration gradient into the thylakoid lumen

electronegativity ability of some elements to attract electrons (often of hydrogen atoms), acquiring partial negative charges in molecules and creating partial positive charges on the hydrogen atoms

electrophoresis technique used to separate DNA fragments according to size

element one of 118 unique substances that cannot be broken down into smaller substances; each element has unique properties and a specified number of protons

elevation movement of a bone upward, such as when the shoulders are shrugged, lifting the scapulae

embryophyte other name for land plant; embryo is protected and nourished by the sporophyte

emergent vegetation wetland plants that are rooted in the soil but have portions of leaves, stems, and flowers extending above the water's surface

emerging disease disease making an initial appearance in a population or that is increasing in incidence or geographic range

Emsleyan/Mertensian mimicry type of mimicry where a harmful species resembles a less harmful one

enantiomers molecules that share overall structure and bonding patterns, but differ in how the atoms are three dimensionally placed such that they are mirror images of each other

Enantiornithes dominant bird group during the Cretaceous period

endemic disease disease that is constantly present, usually at low incidence, in a population

endemic species found only in a specific geographic area that is usually restricted in size

endemic species species native to one place

endergonic describes chemical reactions that require energy input

endocardium innermost layer of tissue in the heart

endocarp innermost part of fruit

endochondral ossification process of bone development from hyaline cartilage

endocrine cell cell that releases ligands involved in endocrine signaling (hormones)

endocrine gland gland that secretes hormones into the surrounding interstitial fluid, which then diffuse into blood and are carried to various organs and tissues within the body

endocrine signal long-distance signal that is delivered by ligands (hormones) traveling through an organisms circulatory system from the signaling cell to the target cell

endocrine system system that controls the response of the various glands in the body and the release of hormones at the appropriate times

endocytosis type of active transport that moves substances, including fluids and particles, into a cell

endodermis layer of cells in the root that forms a selective barrier between the ground tissue and the vascular tissue, allowing water and minerals to enter the root while excluding toxins and pathogens

endomembrane system group of organelles and membranes in eukaryotic cells that work together modifying, packaging, and transporting lipids and proteins

endoplasmic reticulum (ER) series of interconnected membranous structures within eukaryotic cells that collectively modify proteins and synthesize lipids

endoskeleton skeleton of living cells that produce a hard, mineralized tissue located within the soft tissue of organisms

endosperm triploid structure resulting from fusion of a sperm with polar nuclei, which serves as a nutritive tissue for embryo

endospermic dicot dicot that stores food reserves in the endosperm

endosymbiosis engulfment of one cell within another such that the engulfed cell survives, and both cells benefit; the process responsible for the evolution of mitochondria and chloroplasts in eukaryotes

endosymbiotic theory theory that states that eukaryotes may have been a product of one cell engulfing another, one living within another, and evolving over time until the separate cells were no longer recognizable as such

endotherm animal capable of maintaining a relatively constant internal body temperature

energy budget allocation of energy resources for body maintenance, reproduction, and parental care

enhancer segment of DNA that is upstream, downstream, perhaps thousands of nucleotides away, or on another chromosome that influence the transcription of a specific gene

enterocoelom coelom formed by fusion of coelomic pouches budded from the endodermal lining of the archenteron

enterocoely mesoderm of deuterostomes develops as pouches that are pinched off from endodermal tissue, cavity contained within the pouches becomes coelom

enthalpy total energy of a system

entropy (S) measure of randomness or disorder within a system

envelope lipid bilayer that envelopes some viruses

environmental disturbance change in the environment caused by natural disasters or human activities

enzyme catalyst in a biochemical reaction that is usually a complex or conjugated protein

enzyme-linked receptor cell-surface receptor with intracellular domains that are associated with membrane-bound enzymes

eosinophil leukocyte that responds to parasites and is involved in the allergic response

ependymal cell that lines fluid-filled ventricles of the brain and the central canal of the spinal cord; involved in production of cerebrospinal fluid

epicardium outermost tissue layer of the heart

epicotyl embryonic shoot above the cotyledons

epidemic disease that occurs in an unusually high number of individuals in a population at the same time

epidermis outer layer (from ectoderm) that lines the outside of the animal

epidermis single layer of cells found in plant dermal tissue; covers and protects underlying tissue

epigenetic heritable changes that do not involve changes in the DNA sequence

epilepsy neurological disorder characterized by recurrent seizures

epinephrine hormone released by the adrenal medulla in response to a short term stress

epiphyseal plate region between the diaphysis and epiphysis that is responsible for the lengthwise growth of long bones

epiphysis rounded end of bone, covered with articular cartilage and filled with red bone marrow, which produces blood cells

epiphyte plant that grows on other plants but is not dependent upon other plants for nutrition

epistasis antagonistic interaction between genes such that one gene masks or interferes with the expression of another

epithelial tissue tissue that either lines or covers organs or other tissues

epitope small component of an antigen that is specifically recognized by antibodies, B cells, and T cells; the antigenic determinant

equilibrium steady state of an ecosystem where all organisms are in balance with their environment and each other

equilibrium steady state of relative reactant and product concentration in reversible chemical reactions in a closed system

erythropoietin (EPO) hormone produced by the kidneys to stimulate red blood cell production in the bone marrow

esophagus tubular organ that connects the mouth to the stomach

essential nutrient nutrient that cannot be synthesized by the body; it must be obtained from food

estivation torpor in response to extremely high temperatures and low water availability

estrogen reproductive hormone in females that assists in endometrial regrowth, ovulation, and calcium absorption

estrogens - a group of steroid hormones, including estradiol and several others, that are produced by the ovaries and elicit secondary sex characteristics in females as well as control the maturation of the ova

estuary biomes where a source of fresh water, such as a river, meets the ocean

ethology biological study of animal behavior

ethylene volatile plant hormone that is associated with fruit ripening, flower wilting, and leaf fall

eucoelomate animal with a body cavity completely lined with mesodermal tissue

eukaryote organism with cells that have nuclei and membrane-bound organelles

eukaryote-first hypothesis proposal that prokaryotes evolved from eukaryotes

eukaryotic cell cell that has a membrane-bound nucleus and several other membrane-bound compartments or sacs

eukaryotic initiation factor-2 (eIF-2) protein that binds first to an mRNA to initiate translation

Eumetazoa group of animals with true differentiated tissues

euploid individual with the appropriate number of chromosomes for their species

eutherian mammal mammal that possesses a complex placenta, which connects a fetus to the mother; sometimes called placental mammals

eutrophication process whereby nutrient runoff causes the excess growth of microorganisms, depleting dissolved oxygen levels and killing ecosystem fauna

evaporation separation of individual molecules from the surface of a body of water, leaves of a plant, or the skin of an organism

eversion movement of the sole of the foot outward, away from the midline of the body; opposite of inversion

evolution process of gradual change during which new species arise from older species and some species become extinct

evolutionary fitness (also, Darwinian fitness) individual's ability to survive and reproduce

excitatory postsynaptic potential (EPSP) depolarization of a postsynaptic membrane caused by neurotransmitter molecules released from a presynaptic cell

exergonic describes chemical reactions that release free energy

exine outermost covering of pollen

exocarp outermost covering of a fruit

exocytosis process of passing bulk material out of a cell

exon sequence present in protein-coding mRNA after completion of pre-mRNA splicing

exoskeleton a secreted cellular product external skeleton that consists of a hard encasement on the surface of an organism

exotic species (also, invasive species) species that has been introduced to an ecosystem in which it did not evolve

expiratory reserve volume (ERV) amount of additional air that can be exhaled after a normal exhalation

exponential growth accelerating growth pattern seen in species under conditions where resources are not limiting

expressed sequence tag (EST) short STS that is identified with cDNA

extant still-living species

extension movement in which the angle between the bones of a joint increases; opposite of flexion

external fertilization fertilization of egg by sperm outside animal body, often during spawning

extinct no longer existing species

extinction disappearance of a species from Earth; local extinction is the disappearance of a species from a region

extinction rate number of species becoming extinct over time, sometimes defined as extinctions per million species–years to make numbers manageable (E/MSY)

extracellular digestion food is taken into the gastrovascular cavity, enzymes are secreted into the cavity, and the cells lining the cavity absorb nutrients

extracellular domain region of a cell-surface receptor that is located on the cell surface

extracellular matrix material (primarily collagen, glycoproteins, and proteoglycans) secreted from animal cells that provides mechanical protection and anchoring for the cells in the tissue

extremophile organism that grows under extreme or harsh conditions

F_1 first filial generation in a cross; the offspring of the parental generation

F_2 second filial generation produced when F_1 individuals are self-crossed or fertilized with each other

facial bone one of the 14 bones that form the face; provides cavities for the sense organs (eyes, mouth, and nose) and attachment points for facial muscles

facilitated transport process by which material moves down a concentration gradient (from high to low concentration) using integral membrane proteins

FACT complex that "facilitates chromatin transcription" by disassembling nucleosomes ahead of a transcribing RNA polymerase II and reassembling them after the polymerase passes by

faculative anaerobes organisms that can perform both aerobic and anaerobic respiration and can survive in oxygen-rich and oxygen-poor environment

fall and spring turnover seasonal process that recycles nutrients and oxygen from the bottom of a freshwater ecosystem to the top

fallout direct deposit of solid minerals on land or in the ocean from the atmosphere

false negative incorrect test result that should have been positive

falsifiable able to be disproven by experimental results

family division of order in the taxonomic classification system

fecundity potential reproductive capacity of an individual

feedback inhibition effect of a product of a reaction sequence to decrease its further production by inhibiting the activity of the first enzyme in the pathway that produces it

femur (also, thighbone) longest, heaviest, and strongest bone in the body

fermentation process of regenerating NAD^+ with either an inorganic or organic compound serving as the final electron accceptor, occurs in the absence; occurs in the absence of oxygen

fern seedless vascular plant that produces large fronds; the most advanced group of seedless vascular plants

fertilization union of two haploid cells from two individual organisms

FEV1/FVC ratio ratio of how much air can be forced out of the lung in one second to the total amount that is forced out of the lung; a measurement of lung function that can be used to detect disease states

fibrous connective tissue type of connective tissue with a high concentration of fibers

fibrous joint joint held together by fibrous connective tissue

fibrous root system type of root system in which the roots arise from the base of the stem in a cluster, forming a dense network of roots; found in monocots

fibula (also, calf bone) parallels and articulates with the tibia

filament thin stalk that links the anther to the base of the flower

first messenger the hormone that binds to a plasma membrane hormone receptor to trigger a signal transduction pathway

fission (also, binary fission) method by which multicellular organisms increase in size or asexual reproduction in which a unicellular organism splits into two separate organisms by mitosis

fixed action pattern series of instinctual behaviors that, once initiated, always goes to completion regardless of changes in the environment

flagellum (plural = flagella) long, hair-like structure that extends from the plasma membrane and is used to move the cell

flame cell (also, protonephridia) excretory cell found in flatworms

flat bone thin and relatively broad bone found where extensive protection of organs is required or where broad surfaces of muscle attachment are required

flexion movement in which the angle between the bones decreases; opposite of extension

flight feather feather specialized for flight

flower branches specialized for reproduction found in some seed-bearing plants, containing either specialized male or female organs or both male and female organs

flow-resistive work of breathing performed by the alveoli and tissues in the lung

fluid mosaic model describes the structure of the plasma membrane as a mosaic of components including phospholipids, cholesterol, proteins, glycoproteins, and glycolipids (sugar chains attached to proteins or lipids, respectively), resulting in a fluid character (fluidity)

folds on the inner surface of the small intestine whose role is to increase absorption area

follicle stimulating hormone (FSH) reproductive hormone that causes sperm production in men and follicle development in women

follicle-stimulating hormone (FSH) hormone produced by the anterior pituitary that stimulates gamete production

food chain linear representation of a chain of primary producers, primary consumers, and higher- level consumers used to describe ecosystem structure and dynamics

food web graphic representation of a holistic, non-linear web of primary producers, primary consumers, and higher-level consumers used to describe ecosystem structure and dynamics

foodborne disease any illness resulting from the consumption of contaminated food, or of the pathogenic bacteria, viruses, or other parasites that contaminate food

foraging behaviors species use to find food

forced expiratory volume (FEV) (also, forced vital capacity) measure of how much air can be forced out of the lung from maximal inspiration over a specific amount of time

forearm extends from the elbow to the wrist and consists of two bones: the ulna and the radius

foreign DNA DNA that belongs to a different species or DNA that is artificially synthesized

foundation species species which often forms the major structural portion of the habitat

founder effect event that initiates an allele frequency change in part of the population, which is not typical of the original population

fovea region in the center of the retina with a high density of photoreceptors and which is responsible for acute vision

fragmentation cutting or fragmenting of the original animal into parts and the growth of a separate animal from each part

free energy Gibbs free energy is the usable energy, or energy that is available to do work.

free nerve ending ending of an afferent neuron that lacks a specialized structure for detection of sensory stimuli; some respond to touch, pain, or temperature

frequency-dependent selection selection that favors phenotypes that are either common (positive frequency-dependent selection) or rare (negative frequency-dependent selection)

frog tail-less amphibian that belongs to the clade Anura

frontal (coronal) plane plane cutting through an animal separating the individual into front and back portions

frontal lobe part of the cerebral cortex that contains the motor cortex and areas involved in planning, attention, and language

fruit thickened tissue derived from ovary wall that protects the embryo after fertilization and facilitates seed dispersal

FtsZ tubulin-like protein component of the prokaryotic cytoskeleton that is important in prokaryotic cytokinesis (name origin: **F**ilamenting **t**emperature-**s**ensitive mutant **Z**)

functional group group of atoms that provides or imparts a specific function to a carbon skeleton

functional residual capacity (FRC) expiratory reserve volume plus residual volume

functional vital capacity (FVC) amount of air that can be forcibly exhaled after taking the deepest breath possible

furcula wishbone formed by the fusing of the clavicles

fusiform animal body shape that is tubular and tapered at both ends

fusion method of entry by some enveloped viruses, where the viral envelope fuses with the plasma membrane of the host cell

G_0 phase distinct from the G_1 phase of interphase; a cell in G_0 is not preparing to divide

G_1 phase (also, first gap) first phase of interphase centered on cell growth during mitosis

G_2 phase (also, second gap) third phase of interphase during which the cell undergoes final preparations for mitosis

gallbladder organ that stores and concentrates bile

gametangium structure on the gametophyte in which gametes are produced

gamete haploid reproductive cell or sex cell (sperm, pollen grain, or egg)

gametic barrier prezygotic barrier occurring when closely related individuals of different species mate, but differences in their gamete cells (eggs and sperm) prevent fertilization from taking place

gametophyte a multicellular haploid life-cycle stage that produces gametes

gametophyte multicellular stage of the plant that gives rise to haploid gametes or spores

gap junction channel between two adjacent animal cells that allows ions, nutrients, and low molecular weight substances to pass between cells, enabling the cells to communicate

gastric inhibitory peptide hormone secreted by the small intestine in the presence of fatty acids and sugars; it also inhibits acid production and peristalsis in order to slow down the rate at which food enters the small intestine

gastric phase digestive phase beginning once food enters the stomach; gastric acids and enzymes process the ingested materials

gastrin hormone which stimulates hydrochloric acid secretion in the stomach

gastrodermis inner layer (from endoderm) that lines the digestive cavity

gastrovascular cavity digestive system consisting of a single opening

gastrovascular cavity opening that serves as both a mouth and an anus, which is termed an incomplete digestive system

gastrula stage of animal development characterized by the formation of the digestive cavity

gastrulation process in which the blastula folds over itself to form the three germ layers

GC-rich box (GGCG) nonessential eukaryotic promoter sequence that binds cellular factors to increase the efficiency of transcription; may be present several times in a promoter

gel electrophoresis technique used to separate molecules on the basis of size using electric charge

gemma (plural, gemmae) leaf fragment that spreads for asexual reproduction

gemmule structure produced by asexual reproduction in freshwater sponges where the morphology is inverted

gene expression processes that control the turning on or turning off of a gene

gene flow flow of alleles in and out of a population due to the migration of individuals or gametes

gene physical and functional unit of heredity, a sequence of DNA that codes for a protein.

gene pool all of the alleles carried by all of the individuals in the population

gene targeting method for altering the sequence of a specific gene by introducing the modified version on a vector

gene therapy technique used to cure inheritable diseases by replacing mutant genes with good genes

gene therapy treatment of genetic disease by adding genes, using viruses to carry the new genes inside the cell

gene transfer agent (GTA) bacteriophage-like particle that transfers random genomic segments from one species of prokaryote to another

genetic diagnosis diagnosis of the potential for disease development by analyzing disease-causing genes

genetic diversity variety of genes in a species or other taxonomic group or ecosystem, the term can refer to allelic diversity or genome-wide diversity

genetic drift effect of chance on a population's gene pool

genetic engineering alteration of the genetic makeup of an organism

genetic map outline of genes and their location on a chromosome

genetic marker gene or sequence on a chromosome with a known location that is associated with a specific trait

genetic recombination exchange of DNA between homologous pairs of chromosomes

genetic structure distribution of the different possible genotypes in a population

genetic testing process of testing for the presence of disease-causing genes

genetic variance diversity of alleles and genotypes in a population

genetically modified organism (GMO) organism whose genome has been artificially changed

genome annotation process of attaching biological information to gene sequences

genome fusion fusion of two prokaryotic genomes, presumably by endosymbiosis

genome mapping process of finding the location of genes on each chromosome

genome total genetic information of a cell or organism

genomic library collection of cloned DNA which represents all of the sequences and fragments from a genome

genomics study of entire genomes including the complete set of genes, their nucleotide sequence and organization, and their interactions within a species and with other species

genotype underlying genetic makeup, consisting of both physically visible and non-expressed alleles, of an organism

genus division of family in the taxonomic classification system; the first part of the binomial scientific name

genus of chimpanzees and bonobos

geographical variation differences in the phenotypic variation between populations that are separated geographically

geometric isomer isomer with similar bonding patterns differing in the placement of atoms alongside a double covalent bond

germ cells specialized cell line that produces gametes, such as eggs or sperm

germ layer collection of cells formed during embryogenesis that will give rise to future body tissues, more pronounced in vertebrate embryogenesis

gestation length of time for fetal development to birth

gibberellin (GA) plant hormone that stimulates shoot elongation, seed germination, and the maturation and dropping of fruit and flowers

gigantism condition caused by overproduction of GH in children

gill circulation circulatory system that is specific to animals with gills for gas exchange; the blood flows through the gills for oxygenation

gingkophyte gymnosperm with one extant species, the *Gingko biloba*: a tree with fan-shaped leaves

gizzard muscular organ that grinds food

glabrous describes the non-hairy skin found on palms and fingers, soles of feet, and lips of humans and other primates

glia (also, **glial cells**) cells that provide support functions for neurons

gliding movement when relatively flat bone surfaces move past each other

global climate change altered global weather patterns, including a worldwide increase in temperature, due largely to rising levels of atmospheric carbon dioxide

Glomeromycota phylum of fungi that form symbiotic relationships with the roots of trees

glomerular filtration filtration of blood in the glomerular capillary network into the glomerulus

glomerular filtration rate (GFR) amount of filtrate formed by the glomerulus per minute

glomerulus (renal) part of the renal corpuscle that contains the capillary network

glomerulus in the olfactory bulb, one of the two neural clusters that receives signals from one type of olfactory receptor

glucagon hormone produced by the alpha cells of the pancreas in response to low blood sugar; functions to raise blood sugar levels

glucocorticoid corticosteroid that affects glucose metabolism

gluconeogenesis synthesis of glucose from amino acids

glucose-sparing effect effect of GH that causes tissues to use fatty acids instead of glucose as an energy source

GLUT protein integral membrane protein that transports glucose

glycogen storage carbohydrate in animals

glycogenolysis breakdown of glycogen into glucose

glycolipid combination of carbohydrates and lipids

glycolysis process of breaking glucose into two three-carbon molecules with the production of ATP and NADH

glycoprotein combination of carbohydrates and proteins

glycosidic bond bond formed by a dehydration reaction between two monosaccharides with the elimination of a water molecule

gnathostome jawed fish

gnetophyte gymnosperm shrub with varied morphological features that produces vessel elements in its woody tissues; the phylum includes the genera *Ephedra, Gnetum* and *Welwitschia*

goiter enlargement of the thyroid gland caused by insufficient dietary iodine levels

Golgi apparatus eukaryotic organelle made up of a series of stacked membranes that sorts, tags, and packages lipids and proteins for distribution

Golgi tendon organ muscular proprioceptive tension receptor that provides the sensory component of the Golgi tendon reflex

gomphosis the joint in which the tooth fits into the socket like a peg

gonadotropin hormone that regulates the gonads, including FSH and LH

gonadotropin-releasing hormone (GnRH) hormone from the hypothalamus that causes the release of FSH and LH from the anterior pituitary

good genes hypothesis theory of sexual selection that argues individuals develop impressive ornaments to show off their efficient metabolism or ability to fight disease

Gorilla genus of gorillas

G-protein a membrane protein activated by the hormone first messenger to activate formation of cyclic AMP

G-protein-linked receptor cell-surface receptor that activates membrane-bound G-proteins to transmit a signal from the receptor to nearby membrane components

gradual speciation model model that shows how species diverge gradually over time in small steps

grafting method of asexual reproduction where the stem from one plant species is spliced to a different plant

Gram negative bacterium whose cell wall contains little peptidoglycan but has an outer membrane

Gram positive bacterium that contains mainly peptidoglycan in its cell walls

granum stack of thylakoids located inside a chloroplast

granzyme protease that enters target cells through perforin and induces apoptosis in the target cells; used by NK cells and killer T cells

gravitropism response of a plant growth in the same direction as gravity

grazing food web type of food web in which the primary producers are either plants on land or phytoplankton in the water; often associated with a detrital food web within the same ecosystem

greenhouse effect warming of Earth due to carbon dioxide and other greenhouse gases in the atmosphere

greenhouse gases atmospheric gases such as carbon dioxide and methane that absorb and emit radiation, thus trapping heat in Earth's atmosphere

gross primary productivity rate at which photosynthetic primary producers incorporate energy from the sun

ground tissue found towards the interior of the vascular tissue in a stem or root

ground tissue plant tissue involved in photosynthesis; provides support, and stores water and sugars

group I virus virus with a dsDNA genome

group II virus virus with a ssDNA genome

group III virus virus with a dsRNA genome

group IV virus virus with a ssRNA genome with positive polarity

group V virus virus with a ssRNA genome with negative polarity

group VI virus virus with a ssRNA genomes converted into dsDNA by reverse transcriptase

group VII virus virus with a single-stranded mRNA converted into dsDNA for genome replication

growth factor ligand that binds to cell-surface receptors and stimulates cell growth

growth hormone (GH) hormone produced by the anterior pituitary that promotes protein synthesis and body growth

growth hormone-inhibiting hormone (GHIH) hormone produced by the hypothalamus that inhibits growth hormone production, also called somatostatin

growth hormone-releasing hormone (GHRH) hormone released by the hypothalamus that triggers the release of GH

guanine diphosphate (GDP) molecule that is left after the energy is used to start translation

guanine triphosphate (GTP) energy-providing molecule that binds to eIF-2 and is needed for translation

guard cells paired cells on either side of a stoma that control stomatal opening and thereby regulate the movement of gases and water vapor

gustation sense of taste

gymnosperm seed plant with naked seeds (seeds exposed on modified leaves or in cones)

gynoecium (also, carpel) structure that constitute the female reproductive organ

gynoecium the sum of all the carpels in a flower

gyrus (plural: gyri) ridged protrusions in the cortex

habitat isolation reproductive isolation resulting when populations of a species move or are moved to a new habitat, taking up residence in a place that no longer overlaps with the other populations of the same species

habituation ability of a species to ignore repeated stimuli that have no consequence

hagfish eel-like jawless fish that live on the ocean floor and are scavengers

hairpin structure of RNA when it folds back on itself and forms intramolecular hydrogen bonds between complementary nucleotides

halophile organism that require a salt concentration of at least 0.2 M

handicap principle theory of sexual selection that argues only the fittest individuals can afford costly traits

haplodiplodontic haploid and diploid stages alternate

haploid cell, nucleus, or organism containing one set of chromosomes (*n*)

haploid-dominant life-cycle type in which the multicellular haploid stage is prevalent

haplontic haploid stage is the dominant stage

haustoria modified hyphae on many parasitic fungi that penetrate the tissues of their hosts, release digestive enzymes, and/or absorb nutrients from the host

Haversian canal contains the bone's blood vessels and nerve fibers

haze-effect cooling effect of the gases and solids from a volcanic eruption on global climate

heat energy energy transferred from one system to another that is not work (energy of the motion of molecules or particles)

heat energy total bond energy of reactants or products in a chemical reaction

heat of vaporization of water high amount of energy required for liquid water to turn into water vapor

heirloom seed seed from a plant that was grown historically, but has not been used in modern agriculture on a large scale

helicase during replication, this enzyme helps to open up the DNA helix by breaking the hydrogen bonds

helper T lymphocyte (T_H) cell of the adaptive immune system that binds APCs via MHC II cell of the adaptive immune system that binds APCs via MHC II

molecules and stimulates B cells or secretes cytokines to initiate the

immune response

heme group centralized iron-containing group that is surrounded by the alpha and beta subunits of hemoglobin

hemizygous presence of only one allele for a characteristic, as in X-linkage; hemizygosity makes descriptions of dominance and recessiveness irrelevant

hemocoel cavity into which blood is pumped in an open circulatory system

hemocoel internal body cavity seen in arthropods

hemoglobin molecule in red blood cells that can bind oxygen, carbon dioxide, and carbon monoxide

hemolymph mixture of blood and interstitial fluid that is found in insects and other arthropods as well as most mollusks

herbaceous grass-like plant noticeable by the absence of woody tissue

herbivore animal that consumes strictly plant diet

herbivory consumption of plants by insects and other animals

heritability fraction of population variation that can be attributed to its genetic variance

hermaphrodite referring to an animal where both male and female gonads are present in the same individual

hermaphroditism state of having both male and female reproductive parts within the same individual

heterodont tooth different types of teeth that are modified for different purposes

heterogeneity number of ecological niches

heterospecifics individuals that are members of different species

heterosporous produces two types of spores

heterothallic describes when only one mating type is present in an individual mycelium

heterotroph organism that consumes organic substances or other organisms for food

heterozygous having two different alleles for a given gene on the homologous chromosome

hibernation torpor over a long period of time, such as a winter

hilum region in the renal pelvis where blood vessels, nerves, and ureters bunch before entering or exiting the kidney

hinge joint slightly rounded end of one bone fits into the slightly hollow end of the other bone

hippocampus brain structure in the temporal lobe involved in processing memories

histone acetylation epigenetic modification that leads to gene silencing; commonly found in cancer cells found in cancer cells

histone one of several similar, highly conserved, low molecular weight, basic proteins found in the chromatin of all eukaryotic cells; associates with DNA to form nucleosomes

holistic ecosystem model study that attempts to quantify the composition, interactions, and dynamics of entire ecosystems; often limited by economic and logistical difficulties, depending on the ecosystem

holoblastic complete cleavage; takes place in cells with a small amount of yolk

holoenzyme prokaryotic RNA polymerase consisting of α, α, β, β', and σ; this complex is responsible for transcription initiation

homeostasis ability of an organism to maintain constant internal conditions

homeostasis dynamic equilibrium maintaining appropriate body functions

hominin species that are more closely related to humans than chimpanzees

hominoid pertaining to great apes and humans

Homo genus of humans

Homo sapiens sapiens anatomically modern humans

homologous chromosomes chromosomes of the same morphology with genes in the same location; diploid organisms have pairs of homologous chromosomes (homologs), with each homolog derived from a different parent

homologous recombination process by which homologous chromosomes undergo reciprocal physical exchanges at their arms, also known as crossing over

homologous structures parallel structures in diverse organisms that have a common ancestor

homosporous produces one type of spore

homothallic describes when both mating types are present in mycelium

homozygous having two identical alleles for a given gene on the homologous chromosome

honest signal trait that gives a truthful impression of an individual's fitness

horizon soil layer with distinct physical and chemical properties, which differs from other layers depending on how and when it was formed

horizontal gene transfer (HGT) (also, lateral gene transfer) transfer of genes between unrelated species

horizontal transmission transmission of a disease from parent to offspring

hormonal stimuli release of a hormone in response to another hormone

hormone chemical signaling molecule, usually protein or steroid, secreted by endocrine cells that act to control or regulate specific physiological processes

hormone receptor the cellular protein that binds to a hormone

hornworts group of non-vascular plants in which stomata appear

horsetail seedless vascular plant characterized by joints

host an organism that is invaded by a pathogen or parasite

host DNA DNA that is present in the genome of the organism of interest

host organism a parasite lives on

Hox gene (also, homeobox gene) master control gene that can turn on or off large numbers of other genes during embryogenesis

human beta chorionic gonadotropin (β-HCG) hormone produced by the chorion of the zygote that helps to maintain the corpus luteum and elevated levels of progesterone

humerus only bone of the arm

humoral immune response adaptive immune response that is controlled by activated B cells and antibodies

humoral stimuli control of hormone release in response to changes in extracellular fluids such as blood or the ion concentration in the blood

humus organic material of soil; made up of microorganisms, dead animals and plants in varying stages of decay

hybrid offspring of two closely related individuals, not of the same species

hybrid zone area where two closely related species continue to interact and reproduce, forming hybrids

hybridization process of mating two individuals that differ with the goal of achieving a certain characteristic in their offspring

hydrocarbon molecule that consists only of carbon and hydrogen

hydrogen bond weak bond between slightly positively charged hydrogen atoms to slightly negatively charged atoms in other molecules

hydrogenosome organelle carried by parabasalids (Excavata) that functions anaerobically and outputs hydrogen gas as a byproduct; likely evolved from mitochondria

hydrolysis reaction causes breakdown of larger molecules into smaller molecules with the utilization of water

hydrophilic describes ions or polar molecules that interact well with other polar molecules such as water

hydrophilic molecule with the ability to bond with water; "water-loving"

hydrophobic describes uncharged non-polar molecules that do not interact well with polar molecules such as water

hydrophobic molecule that does not have the ability to bond with water; "water-hating"

hydrosphere area of the Earth where water movement and storage occurs

hydrostatic skeleton skeleton that consists of aqueous fluid held under pressure in a closed body compartment

hydrothermal vent fissure in Earth's surface that releases geothermally heated water

Hylobatidae family of gibbons

Hylonomus one of the earliest reptiles

hyoid bone lies below the mandible in the front of the neck

hyperextension extension past the regular anatomical position

hyperglycemia high blood sugar level

hyperopia (also, farsightedness) visual defect in which the image focus falls behind the retina, thereby making images in the distance clear, but close-up images blurry

hyperplasia abnormally high cell growth and division

hyperpolarization change in the membrane potential to a more negative value

hypersensitivities spectrum of maladaptive immune responses toward harmless foreign particles or self antigens; occurs after tissue sensitization and includes immediate-type (allergy), delayed- type, and autoimmunity

hyperthermophile organism that grows at temperatures between 80–122 °C

hyperthyroidism overactivity of the thyroid gland

hypertonic situation in which extracellular fluid has a higher osmolarity than the fluid inside the cell, resulting in water moving out of the cell

hypha fungal filament composed of one or more cells

hypocotyl embryonic axis above the cotyledons

hypoglycemia low blood sugar level

hypophyseal portal system system of blood vessels that carries hormones from the hypothalamus to the anterior pituitary

hypoplasia abnormally low cell growth and division

hypothalamus brain structure that controls hormone release and body homeostasis

hypothesis suggested explanation for an observation, which can be tested

hypothesis-based science form of science that begins with a specific question and potential testable answers

hypothyroidism underactivity of the thyroid gland

hypotonic situation in which extracellular fluid has a lower osmolarity than the fluid inside the cell, resulting in water moving into the cell

ileum last part of the small intestine; connects the small intestine to the large intestine; important for absorption of B-12

immune response

immune tolerance acquired ability to prevent an unnecessary or harmful immune response to a detected foreign body known not to cause disease or to self-antigens

immunodeficiency failure, insufficiency, or delay at any level of the immune system, which may be acquired or inherited

imprinting identification of parents by newborns as the first organism they see after birth

inbreeding depression increase in abnormalities and disease in inbreeding populations

inbreeding mating of closely related individuals

incomplete dominance in a heterozygote, expression of two contrasting alleles such that the individual displays an intermediate phenotype

incus (also, anvil) second of the three bones of the middle ear

indeterminate cleavage early stage of development when germ cells or “stem cells” are not yet pre-determined to develop into specific cell types

induced fit dynamic fit between the enzyme and its substrate, in which both components modify their structures to allow for ideal binding

induced mutation mutation that results from exposure to chemicals or environmental agents

inducible operon operon that can be activated or repressed depending on cellular needs and the surrounding environment

inductive reasoning form of logical thinking that uses related observations to arrive at a general conclusion

inert gas (also, noble gas) element with filled outer electron shell that is unreactive with other atoms

inferior vena cava drains blood from the veins that come from the lower organs and the legs

inferior vena cava one of the main veins in the human body

infertility inability to conceive, carry, and deliver children

inflammation localized redness, swelling, heat, and pain that results from the movement of leukocytes and fluid through opened capillaries to a site of infection

ingestion act of taking in food

inhibin hormone made by Sertoli cells; provides negative feedback to hypothalamus in control of FSH and GnRH release

inhibitor molecule that binds to a protein (usually an enzyme) and keeps it from functioning

inhibitory postsynaptic potential (IPSP) hyperpolarization of a postsynaptic membrane caused by neurotransmitter molecules released from a presynaptic cell

initiation complex protein complex containing eIF2-2 that starts translation

initiation site nucleotide from which mRNA synthesis proceeds in the 5' to 3' direction; denoted with a "+1"

initiator tRNA in prokaryotes, called tRNA f ; in eukaryotes, called tRNAi; a tRNA that interacts with a start codon, binds directly to the ribosome P site, and links to a special methionine to begin a polypeptide chain

innate behavior instinctual behavior that is not altered by changes in the environment

innate immunity immunity that occurs naturally because of genetic factors or physiology, and is not induced by infection or vaccination

inner cell mass inner layer of cells in the blastocyst

inner ear innermost part of the ear; consists of the cochlea and the vestibular system

inorganic compound chemical compound that does not contain carbon; it is not part of or produced by a living organism

inositol phospholipid lipid present at small concentrations in the plasma membrane that is converted into a second messenger; it has inositol (a carbohydrate) as its hydrophilic head group

inositol triphosphate (IP_3) cleavage product of PIP_2 that is used for signaling within the cell

insectivorous plant plant that has specialized leaves to attract and digest insects

inspiratory capacity (IC) tidal volume plus inspiratory reserve volume

inspiratory reserve volume (IRV) amount of additional air that can be inspired after a normal inhalation

insulin hormone produced by the beta cells of the pancreas in response to high blood glucose levels; functions to lower blood glucose levels

insulin-like growth factor (IGF) growth-promoting protein produced by the liver

integral protein protein integrated into the membrane structure that interacts extensively with the hydrocarbon chains of membrane lipids and often spans the membrane; these proteins can be removed only by the disruption of the membrane by detergents

integument layer of sporophyte tissue that surrounds the megasporangium, and later, the embryo

intercalary meristem meristematic tissue located at nodes and the bases of leaf blades; found only in monocots

intercellular signaling communication between cells

intercostal muscle muscle connected to the rib cage that contracts upon inspiration

interferon cytokine that inhibits viral replication and modulates the immune response

interkinesis (also, *interphase II*) brief period of rest between meiosis I and meiosis II

interlobar artery artery that branches from the segmental artery and travels in between the renal lobes

intermediate filament cytoskeletal component, composed of several intertwined strands of fibrous protein, that bears tension, supports cell-cell junctions, and anchors cells to extracellular structures

intermittent symptom symptom that occurs periodically

internal fertilization fertilization of egg by sperm inside the body of the female

internal receptor (also, intracellular receptor) receptor protein that is located in the cytosol of a cell and binds to ligands that pass through the plasma membrane

internode region between nodes on the stem

interphase period of the cell cycle leading up to mitosis; includes G1, S, and G2 phases (the interim period between two consecutive cell divisions

intersexual selection selection of a desirable mate of the opposite sex

interspecific competition competition between species for resources in a shared habitat or environment

interstitial cell of Leydig cell in seminiferous tubules that makes testosterone

interstitial fluid fluid between cells

intertidal zone part of the ocean that is closest to land; parts extend above the water at low tide

intervertebral disc composed of fibrous cartilage; lies between adjacent vertebrae from the second cervical vertebra to the sacrum

intestinal phase third digestive phase; begins when chyme enters the small intestine triggering digestive secretions and controlling the rate of gastric emptying

intine inner lining of the pollen

intracellular hormone receptor a hormone receptor in the cytoplasm or nucleus of a cell

intracellular mediator (also, second messenger) small molecule that transmits signals within a cell

intracellular signaling communication within cells

intramembranous ossification process of bone development from fibrous membranes

intrapleural space space between the layers of pleura

intrasexual selection competition between members of the same sex for a mate

intraspecific competition competition between members of the same species

introduction opening section of a scientific paper, which provides background information about what was known in the field prior to the research reported in the paper

intron non–protein-coding intervening sequences that are spliced from mRNA during processing

inversion soles of the feet moving inward, toward the midline of the body

invertebrata (also, invertebrates) category of animals that do not possess a cranium or vertebral column

ion created when carbonic acid dissociates into H^+ and (HCO^-)

ion channel-linked receptor cell-surface receptor that forms a plasma membrane channel, which opens when a ligand binds to the extracellular domain (ligand-gated channels)

ionic bond chemical bond that forms between ions with opposite charges (cations and anions)

iris pigmented, circular muscle at the front of the eye that regulates the amount of light entering the eye

irregular bone bone with complex shapes; examples include vertebrae and hip bones

irreversible chemical reaction chemical reaction where reactants proceed uni-directionally to form products

island biogeography study of life on island chains and how their geography interacts with the diversity of species found there

islets of Langerhans (pancreatic islets) endocrine cells of the pancreas

isomerase enzyme that converts a molecule into its isomer

isomers molecules that differ from one another even though they share the same chemical formula

isotonic situation in which the extracellular fluid has the same osmolarity as the fluid inside the cell, resulting in no net movement of water into or out of the cell

isotope one or more forms of an element that have different numbers of neutrons

isthmus tissue mass that connects the two lobes of the thyroid gland

iteroparity life history strategy characterized by multiple reproductive events during the lifetime of a species

jasmonates small family of compounds derived from the fatty acid linoleic acid

jejunum second part of the small intestine

joint point at which two or more bones meet

J-shaped growth curve shape of an exponential growth curve

juxtaglomerular cell cell in the afferent and efferent arterioles that responds to stimuli from the macula densa

juxtamedullary nephron nephron that lies in the cortex but close to the renal medulla

karyogamy fusion of nuclei

karyogram photographic image of a karyotype

karyokinesis mitotic nuclear division

karyotype number and appearance of an individuals chromosomes; includes the size, banding patterns, and centromere position

keystone species species whose presence is key to maintaining biodiversity in an ecosystem and to upholding an ecological community's structure

kidney organ that performs excretory and osmoregulatory functions

kin selection sacrificing one's own life so that one's genes will be passed on to future generations by relatives

kinase enzyme that catalyzes the transfer of a phosphate group from ATP to another molecule

kinesis undirected movement of an organism in response to a stimulus

kinesthesia sense of body movement

kinetic energy type of energy associated with objects or particles in motion

kinetochore protein structure associated with the centromere of each sister chromatid that attracts and binds spindle microtubules during prometaphase

kinetoplast mass of DNA carried within the single, oversized mitochondrion, characteristic of kinetoplastids (phylum: Euglenozoa)

kingdom division of domain in the taxonomic classification system

Kozak's rules determines the correct initiation AUG in a eukaryotic mRNA; the following consensus sequence must appear around the AUG: 5'-GCC(**purine**)CCAUG**G**-3'; the bolded bases are most important

Krebs cycle (also, citric acid cycle) alternate name for the citric acid cycle, named after Hans Krebs who first identified the steps in the pathway in the 1930s in pigeon flight muscles; see citric acid cycle

***K*-selected species** species suited to stable environments that produce a few, relatively large offspring and provide parental care

labia majora large folds of tissue covering the inguinal area

labia minora smaller folds of tissue within the labia majora

labyrinth bony, hollow structure that is the most internal part of the ear; contains the sites of transduction of auditory and vestibular information

lac operon operon in prokaryotic cells that encodes genes required for processing and intake of lactose

lactase enzyme that breaks down lactose into glucose and galactose

lacuna space in cartilage and bone that contains living cells

lagging strand during replication, the strand that is replicated in short fragments and away from the replication fork

lamella layer of compact tissue that surrounds a central canal called the Haversian canal

lamina leaf blade

lamprey jawless fish characterized by a toothed, funnel-like, sucking mouth

lancelet member of Cephalochordata; named for its blade-like shape

large 60S ribosomal subunit second, larger ribosomal subunit that binds to the RNA to translate it into protein

large intestine digestive system organ that reabsorbs water from undigested material and processes waste matter

larynx voice box, a short passageway connecting the pharynx and the trachea

latency virus that remains in the body for a long period of time but only causes intermittent symptoms

lateral line sense organ that runs the length of a fish's body; used to detect vibration in the water

lateral meristem meristematic tissue that enables a plant to increase in thickness or girth

lateral rotation rotation away from the midline of the body

law of dominance in a heterozygote, one trait will conceal the presence of another trait for the same characteristic

law of independent assortment genes do not influence each other with regard to sorting of alleles into gametes; every possible combination of alleles is equally likely to occur

law of mass action chemical law stating that the rate of a reaction is proportional to the concentration of the reacting substances

law of segregation paired unit factors (i.e., genes) segregate equally into gametes such that offspring have an equal likelihood of inheriting any combination of factors

layering method of propagating plants by bending a stem under the soil

leading strand strand that is synthesized continuously in the 5'-3' direction which is synthesized in the direction of the replication fork

learned behavior behavior that responds to changes in the environment

lens transparent, convex structure behind the cornea that helps focus light waves on the retina

lenticel opening on the surface of mature woody stems that facilitates gas exchange

lepidosaur modern lizards, snakes, and tuataras

leptin hormone produced by adipose tissue that promotes feelings of satiety and reduces hunger

lichen close association of a fungus with a photosynthetic alga or bacterium that benefits both partners

life cycle the sequence of events in the development of an organism and the production of cells that produce offspring

life history inherited pattern of resource allocation under the influence of natural selection and other evolutionary forces

life science field of science, such as biology, that studies living things

life table table showing the life expectancy of a population member based on its age

ligand molecule produced by a signaling cell that binds with a specific receptor, delivering a signal in the process

ligase enzyme that catalyzes the formation of a phosphodiester linkage between the 3' OH and 5' phosphate ends of the DNA

light harvesting complex complex that passes energy from sunlight to the reaction center in each photosystem; it consists of multiple antenna proteins that contain a mixture of 300–400 chlorophyll *a* and *b* molecules as well as other pigments like carotenoids

light microscope an instrument that magnifies an object using a beam visible light passed and bent through a lens system to visualize a specimen

light-dependent reaction first stage of photosynthesis where certain wavelengths of the visible light are absorbed to form two energy-carrying molecules (ATP and NADPH)

light-independent reaction second stage of photosynthesis, though which carbon dioxide is used to build carbohydrate molecules using energy from ATP and NADPH

lignin complex polymer impermeable to water

limbic system connected brain areas that process emotion and motivation

linkage analysis procedure that analyzes the recombination of genes to determine if they are linked

linkage phenomenon in which alleles that are located in close proximity to each other on the same chromosome are more likely to be inherited together

lipase enzyme that chemically breaks down lipids

lipid macromolecule that is nonpolar and insoluble in water

lipid-derived hormone hormone derived mostly from cholesterol

litmus paper (also, pH paper) filter paper that has been treated with a natural water-soluble dye that changes its color as the pH of the environment changes so it can be used as a pH indicator

liver organ that produces bile for digestion and processes vitamins and lipids

liverworts most primitive group of the non-vascular plants

loam soil that has no dominant particle size

lobes of the kidney renal pyramid along with the adjoining cortical region

locus position of a gene on a chromosome

logistic growth leveling off of exponential growth due to limiting resources

long bone bone that is longer than wide, and has a shaft and two ends

long-term depression (LTD) prolonged decrease in synaptic coupling between a pre- and postsynaptic cell

long-term potentiation (LTP) prolonged increase in synaptic coupling between a pre-and postsynaptic cell

loop of Henle part of the renal tubule that loops into the renal medulla

loose (areolar) connective tissue type of connective tissue with small amounts of cells, matrix, and fibers; found around blood vessels

Lophotrochozoa clade of protostomes that exhibit a trochophore larvae stage or a lophophore feeding structure

lower limb consists of the thigh, the leg, and the foot

lung capacity measurement of two or more lung volumes (how much air can be inhaled from the end of an expiration to maximal capacity)

lung volume measurement of air for one lung function (normal inhalation or exhalation)

luteinizing hormone (LH) reproductive hormone in both men and women, causes testosterone production in men and ovulation and lactation in women

lycophyte club moss

lymph node specialized organ that contains a large number of macrophages that clean the lymph before the fluid is returned to the heart

lymph watery fluid that bathes tissues and organs with protective white blood cells and does not contain erythrocytes

lymphocyte leukocyte that is histologically identifiable by its large nuclei; it is a small cell with very little cytoplasm

lysis buffer solution used to break the cell membrane and release cell contents

lysis bursting of a cell

lysogenic cycle type of virus replication in which the viral genome is incorporated into the genome of the host cell

lysosome organelle in an animal cell that functions as the cell's digestive component; it breaks down proteins, polysaccharides, lipids, nucleic acids, and even worn-out organelles

lytic cycle type of virus replication in which virions are released through lysis, or bursting, of the cell

macroevolution broader scale evolutionary changes seen over paleontological time

macromolecule large molecule, typically formed by the joining of smaller molecules

macronutrient nutrient that is required in large amounts for plant growth; carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur

macrophage large phagocytic cell that engulfs foreign particles and pathogens

macula densa group of cells that senses changes in sodium ion concentration; present in parts of the renal tubule and collecting ducts

madreporite pore for regulating entry and exit of water into the water vascular system

major depression mental illness characterized by prolonged periods of sadness

major histocompatibility class (MHC) I/II molecule protein found on the surface of all nucleated cells (I) or specifically on antigen-presenting cells (II) that signals to immune cells whether the cell is healthy/normal or is infected/cancerous; it provides the appropriate template into which antigens can be loaded for recognition by lymphocytes

malleus (also, hammer) first of the three bones of the middle ear

Malpighian tubule excretory tubules found in arthropods

maltase enzyme that breaks down maltose into glucose

mammal one of the groups of endothermic vertebrates that possesses hair and mammary glands

mammary gland in female mammals, a gland that produces milk for newborns

mantle (also, pallium) specialized epidermis that encloses all visceral organs and secretes shells

mark and recapture technique used to determine population size in mobile organisms

marsupial one of the groups of mammals that includes the kangaroo, koala, bandicoot, Tasmanian devil, and several other species; young develop within a pouch

mass extinction event that wipes out the majority of species within a relatively short geological time period

mass number total number of protons and neutrons in an atom

mast cell leukocyte that produces inflammatory molecules, such as histamine, in response to large pathogens and allergens

mastax jawed pharynx unique to the rotifers

materials and methods section of a scientific paper that includes a complete description of the substances, methods, and techniques used by the researchers to gather data

mating factor signaling molecule secreted by yeast cells to communicate to nearby yeast cells that they are available to mate and communicating their mating orientation

matrix component of connective tissue made of both living and non-living (ground substances) cells

matrix protein envelope protein that stabilizes the envelope and often plays a role in the assembly of progeny virions

matter anything that has mass and occupies space

maximum parsimony applying the simplest, most obvious way with the least number of steps

mechanoreceptor sensory receptor modified to respond to mechanical disturbance such as being bent, touch, pressure, motion, and sound

medial rotation rotation toward the midline of the body

medulla middle layer of an organ like the kidney or adrenal gland

medusa free-floating cnidarian body plan with mouth on underside and tentacles hanging down from a bell

megafauna large animals

megagametogenesis second phase of female gametophyte development, during which the surviving haploid megaspore undergoes mitosis to produce an eight-nucleate, seven-cell female gametophyte, also known as the megagametophyte or embryo sac.

megapascal (MPa) pressure units that measure water potential

megaphyll larger leaves with a pattern of branching veins

megasporangium tissue found in the ovary that gives rise to the female gamete or egg

megaspore female spore

megasporocyte megaspore mother cell; larger spore that germinates into a female gametophyte in a heterosporous plant

megasporogenesis first phase of female gametophyte development, during which a single cell in the diploid megasporangium undergoes meiosis to produce four megaspores, only one of which survives

megasporophyll bract (a type of modified leaf) on the central axis of a female gametophyte

meiosis a nuclear division process that results in four haploid cells

meiosis I first round of meiotic cell division; referred to as reduction division because the ploidy level is reduced from diploid to haploid

meiosis II second round of meiotic cell division following meiosis I; sister chromatids are separated into individual chromosomes, and the result is four unique haploid cells

Meissner's corpuscle (also, tactile corpuscle) encapsulated, rapidly-adapting mechanoreceptor in the skin that responds to light touch

membrane potential difference in electrical potential between the inside and outside of a cell

memory cell antigen-specific B or T lymphocyte that does not differentiate into effector cells during the primary immune response but that can immediately become an effector cell upon re- exposure to the same pathogen

meninge membrane that covers and protects the central nervous system

menopause loss of reproductive capacity in women due to decreased sensitivity of the ovaries to FSH and LH

menstrual cycle cycle of the degradation and re-growth of the endometrium

meristem plant region of continuous growth

meristematic tissue tissue containing cells that constantly divide; contributes to plant growth

Merkel's disc unencapsulated, slowly-adapting mechanoreceptor in the skin that responds to touch

meroblastic partial cleavage; takes place in cells with a large amount of yolk

mesocarp middle part of a fruit

mesocosm portion of a natural ecosystem to be used for experiments

mesoglea non-living, gel-like matrix present between ectoderm and endoderm in cnidarians

mesohyl collagen-like gel containing suspended cells that perform various functions in the sponge

mesophyll middle layer of chlorophyll-rich cells in a leaf

messenger RNA (mRNA) RNA that carries information from DNA to ribosomes during protein synthesis

metabolism all the chemical reactions that take place inside cells, including anabolism and catabolism

metabolome complete set of metabolites which are related to the genetic makeup of an organism

metabolomics study of small molecule metabolites found in an organism

metacarpus five bones that comprise the palm

metagenomics study of the collective genomes of multiple species that grow and interact in an environmental niche

metamerism series of body structures that are similar internally and externally, such as segments

metaphase plate equatorial plane midway between the two poles of a cell where the chromosomes align during metaphase

metaphase stage of mitosis during which chromosomes are aligned at the metaphase plate

metatarsal one of the five bones of the foot

Metazoa group containing all animals

microbial mat multi-layered sheet of prokaryotes that may include bacteria and archaea

microbiology study of the structure and function of microorganisms

microcosm re-creation of natural ecosystems entirely in a laboratory environment to be used for experiments

microevolution changes in a population's genetic structure

microfilament narrowest element of the cytoskeleton system; it provides rigidity and shape to the cell and enables cellular movements

microglia glia that scavenge and degrade dead cells and protect the brain from invading microorganisms

micronutrient nutrient required in small amounts; also called trace element

microphyll small size and simple vascular system with a single unbranched vein

micropropagation propagation of desirable plants from a plant part; carried out in a laboratory

micropyle opening on the ovule sac through which the pollen tube can gain entry

microRNA (miRNA) small RNA molecules (approximately 21 nucleotides in length) that bind to RNA molecules to degrade them

microsatellite polymorphism variation between individuals in the sequence and number of repeats of microsatellite DNA

microscope an instrument that magnifies an object

microsporangium tissue that gives rise to the microspores or the pollen grain

microspore male spore

microsporocyte smaller spore that produces a male gametophyte in a heterosporous plant

microsporophyll central axis of a male cone on which bracts (a type of modified leaf) are attached

microtubule widest element of the cytoskeleton system; it helps the cell resist compression, provides a track along which vesicles move through the cell, pulls replicated chromosomes to opposite ends of a dividing cell, and is the structural element of centrioles, flagella, and cilia

microvilli cellular processes that increase the surface area of cells

middle ear part of the hearing apparatus that functions to transfer energy from the tympanum to the oval window of the inner ear

midsagittal plane plane cutting through an animal separating the individual into even right and left sides

migration long-range seasonal movement of animal species

Milankovitch cycles cyclic changes in the Earth's orbit that may affect climate

mineral inorganic, elemental molecule that carries out important roles in the body

mineral soil type of soil that is formed from the weathering of rocks and inorganic material; composed primarily of sand, silt, and clay

mineralocorticoid corticosteroid that affects ion and water balance

mismatch repair type of repair mechanism in which mismatched bases are removed after replication

mitochondria (singular = mitochondrion) cellular organelles responsible for carrying out cellular respiration, resulting in the production of ATP, the cell's main energy-carrying molecule

mitochondria-first hypothesis proposal that prokaryotes acquired a mitochondrion first, followed by nuclear development

mitosis (also, karyokinesis) period of the cell cycle during which the duplicated chromosomes are separated into identical nuclei; includes prophase, prometaphase, metaphase, anaphase, and telophase

mitosome nonfunctional organelle carried in the cells of diplomonads (Excavata) that likely evolved from a mitochondrion

mitotic phase period of the cell cycle during which duplicated chromosomes are distributed into two nuclei and cytoplasmic contents are divided; includes karyokinesis (mitosis) and cytokinesis

mitotic spindle apparatus composed of microtubules that orchestrates the movement of chromosomes during mitosis

mixotroph organism that can obtain nutrition by autotrophic or heterotrophic means, usually facultatively

model organism species that is studied and used as a model to understand the biological processes in other species represented by the model organism

model system species or biological system used to study a specific biological phenomenon to be applied to other different species

modern synthesis overarching evolutionary paradigm that took shape by the 1940s and is generally accepted today

molality number of moles of solute per kilogram of solvent

molarity number of moles of solute per liter of solution

mold tangle of visible mycelia with a fuzzy appearance

mole gram equivalent of the molecular weight of a substance

molecular biology study of biological processes and their regulation at the molecular level, including interactions among molecules such as DNA, RNA, and proteins

molecular cloning cloning of DNA fragments

molecular systematics technique using molecular evidence to identify phylogenetic relationships

molecule chemical structure consisting of at least two atoms held together by one or more chemical bonds

molecule two or more atoms chemically bonded together

Mollusca phylum of protostomes with soft bodies and no segmentation

monocarpic plants that flower once in their lifetime

monocot related group of angiosperms that produce embryos with one cotyledon and pollen with a single ridge

monocyte type of white blood cell that circulates in the blood and lymph and differentiates into macrophages after it moves into infected tissue

monoecious describes a species in which the male and female reproductive organs are on the same plant

monogamy mating system whereby one male and one female remain coupled for at least one mating season

monogastric digestive system that consists of a single-chambered stomach

monohybrid result of a cross between two true-breeding parents that express different traits for only one characteristic

monomer smallest unit of larger molecules called polymers

monophyletic group (also, clade) organisms that share a single ancestor

monosaccharide single unit or monomer of carbohydrates

monosomy otherwise diploid genotype in which one chromosome is missing

monotreme egg-laying mammal

morning sickness condition in the mother during the first trimester; includes feelings of nausea

mortality rate proportion of population surviving to the beginning of an age interval that die during the age interval

mosses group of bryophytes in which a primitive conductive system appears

motor end plate sarcolemma of the muscle fiber that interacts with the neuron

MRSA (methicillin-resistant *Staphylococcus aureus*) very dangerous *Staphylococcus aureus* strain resistant to multiple antibiotics

mucin complex glycoprotein found in mucus

mucosa-associated lymphoid tissue (MALT) collection of lymphatic tissue that combines with epithelial tissue lining the mucosa throughout the body

mucus sticky protein-containing fluid secretion in the lung that traps particulate matter to be expelled from the body

Müllerian mimicry type of mimicry where species share warning coloration and all are harmful to predators

multiple cloning site (MCS) site that can be recognized by multiple restriction endonucleases

multiple fruit fruit that develops from multiple flowers on an inflorescence

muscle spindle proprioceptive stretch receptor that lies within a muscle and that shortens the muscle to an optimal length for efficient contraction

mutation variation in the nucleotide sequence of a genome

mutualism symbiotic relationship between two species where both species benefit

myc oncogene that causes cancer in many cancer cells

mycelium mass of fungal hyphae

mycetismus ingestion of toxins in poisonous mushrooms

mycology scientific study of fungi

mycorrhiza mutualistic association between fungi and vascular plant roots

mycorrhizae a mutualistic relationship between a plant and a fungus. Mycorrhizae are connections between fungal hyphae, which provide soil minerals to the plant, and plant roots, which provide carbohydrates to the fungus

mycosis fungal infection

mycotoxicosis poisoning by a fungal toxin released in food

myelin fatty substance produced by glia that insulates axons

myocardial infarction (also, heart attack) complete blockage of the coronary arteries and death of the cardiac muscle tissue

myocardium heart muscle cells that make up the middle layer and the bulk of the heart wall

myofibril long cylindrical structures that lie parallel to the muscle fiber

myofilament small structures that make up myofibrils

myopia (also, nearsightedness) visual defect in which the image focus falls in front of the retina, thereby making images in the distance blurry, but close-up images clear

myosin contractile protein that interacts with actin for muscle contraction

Myxini hagfishes

nacre calcareous secretion produced by bivalves to line the inner side of shells as well as to coat intruding particulate matter

nasal cavity opening of the respiratory system to the outside environment

natural killer (NK) cell lymphocyte that can kill cells infected with viruses or tumor cells

natural science field of science that is related to the physical world and its phenomena and processes

natural selection reproduction of individuals with favorable genetic traits that survive environmental change because of those traits, leading to evolutionary change

nauplius larval stage in the early development of crustaceans

nectar guide pigment pattern on a flower that guides an insect to the nectaries

nectar liquid rich in sugars produced by flowers to attract animal pollinators

negative feedback loop feedback to a control mechanism that increases or decreases a stimulus instead of maintaining it

negative gravitropism growth away from Earth's gravity

negative polarity ssRNA viruses with genomes complimentary to their mRNA

negative regulator protein that prevents transcription

nematocyst harpoon-like organelle within cnidocyte with pointed projectile and poison to stun and entangle prey

Nematoda phylum of worm-like animals that are triploblastic, pseudocoelomates that can be free- living or parasitic

Nemertea phylum of dorsoventrally flattened protostomes known as ribbon worms

Neognathae birds other than the Paleognathae

Neornithes modern birds

nephridia excretory structures found in annelids

nephridiopore pore found at the end of nephridia

nephron functional unit of the kidney

neritic zone part of the ocean that extends from low tide to the edge of the continental shelf

net consumer productivity energy content available to the organisms of the next trophic level

net primary productivity energy that remains in the primary producers after accounting for the organisms' respiration and heat loss

net primary productivity measurement of the energy accumulation within an ecosystem, calculated as the total amount of carbon fixed per year minus the amount that is oxidized during cellular respiration

net production efficiency (NPE) measure of the ability of a trophic level to convert the energy it receives from the previous trophic level into biomass

neural stimuli stimulation of endocrine glands by the nervous system

neural tube tube-like structure that forms from the ectoderm and gives rise to the brain and spinal cord

neurobiology study of the biology of the nervous system

neurodegenerative disorder nervous system disorder characterized by the progressive loss of neurological functioning, usually caused by neuron death

neuron specialized cell that can receive and transmit electrical and chemical signals

neurotransmitter chemical ligand that carries a signal from one nerve cell to the next

neutron uncharged particle that resides in the nucleus of an atom; has a mass of one amu

neutrophil phagocytic leukocyte that engulfs and digests pathogens

next-generation sequencing group of automated techniques used for rapid DNA sequencing

nitrification conversion of ammonium into nitrite and nitrate in soils

nitrogen fixation process by which gaseous nitrogen is transformed, or "fixed" into more readily available forms such as ammonia

nitrogenase enzyme that is responsible for the reduction of atmospheric nitrogen to ammonia

noble gas see inert gas

nociception neural processing of noxious (such as damaging) stimuli

node point along the stem at which leaves, flowers, or aerial roots originate

nodes of Ranvier gaps in the myelin sheath where the signal is recharged

nodule novel structure on the roots of certain plants (legumes) that results from the symbiotic interaction between the plant and soil bacteria, is the site of nitrogen fixation

nodules specialized structures that contain *Rhizobia* bacteria where nitrogen fixation takes place

nondisjunction failure of synapsed homologs to completely separate and migrate to separate poles during the first cell division of meiosis

non-electrolyte solute that does not break down into ions when dissolved in water

non-endospermic dicot dicot that stores food reserves in the developing cotyledon

nonparental (recombinant) type progeny resulting from homologous recombination that exhibits a different allele combination compared with its parents

nonpolar covalent bond type of covalent bond that forms between atoms when electrons are shared equally between them

nonrandom mating changes in a population's gene pool due to mate choice or other forces that cause individuals to mate with certain phenotypes more than others

non-renewable resource resource, such as fossil fuel, that is either regenerated very slowly or not at all

nonsense codon one of the three mRNA codons that specifies termination of translation

nontemplate strand strand of DNA that is not used to transcribe mRNA; this strand is identical to the mRNA except that T nucleotides in the DNA are replaced by U nucleotides in the mRNA

non-vascular plant plant that lacks vascular tissue, which is formed of specialized cells for the transport of water and nutrients

norepinephrine hormone released by the adrenal medulla in response to a short-term stress hormone production by the gonads

norepinephrine neurotransmitter and hormone released by activation of the sympathetic nervous system

northern blotting transfer of RNA from a gel to a nylon membrane

notochord flexible, rod-shaped support structure that is found in the embryonic stage of all chordates and in the adult stage of some chordates

nuclear envelope double-membrane structure that constitutes the outermost portion of the nucleus

nucleic acid biological macromolecule that carries the genetic blueprint of a cell and carries instructions for the functioning of the cell

nucleoid central part of a prokaryotic cell in which the chromosome is found

nucleolus darkly staining body within the nucleus that is responsible for assembling the subunits of the ribosomes

nucleoplasm semi-solid fluid inside the nucleus that contains the chromatin and nucleolus

nucleosome subunit of chromatin composed of a short length of DNA wrapped around a core of histone proteins

nucleotide excision repair type of DNA repair mechanism in which the wrong base, along with a few nucleotides upstream or downstream, are removed

nucleotide monomer of nucleic acids; contains a pentose sugar, one or more phosphate groups, and a nitrogenous base

nucleus cell organelle that houses the cell's DNA and directs the synthesis of ribosomes and proteins

nucleus core of an atom; contains protons and neutrons

nucleus-first hypothesis proposal that prokaryotes acquired a nucleus first, and then the mitochondrion

nutrient essential substances for growth, such as carbon and nitrogen

O horizon layer of soil with humus at the surface and decomposed vegetation at the base

obligate aerobes organisms, such as humans, that must perform aerobic respiration to survive

obligate anaerobes organisms that only perform anaerobic respiration and often cannot survive in the presence of oxygen

obstructive disease disease (such as emphysema and asthma) that arises from obstruction of the airways; compliance increases in these diseases

occipital lobe part of the cerebral cortex that contains visual cortex and processes visual stimuli

ocean upwelling rising of deep ocean waters that occurs when prevailing winds blow along surface waters near a coastline

oceanic zone part of the ocean that begins offshore where the water measures 200 m deep or deeper

Octamer box (ATTTGCAT) nonessential eukaryotic promoter sequence that binds cellular factors to increase the efficiency of transcription; may be present several times in a promoter

octet rule rule that atoms are most stable when they hold eight electrons in their outermost shells

odorant airborne molecule that stimulates an olfactory receptor

Okazaki fragment DNA fragment that is synthesized in short stretches on the lagging strand

olfaction sense of smell

olfactory bulb neural structure in the vertebrate brain that receives signals from olfactory receptors

olfactory epithelium specialized tissue in the nasal cavity where olfactory receptors are located

olfactory receptor dendrite of a specialized neuron

oligodendrocyte glial cell that myelinates central nervous system neuron axons

oligosaccharin hormone important in plant defenses against bacterial and fungal infections

omega fat type of polyunsaturated fat that is required by the body; the numbering of the carbon omega starts from the methyl end or the end that is farthest from the carboxylic end

omnivore animal that consumes both plants and animals

oncogene mutated version of a normal gene involved in the positive regulation of the cell cycle

oncogenic virus virus that has the ability to cause cancer

oncolytic virus virus engineered to specifically infect and kill cancer cells

one-child policy China's policy to limit population growth by limiting urban couples to have only one child or face the penalty of a fine

oogenesis process of producing haploid eggs

open circulatory system system in which the blood is mixed with interstitial fluid and directly covers the organs

operant conditioning learned behaviors in response to positive and/or negative reinforcement

operator region of DNA outside of the promoter region that binds activators or repressors that control gene expression in prokaryotic cells

operon collection of genes involved in a pathway that are transcribed together as a single mRNA in prokaryotic cells

opposition movement of the thumb toward the fingers of the same hand, making it possible to grasp and hold objects

opsonization process that enhances phagocytosis using proteins to indicate the presence of a pathogen to phagocytic cells

orbital region surrounding the nucleus; contains electrons

order division of class in the taxonomic classification system

organ collection of related tissues grouped together performing a common function

organ of Corti in the basilar membrane, the site of the transduction of sound, a mechanical wave, to a neural signal

organ system level of organization that consists of functionally related interacting organs

organelle compartment or sac within a cell

organelle small structures that exist within cells and carry out cellular functions

organic compound chemical compound that contains carbon

organic molecule any molecule containing carbon (except carbon dioxide)

organic soil type of soil that is formed from sedimentation; composed primarily of organic material

organism individual living entity

organogenesis formation of organs in animal embryogenesis

organogenesis process of organ formation

origin (also, ORI) region of the prokaryotic chromosome where replication begins (origin of replication)

Ornithorhynchidae clade that includes the duck-billed platypus

osculum large opening in the sponge's body through which water leaves

osmoconformer organism that changes its tonicity based on its environment

osmolarity total amount of substances dissolved in a specific amount of solution

osmophile organism that grows in a high sugar concentration

osmoreceptor receptor in the hypothalamus that monitors the concentration of electrolytes in the blood

osmoregulation mechanism by which water and solute concentrations are maintained at desired levels

osmoregulator organism that maintains its tonicity irrespective of its environment

osmosis transport of water through a semipermeable membrane according to the concentration gradient of water across the membrane that results from the presence of solute that cannot pass through the membrane

osmotic balance balance of the amount of water and salt input and output to and from a biological system without disturbing the desired osmotic pressure and solute concentration in every compartment

osmotic pressure pressure exerted on a membrane to equalize solute concentration on either side

osseous tissue connective tissue that constitutes the endoskeleton

ossicle one of the three bones of the middle ear

ossification (also, osteogenesis) process of bone formation by osteoblasts

Osteichthyes bony fish

osteoblast bone cell responsible for bone formation

osteoclast large bone cells with up to 50 nuclei, responsible for bone remodeling

osteocyte mature bone cells and the main cell in bone tissue

osteon cylindrical structure aligned parallel to the long axis of the bone

osteon subunit of compact bone

ostium (plural: ostia) holes between blood vessels that allow the movement of hemolymph through the body of insects, arthropods, and mollusks with open circulatory systems

ostium pore present on the sponge's body through which water enters

ostracoderm one of the earliest jawless fish covered in bone

outer ear part of the ear that consists of the pinna, ear canal, and tympanum and which conducts sound waves into the middle ear

outer loose layer that covers the surface of Earth

oval window thin diaphragm between the middle and inner ears that receives sound waves from contact with the stapes bone of the middle ear

ovarian cycle cycle of preparation of egg for ovulation and the conversion of the follicle to the corpus luteum

ovary chamber that contains and protects the ovule or female megasporangium

oviduct (also, fallopian tube) muscular tube connecting the uterus with the ovary area

oviger additional pair of appendages present on some arthropods between the chelicerae and pedipalps

oviparity process by which fertilized eggs are laid outside the female's body and develop there, receiving nourishment from the yolk that is a part of the egg

ovoviparity process by which fertilized eggs are retained within the female; the embryo obtains its nourishment from the egg's yolk and the young are fully developed when they are hatched

ovulate cone cone containing two ovules per scale

ovulation release of the egg by the most mature follicle

ovule female gametophyte

oxidative phosphorylation production of ATP using the process of chemiosmosis and oxygen

oxygen dissociation curve curve depicting the affinity of oxygen for hemoglobin

oxygen-carrying capacity amount of oxygen that can be transported in the blood

oxytocin hormone released by the posterior pituitary to stimulate uterine contractions during childbirth and milk let-down in the mammary glands

P_0 parental generation in a cross

P680 reaction center of photosystem II

P700 reaction center of photosystem I

Pacinian corpuscle encapsulated mechanoreceptor in the skin that responds to deep pressure and vibration

Paleognathae ratites; flightless birds, including ostriches and emus

paleontology study of life's history by means of fossils

palmately compound leaf leaf type with leaflets that emerge from a point, resembling the palm of a hand

pancreas organ located between the stomach and the small intestine that contains exocrine and endocrine cells; gland that secretes digestive juices

pandemic widespread, usually worldwide, epidemic disease

papilla one of the small bump-like projections from the tongue

paracentric inversion that occurs outside of the centromere

paracrine signal signal between nearby cells that is delivered by ligands traveling in the liquid medium in the space between the cells

parafollicular cell thyroid cell that produces the hormone calcitonin

parapodium fleshy, flat, appendage that protrudes in pairs from each segment of polychaetes

parasite organism that uses resources from another species, the host

parasitic plant plant that is dependent on its host for survival

parasitism symbiotic relationship in which one member of the association benefits at the expense of the other

parasympathetic nervous system division of autonomic nervous system that regulates visceral functions during rest and digestion

parathyroid gland gland located on the surface of the thyroid that produces parathyroid hormone

parathyroid hormone (PTH) hormone produced by the parathyroid glands in response to low blood Ca^{2+} levels; functions to raise blood Ca^{2+} levels

Parazoa group of animals without true differentiated tissues

parenchyma cell most common type of plant cell; found in the stem, root, leaf, and in fruit pulp; site of photosynthesis and starch storage

parent material organic and inorganic material in which soils form

parental types progeny that exhibits the same allelic combination as its parents

parietal lobe part of the cerebral cortex involved in processing touch and the sense of the body in space

Parkinson's disease neurodegenerative disorder that affects the control of movement

parthenogenesis form of asexual reproduction where an egg develops into a complete individual without being fertilized

partial pressure amount of pressure exerted by one gas within a mixture of gases

particulate matter small particle such as dust, dirt, viral particles, and bacteria that are in the air

passive immunity transfer of antibodies from one individual to another to provide temporary protection against pathogens

passive transport method of transporting material through a membrane that does not require energy

patella (also, kneecap) triangular bone that lies anterior to the knee joint

pathogen agent with the ability to cause disease

pathogen an agent, usually a microorganism, that causes disease in the organisms that they invade

pathogen-associated molecular pattern (PAMP) carbohydrate, polypeptide, and nucleic acid "signature" that is expressed by viruses, bacteria, and parasites but differs from molecules on host cells

pattern recognition receptor (PRR) molecule on macrophages and dendritic cells that binds molecular signatures of pathogens and promotes pathogen engulfment and destruction

peat moss Sphagnum

pectoral girdle bones that transmit the force generated by the upper limbs to the axial skeleton

pedipalp second pair of appendages in Chelicerata

peer-reviewed manuscript scientific paper that is reviewed by a scientist's colleagues who are experts in the field of study

pelagic realm (also, pelagic zone) open ocean waters that are not close to the bottom or near the shore

pellicle outer cell covering composed of interlocking protein strips that function like a flexible coat of armor, preventing cells from being torn or pierced without compromising their range of motion

pelvic girdle bones that transmit the force generated by the lower limbs to the axial skeleton

penis male reproductive structure for urine elimination and copulation

pepsin enzyme found in the stomach whose main role is protein digestion

pepsinogen inactive form of pepsin

peptide bond bond formed between two amino acids by a dehydration reaction

peptide hormone hormone composed of a polypeptide chain

peptidoglycan material composed of polysaccharide chains cross-linked to unusual peptides

peptidyl transferase RNA-based enzyme that is integrated into the 50S ribosomal subunit and catalyzes the formation of peptide bonds

perception individual interpretation of a sensation; a brain function

perforin destructive protein that creates a pore in the target cell; used by NK cells and killer T cells

perianth (also, petal or sepal) part of the flower consisting of the calyx and/or corolla; forms the outer envelope of the flower

perianth part of the plant consisting of the calyx (sepals) and corolla (petals)

pericardium membrane layer protecting the heart; also part of the epicardium

pericarp collective term describing the exocarp, mesocarp, and endocarp; the structure that encloses the seed and is a part of the fruit

pericentric inversion that involves the centromere

pericycle outer boundary of the stele from which lateral roots can arise

periderm outermost covering of woody stems; consists of the cork cambium, cork cells, and the phelloderm

periodic table organizational chart of elements indicating the atomic number and atomic mass of each element; provides key information about the properties of the elements

peripheral protein protein found at the surface of a plasma membrane either on its exterior or interior side; these proteins can be removed (washed off of the membrane) by a high-salt wash

peripheral resistance resistance of the artery and blood vessel walls to the pressure placed on them by the force of the heart pumping

perirenal fat capsule fat layer that suspends the kidneys

peristalsis wave-like movements of muscle tissue

peristome tissue that surrounds the opening of the capsule and allows periodic release of spores

peritubular capillary network capillary network that surrounds the renal tubule after the efferent artery exits the glomerulus

permafrost perennially frozen portion of the Arctic tundra soil

permanent tissue plant tissue composed of cells that are no longer actively dividing

permissive cell type that is able to support productive replication of a virus

peroxisome small, round organelle that contains hydrogen peroxide, oxidizes fatty acids and amino acids, and detoxifies many poisons

petal modified leaf interior to the sepals; colorful petals attract animal pollinators

petiole stalk of the leaf

Petromyzontidae clade of lampreys

pH paper see litmus paper

pH scale scale ranging from zero to 14 that is inversely proportional to the concentration of hydrogen ions in a solution

phage therapy treatment of bacterial diseases using bacteriophages specific to a particular bacterium

phagolysosome cellular body formed by the union of a phagosome containing the ingested particle with a lysosome that contains hydrolytic enzymes

phalange one of the bones of the fingers or toes

pharmacogenomics study of drug interactions with the genome or proteome; also called toxicogenomics

pharyngeal slit opening in the pharynx

pharynx throat; a tube that starts in the internal nares and runs partway down the neck, where it opens into the esophagus and the larynx

phenotype observable traits expressed by an organism

pheromone substance released by an animal that can affect the physiology or behavior of other animals

phloem tissue responsible for transport of sugars, proteins, and other solutes

phosphatase enzyme that removes the phosphate group from a molecule that has been previously phosphorylated

phosphoanhydride bond bond that connects phosphates in an ATP molecule

phosphodiester linkage covalent chemical bond that holds together the polynucleotide chains with a phosphate group linking two pentose sugars of neighboring nucleotides

phosphodiesterase (PDE) enzyme that deactivates cAMP, stopping hormone activity

phosphodiesterase enzyme that degrades cAMP, producing AMP, to terminate signaling

phospholipid major constituent of the membranes; composed of two fatty acids and a phosphate-containing group attached to a glycerol backbone

phosphorylation addition of a high-energy phosphate to a compound, usually a metabolic intermediate, a protein, or ADP

photic zone portion of the ocean that light can penetrate

photoact ejection of an electron from a reaction center using the energy of an absorbed photon

photoautotroph organism capable of producing its own organic compounds from sunlight

photomorphogenesis growth and development of plants in response to light

photon distinct quantity or "packet" of light energy

photoperiodism occurrence of plant processes, such as germination and flowering, according to the time of year

photosystem group of proteins, chlorophyll, and other pigments that are used in the light-dependent reactions of photosynthesis to absorb light energy and convert it into chemical energy

photosystem I integral pigment and protein complex in thylakoid membranes that uses light energy to transport electrons from plastocyanin to $NADP^+$ (which becomes reduced to NADPH in the process)

photosystem II integral protein and pigment complex in thylakoid membranes that transports electrons from water to the electron transport chain; oxygen is a product of PSII

phototroph organism that is able to make its own food by converting solar energy to chemical energy

phototropin blue-light receptor that promotes phototropism, stomatal opening and closing, and other responses that promote photosynthesis

phototropism directional bending of a plant toward a light source

phyllotaxy arrangement of leaves on a stem

phylogenetic tree diagram showing the evolutionary relationships among various biological species based on similarities and differences in genetic or physical traits or both; in essence, a hypothesis concerning evolutionary connections

phylogenetic tree diagram used to reflect the evolutionary relationships among organisms or groups of organisms

phylogeny evolutionary history and relationship of an organism or group of organisms

phylum (plural: phyla) division of kingdom in the taxonomic classification system

physical map representation of the physical distance between genes or genetic markers

physical science field of science, such as geology, astronomy, physics, and chemistry, that studies nonliving matter

physiological dead space (also, physiological shunt) region of the lung that lacks proper ventilation/perfusion due to a physiological change in the lung (like inflammation or edema)

phytochrome plant pigment protein that exists in two reversible forms (Pr and Pfr) and mediates morphologic changes in response to red light

pia mater thin membrane layer directly covering the brain and spinal cord

pigment molecule that is capable of absorbing certain wavelengths of light and reflecting others (which accounts for its color)

pilidium larval form found in some nemertine species

pilus surface appendage of some prokaryotes used for attachment to surfaces including other prokaryotes

pinacocyte epithelial-like cell that forms the outermost layer of sponges and encloses a jelly-like substance called mesohyl

pinna cartilaginous outer ear

pinnately compound leaf leaf type with a divided leaf blade consisting of leaflets arranged on both sides of the midrib

pinocytosis a variation of endocytosis that imports macromolecules that the cell needs from the extracellular fluid

pioneer species first species to appear in primary and secondary succession

pistil fused group of carpels

pith round tissue found towards the interior of the vascular tissue in a stem or root

pituitary dwarfism condition caused by underproduction of GH in children

pituitary gland endocrine gland located at the base of the brain composed of an anterior and posterior region; also called hypophysis

pituitary stalk (also, infundibulum) stalk that connects the pituitary gland to the hypothalamus

pivot joint joint with the rounded end of one bone fitting into a ring formed by the other bone

placenta organ that supports the diffusion of nutrients and waste between the mother's and fetus' blood

plagiarism using other people's work or ideas without proper citation, creating the false impression that those are the author's original ideas

planar joint joint with bones whose articulating surfaces are flat

planktivore animal species that eats plankton

plankton diverse group of mostly microscopic organisms that drift in marine and freshwater systems and serve as a food source for larger aquatic organisms

planospiral shell shape coiled around a vertical axis

plantar flexion bending at the ankle such that the heel is lifted, such as when standing on the toes

planuliform larval form found in phylum Nemertea

plasma cell immune cell that secrets antibodies; these cells arise from B cells that were stimulated by antigens

plasma liquid component of blood that is left after the cells are removed

plasma membrane hormone receptor a hormone receptor on the surface of the plasma membrane of a cell

plasma membrane phospholipid bilayer with embedded (integral) or attached (peripheral) proteins, and separates the internal content of the cell from its surrounding environment

plasmid extrachromosomal, covalently closed, circular DNA molecule that may only contain one or a few genes; common in prokaryotes

plasmodesma (plural = plasmodesmata) channel that passes between the cell walls of adjacent plant cells, connects their cytoplasm, and allows materials to be transported from cell to cell

plasmogamy fusion of cytoplasm

plasmolysis detaching of the cell membrane from the cell wall and constriction of the cell membrane when a plant cell is in a hypertonic solution

plastid one of a group of related organelles in plant cells that are involved in the storage of starches, fats, proteins, and pigments

platelet (also, thrombocyte) small cellular fragment that collects at wounds, cross-reacts with clotting factors, and forms a plug to prevent blood loss

Platyrrhini clade of New World monkeys

Plesiadapis oldest known primate-like mammal

pleura tissue layer that surrounds the lungs and lines the interior of the thoracic cavity

pleurisy painful inflammation of the pleural tissue layers

plumule shoot that develops from the germinating seed

pneumatic bone air-filled bone

point mutation mutation that affects a single base

polar covalent bond type of covalent bond that forms as a result of unequal sharing of electrons, resulting in the creation of slightly positive and slightly negative charged regions of the molecule

polar nuclei found in the ovule sac; fusion with one sperm cell forms the endosperm

pollen grain structure containing the male gametophyte of the plant

pollen tube extension from the pollen grain that delivers sperm to the egg cell

pollination transfer of pollen from the anther to the stigma

pollination transfer of pollen to the stigma

poly-A tail a series of adenine nucleotides that are attached to the 3' end of an mRNA to protect the end from degradation

poly-A tail modification added to the 3' end of pre-mRNAs to protect mRNA from degradation and assist mRNA export from the nucleus

polyandry mating system where one female mates with many males

polycarpic plants that flower several times in their lifetime

polygenic phenotypic characteristic caused by two or more genes

polygyny mating system where one male mates with many females

polymer chain of monomer residues that is linked by covalent bonds; polymerization is the process of polymer formation from monomers by condensation

polymerase chain reaction (PCR) technique used to amplify DNA

polymorphic possessing multiple body plans within the lifecycle of a group of organisms

polynucleotide long chain of nucleotides

polyp stalk-like sessile life form of a cnidarians with mouth and tentacles facing upward, usually sessile but may be able to glide along surface

polypeptide long chain of amino acids linked by peptide bonds

polyploid individual with an incorrect number of chromosome sets

polysaccharide long chain of monosaccharides; may be branched or unbranched

polysome mRNA molecule simultaneously being translated by many ribosomes all going in the same direction

polyspermy condition in which one egg is fertilized by multiple sperm

polytomy branch on a phylogenetic tree with more than two groups or taxa

Pongo genus of orangutans

population all of the individuals of a species living within a specific area

population density number of population members divided by the area or volume being measured

population genetics study of how selective forces change the allele frequencies in a population over time

population growth rate number of organisms added in each reproductive generation

population size (*N*) number of population members in a habitat at the same time

population variation distribution of phenotypes in a population

Porifera phylum of animals with no true tissues, but a porous body with rudimentary endoskeleton

positive feedback loop feedback to a control mechanism that continues the direction of a stimulus

positive gravitropism growth toward Earth's gravitational center

positive polarity ssRNA virus with a genome that contains the same base sequences and codons found in their mRNA

positive regulator protein that increases transcription

post-anal tail muscular, posterior elongation of the body extending beyond the anus in chordates

posterior pituitary extension of the brain that releases hormones produced by the hypothalamus; along with the infundibulum, it is also referred to as the neurohypophysis

post-transcriptional control of gene expression after the RNA molecule has been created but before it is translated into protein

post-translational control of gene expression after a protein has been created

postzygotic barrier reproductive isolation mechanism that occurs after zygote formation

potential energy type of energy that has the potential to do work; stored energy

potocytosis variation of pinocytosis that uses a different coating protein (caveolin) on the cytoplasmic side of the plasma membrane

precapillary sphincter small muscle that controls blood circulation in the capillary beds

predator animal species that hunt and are carnivores or "flesh eaters"

preinitiation complex cluster of transcription factors and other proteins that recruit RNA polymerase II for transcription of a DNA template

presbyopia visual defect in which the image focus falls behind the retina, thereby making images in the distance clear, but close-up images blurry; caused by age-based changes in the lens

prezygotic barrier reproductive isolation mechanism that occurs before zygote formation

primary active transport active transport that moves ions or small molecules across a membrane and may create a difference in charge across that membrane

primary bronchus (also, main bronchus) region of the airway within the lung that attaches to the trachea and bifurcates to each lung where it branches into secondary bronchi

primary consumer trophic level that obtains its energy from the primary producers of an ecosystem

primary electron acceptor pigment or other organic molecule in the reaction center that accepts an energized electron from the reaction center

primary feather feather located at the tip of the wing that provides thrust

primary growth growth resulting in an increase in length of the stem and the root; caused by cell division in the shoot or root apical meristem

primary producer trophic level that obtains its energy from sunlight, inorganic chemicals, or dead and/or decaying organic material

primary structure linear sequence of amino acids in a protein

primary succession succession on land that previously has had no life

primase enzyme that synthesizes the RNA primer; the primer is needed for DNA pol to start synthesis of a new DNA strand

Primates order of lemurs, tarsiers, monkeys, apes, and humans

primer short stretch of nucleotides that is required to initiate replication; in the case of replication, the primer has RNA nucleotides

prion infectious particle that consists of proteins that replicate without DNA or RNA

probe small DNA fragment used to determine if the complementary sequence is present in a DNA sample

product molecule found on the right side of a chemical equation

product rule probability of two independent events occurring simultaneously can be calculated by multiplying the individual probabilities of each event occurring alone

productive viral infection that leads to the production of new virions

progesterone reproductive hormone in women; assists in endometrial re-growth and inhibition of FSH and LH release

prognathic jaw long jaw

progymnosperm transitional group of plants that resembled conifers because they produced wood, yet still reproduced like ferns

prokaryote single-celled organism that lacks organelles and does not have nuclei surrounded by a nuclear membrane

prokaryote unicellular organism that lacks a nucleus or any other membrane-bound organelle

prolactin (PRL) hormone produced by the anterior pituitary that stimulates milk production

prolactin-inhibiting hormone hormone produced by the hypothalamus that inhibits the release of prolactin

prolactin-releasing hormone hormone produced by the hypothalamus that stimulates the release of prolactin

prometaphase stage of mitosis during which the nuclear membrane breaks down and mitotic spindle fibers attach to kinetochores

promoter DNA sequence to which RNA polymerase and associated factors bind and initiate transcription

pronation movement in which the palm faces backward

proofreading function of DNA pol in which it reads the newly added base before adding the next one

prophage phage DNA that is incorporated into the host cell genome

prophase stage of mitosis during which chromosomes condense and the mitotic spindle begins to form

proprioception sense about how parts of the body are oriented in space

proprioception sense of limb position; used to track kinesthesia

prosimian division of primates that includes bush babies of Africa, lemurs of Madagascar, and lorises, pottos, and tarsiers of Southeast Asia

prostate gland structure that is a mixture of smooth muscle and glandular material and that contributes to semen

prosthetic group (also, prosthetic cofactor) molecule bound to a protein that facilitates the function of the protein

protease enzyme that breaks down proteins

proteasome organelle that degrades proteins

protein biological macromolecule composed of one or more chains of amino acids

protein signature set of uniquely expressed proteins in the diseased state

proteome entire set of proteins produced by a cell type

proteomics study of the function of proteomes

proton positively charged particle that resides in the nucleus of an atom; has a mass of one amu and a charge of +1

protonema tangle of single celled filaments that forms from the haploid spore

proto-oncogene normal gene that when mutated becomes an oncogene

protostome blastopore develops into the mouth of protostomes, with the second opening developing into the anus

protraction anterior movement of a bone in the horizontal plane

proventriculus glandular part of a bird's stomach

proximal convoluted tubule (PCT) part of the renal tubule that lies close to the glomerulus

PrP^{C} normal prion protein

PrP^{SC} infectious form of a prion protein

pseudocoelomate animal with a body cavity located between the mesoderm and endoderm

pseudopeptidoglycan component of archaea cell walls that is similar to peptidoglycan in morphology but contains different sugars

pseudostratified layer of epithelia that appears multilayered, but is a simple covering

psychrophile organism that grows at temperatures of -15 °C or lower

pulmocutaneous circulation circulatory system in amphibians; the flow of blood to the lungs and the moist skin for gas exchange

pulmonary circulation flow of blood away from the heart through the lungs where oxygenation occurs and then returns to the heart again

pump active transport mechanism that works against electrochemical gradients

punctuated equilibrium model for rapid speciation that can occur when an event causes a small portion of a population to be cut off from the rest of the population

Punnett square visual representation of a cross between two individuals in which the gametes of each individual are denoted along the top and side of a grid, respectively, and the possible zygotic genotypes are recombined at each box in the grid

pupil small opening though which light enters

pure culture growth of a single type of cell in the laboratory

purine type of nitrogenous base in DNA and RNA; adenine and guanine are purines

pyrimidine type of nitrogenous base in DNA and RNA; cytosine, thymine, and uracil are pyrimidines

pyruvate three-carbon sugar that can be decarboxylated and oxidized to make acetyl CoA, which enters the citric acid cycle under aerobic conditions; the end product of glycolysis

quadrat square made of various materials used to determine population size and density in slow moving or stationary organisms

quaternary structure association of discrete polypeptide subunits in a protein

quiescent refers to a cell that is performing normal cell functions and has not initiated preparations for cell division

quorum sensing method of cellular communication used by bacteria that informs them of the abundance of similar (or different) bacteria in the environment

radial cleavage cleavage axes are parallel or perpendicular to the polar axis, resulting in the alignment of cells between the two poles

radial glia glia that serve as scaffolds for developing neurons as they migrate to their final destinations

radial symmetry type of symmetry with multiple planes of symmetry, with body parts (rays) arranged around a central disk

radiation hybrid mapping information obtained by fragmenting the chromosome with x-rays

radicle original root that develops from the germinating seed

radioisotope isotope that emits radiation composed of subatomic particles to form more stable elements

radioresistant organism that grows in high levels of radiation

radius bone located along the lateral (thumb) side of the forearm; articulates with the humerus at the elbow

radula tongue-like organ with chitinous ornamentation

raphe slit in the silica shell of diatoms through which the protist secretes a stream of mucopolysaccharides for locomotion and attachment to substrates

reactant molecule found on the left side of a chemical equation

reaction center complex of chlorophyll molecules and other organic molecules that is assembled around a special pair of chlorophyll molecules and a primary electron acceptor; capable of undergoing oxidation and reduction

reading frame sequence of triplet codons in mRNA that specify a particular protein; a ribosome shift of one or two nucleotides in either direction completely abolishes synthesis of that protein

reception receipt of a signal (such as light or sound) by sensory receptors

receptive field region in space in which a stimulus can activate a given sensory receptor

receptor potential membrane potential in a sensory receptor in response to detection of a stimulus

receptor protein in or on a target cell that bind to ligands

receptor-mediated endocytosis variation of endocytosis that involves the use of specific binding proteins in the plasma membrane for specific molecules or particles, and clathrin-coated pits that become clathrin-coated vesicles

recessive lethal inheritance pattern in which an allele is only lethal in the homozygous form; the heterozygote may be normal or have some altered, non-lethal phenotype

recessive trait that appears “latent” or non-expressed when the individual also carries a dominant trait for that same characteristic; when present as two identical copies, the recessive trait is expressed

reciprocal cross paired cross in which the respective traits of the male and female in one cross become the respective traits of the female and male in the other cross

recombinant DNA combination of DNA fragments generated by molecular cloning that does not exist in nature; also known as a chimeric molecule

recombinant protein protein product of a gene derived by molecular cloning

recombination frequency average number of crossovers between two alleles; observed as the number of nonparental types in a population of progeny

recombination nodules protein assemblies formed on the synaptonemal complex that mark the points of crossover events and mediate the multistep process of genetic recombination between non-sister chromatids

recruitment process of opening airways that normally remain closed when the cardiac output increases

rectum area of the body where feces is stored until elimination

red blood cell small (7–8 μm) biconcave cell without mitochondria (and in mammals without nuclei) that is packed with hemoglobin, giving the cell its red color; transports oxygen through the body

redox reaction chemical reaction that consists of the coupling of an oxidation reaction and a reduction reaction

reduction division nuclear division that produces daughter nuclei each having one-half as many chromosome sets as the parental nucleus; meiosis I is a reduction division

reduction gain of electron(s) by an atom or molecule

reflex action action in response to direct physical stimulation of a nerve

refractory period period after an action potential when it is more difficult or impossible for an action potential to be fired; caused by inactivation of sodium channels and activation of additional potassium channels of the membrane

regulatory T (T_{reg}) cell specialized lymphocyte that suppresses local inflammation and inhibits the secretion of cytokines, antibodies, and other stimulatory immune factors; involved in immune tolerance

reinforcement continued speciation divergence between two related species due to low fitness of hybrids between them

relative fitness individual's ability to survive and reproduce relative to the rest of the population

relative species abundance absolute population size of a particular species relative to the population sizes of other species within the community

renal artery branch of the artery that enters the kidney

renal capsule layer that encapsulates the kidneys

renal column area of the kidney through which the interlobar arteries travel in the process of supplying blood to the renal lobes

renal corpuscle glomerulus and the Bowman's capsule together

renal fascia connective tissue that supports the kidneys

renal pelvis region in the kidney where the calyces join the ureters

renal pyramid conical structure in the renal medulla

renal tubule tubule of the nephron that arises from the glomerulus

renal vein branch of a vein that exits the kidney and joins the inferior vena cava

renin enzyme produced by the juxtaglomerular apparatus of the kidneys that reacts with angiotensinogen to cause the release of aldosterone

renin-angiotensin-aldosterone biochemical pathway that activates angiotensin II, which increases blood pressure

replication fork Y-shaped structure formed during initiation of replication

replicative intermediate dsRNA intermediate made in the process of copying genomic RNA

repressor protein that binds to the operator of prokaryotic genes to prevent transcription

reproductive cloning cloning of entire organisms

reproductive isolation situation that occurs when a species is reproductively independent from other species; this may be brought about by behavior, location, or reproductive barriers

residence time measure of the average time an individual water molecule stays in a particular reservoir

residual volume (RV) amount of air remaining in the lung after a maximal expiration

resilience (ecological) speed at which an ecosystem recovers equilibrium after being disturbed

resistance (ecological) ability of an ecosystem to remain at equilibrium in spite of disturbances

resistance measurement of lung obstruction

resorption process by which osteoclasts release minerals stored in bones

respiratory bronchiole terminal portion of the bronchiole tree that is attached to the terminal bronchioles and alveoli ducts, alveolar sacs, and alveoli

respiratory distress syndrome disease that arises from a deficient amount of surfactant

respiratory quotient (RQ) ratio of carbon dioxide production to each oxygen molecule consumed

respiratory rate number of breaths per minute

restriction endonuclease enzyme that can recognize and cleave specific DNA sequences

restriction fragment length polymorphism (RFLP) variation between individuals in the length of DNA fragments generated by restriction endonucleases

restrictive disease disease that results from a restriction and decreased compliance of the alveoli; respiratory distress syndrome and pulmonary fibrosis are examples

results section of a scientific paper in which the author narrates the experimental findings and presents relevant figures, pictures, diagrams, graphs, and tables, without any further interpretation

resuscitation process by which prokaryotes that are in the VBNC state return to viability

retina layer of photoreceptive and supporting cells on the inner surface of the back of the eye

retinoblastoma protein (Rb) regulatory molecule that exhibits negative effects on the cell cycle by interacting with a transcription factor (E2F)

retraction movement in which a joint moves back into position after protraction

reverse genetics method of determining the function of a gene by starting with the gene itself instead of starting with the gene product

reverse transcriptase enzyme found in Baltimore groups VI and VII that converts single-stranded RNA into double-stranded DNA

reverse transcriptase PCR (RT-PCR) PCR technique that involves converting RNA to DNA by reverse transcriptase

reversible chemical reaction chemical reaction that functions bi-directionally, where products may turn into reactants if their concentration is great enough

review article paper that summarizes and comments on findings that were published as primary literature

rhizobia soil bacteria that symbiotically interact with legume roots to form nodules and fix nitrogen

rhizoids thin filaments that anchor the plant to the substrate

rhizome modified underground stem that grows horizontally to the soil surface and has nodes and internodes

rhizosphere area of soil affected by root secretions and microorganisms

Rho-dependent termination in prokaryotes, termination of transcription by an interaction between RNA polymerase and the rho protein at a run of G nucleotides on the DNA template

rhodopsin main photopigment in vertebrates

Rho-independent termination sequence-dependent termination of prokaryotic mRNA synthesis; caused by hairpin formation in the mRNA that stalls the polymerase

rhynchocoel cavity present above the mouth that houses the proboscis

rib one of 12 pairs of long, curved bones that attach to the thoracic vertebrae and curve toward the front of the body to form the ribcage

ribonuclease enzyme that breaks down RNA

ribonucleic acid (RNA) single-stranded, often internally base paired, molecule that is involved in protein synthesis

ribosomal RNA (rRNA) RNA that ensures the proper alignment of the mRNA and the ribosomes during protein synthesis and catalyzes the formation of the peptide linkage

ribosome cellular organelle that carries out protein synthesis

ring of life phylogenetic model where all three domains of life evolved from a pool of primitive prokaryotes

RISC protein complex that binds along with the miRNA to the RNA to degrade it

RNA editing direct alteration of one or more nucleotides in an mRNA that has already been synthesized

RNA stability how long an RNA molecule will remain intact in the cytoplasm

RNA-binding protein (RBP) protein that binds to the 3' or 5' UTR to increase or decrease the RNA stability

rod strongly photosensitive, achromatic, cylindrical neuron in the outer edges of the retina that detects dim light and is used in peripheral and nighttime vision

root cap protective cells covering the tip of the growing root

root hair hair-like structure that is an extension of epidermal cells; increases the root surface area and aids in absorption of water and minerals

root system belowground portion of the plant that supports the plant and absorbs water and minerals

rooted single ancestral lineage on a phylogenetic tree to which all organisms represented in the diagram relate

rotational movement movement of a bone as it rotates around its own longitudinal axis

rough endoplasmic reticulum (RER) region of the endoplasmic reticulum that is studded with ribosomes and engages in protein modification and phospholipid synthesis

roughage component of food that is low in energy and high in fiber

***r*-selected species** species suited to changing environments that produce many offspring and provide little or no parental care

Ruffini ending (also, bulbous corpuscle) slowly-adapting mechanoreceptor in the skin that responds to skin stretch and joint position

ruminant animal with a stomach divided into four compartments

runner stolon that runs above the ground and produces new clone plants at nodes

S phase second, or synthesis, stage of interphase during which DNA replication occurs

saddle joint joint with concave and convex portions that fit together; named because the ends of each bone resemble a saddle

sagittal plane plane cutting through an animal separating the individual into right and left sides

salamander tailed amphibian that belongs to the clade Urodela

salivary amylase enzyme found in saliva, which converts carbohydrates to maltose

saltatory conduction "jumping" of an action potential along an axon from one node of Ranvier to the next

sand soil particles between 0.1–2 mm in diameter

saprobe organism that derives nutrients from decaying organic matter; also saprophyte

saprophyte plant that does not have chlorophyll and gets its food from dead matter

sarcolemma plasma membrane of a skeletal muscle fiber

sarcomere functional unit of skeletal muscle

Sarcopterygii lobe-finned fish

satellite glia glial cell that provides nutrients and structural support for neurons in the peripheral nervous system

saturated fatty acid long-chain of hydrocarbon with single covalent bonds in the carbon chain; the number of hydrogen atoms attached to the carbon skeleton is maximized

sauropsid reptile or bird

scapula flat, triangular bone located at the posterior pectoral girdle

scarification mechanical or chemical processes to soften the seed coat

schizocoelom coelom formed by groups of cells that split from the endodermal layer

schizocoely during development of protostomes, a solid mass of mesoderm splits apart and forms the hollow opening of the coelom

schizophrenia mental disorder characterized by the inability to accurately perceive reality; patients often have difficulty thinking clearly and can suffer from delusions

Schwann cell glial cell that creates myelin sheath around a peripheral nervous system neuron axon

science knowledge that covers general truths or the operation of general laws, especially when acquired and tested by the scientific method

scientific method method of research with defined steps that include observation, formulation of a hypothesis, testing, and confirming or falsifying the hypothesis

scion the part of a plant that is grafted onto the root stock of another plant

sclerenchyma cell plant cell that has thick secondary walls and provides structural support; usually dead at maturity

sclerocyte cell that secretes silica spicules into the mesohyl

scrotum sac containing testes; exterior to the body

scutellum type of cotyledon found in monocots, as in grass seeds

sebaceous gland in mammals, a skin gland that produce a lipid mixture called *sebum*

second messenger small, non-protein molecule that propagates a signal within the cell after activation of a receptor causes its release

secondary active transport movement of material that is due to the electrochemical gradient established by primary active transport

secondary consumer usually a carnivore that eat primary consumers

secondary feather feather located at the base of the wing that provides lift

secondary growth growth resulting in an increase in thickness or girth; caused by the lateral meristem and cork cambium

secondary plant compound compound produced as byproducts of plant metabolic processes that is usually toxic, but is sequestered by the plant to defend against herbivores

secondary structure regular structure formed by proteins by intramolecular hydrogen bonding between the oxygen atom of one amino acid residue and the hydrogen attached to the nitrogen atom of another amino acid residue

secondary succession succession in response to environmental disturbances that move a community away from its equilibrium

secretin hormone which stimulates sodium bicarbonate secretion in the small intestine

seed structure containing the embryo, storage tissue and protective coat

seedless vascular plant plant that does not produce seeds

segmental artery artery that branches from the renal artery

selective pressure environmental factor that causes one phenotype to be better than another

selectively permeable characteristic of a membrane that allows some substances through but not others

self-pollination transfer of pollen from the anther to the stigma of same flower

semelparity life history strategy characterized by a single reproductive event followed by death

semen fluid mixture of sperm and supporting materials

semicircular canal one of three half-circular, fluid-filled tubes in the vestibular labyrinth that monitors angular acceleration and deceleration

semilunar valve membranous flap of connective tissue between the aorta and a ventricle of the heart (the aortic or pulmonary semilunar valves)

seminal vesicle secretory accessory gland in males; contributes to semen

seminiferous tubule site of sperm production in testes

semi-permeable membrane membrane that allows only certain solutes to pass through

senescence process that describes aging in plant tissues

sensory receptor specialized neuron or other cells associated with a neuron that is modified to receive specific sensory input

sensory transduction conversion of a sensory stimulus into electrical energy in the nervous system by a change in the membrane potential

sensory-somatic nervous system system of sensory and motor nerves

sepal modified leaf that encloses the bud; outermost structure of a flower

septa cell wall division between hyphae

septum structure formed in a bacterial cell as a precursor to the separation of the cell into two daughter cells

sequence mapping mapping information obtained after DNA sequencing

serendipity fortunate accident or a lucky surprise smallest fundamental unit of structure and function in living things

serotype strain of bacteria that carries a set of similar antigens on its cell surface, often many in a bacterial species

Sertoli cell cell in seminiferous tubules that assists developing sperm and makes inhibin

serum plasma without the coagulation factors

sesamoid bone small, flat bone shaped like a sesame seed; develops inside tendons

sessile leaf without a petiole that is attached directly to the plant stem

set point midpoint or target point in homeostasis

seta stalk that supports the capsule in mosses

seta/chaeta chitinous projection from the cuticle

sex-linked any gene on a sex chromosome

sexual dimorphism phenotypic difference between the males and females of a population

sexual reproduction mixing of genetic material from two individuals to produce genetically unique offspring

shared ancestral character describes a characteristic on a phylogenetic tree that is shared by all organisms on the tree

shared derived character describes a characteristic on a phylogenetic tree that is shared only by a certain clade of organisms

Shine-Dalgarno sequence (AGGAGG); initiates prokaryotic translation by interacting with rRNA molecules comprising the 30S ribosome

shoot system aboveground portion of the plant; consists of non-reproductive plant parts, such as leaves and stems, and reproductive parts, such as flowers and fruits

short bone bone that has the same width and length, giving it a cube-like shape

shotgun sequencing method used to sequence multiple DNA fragments to generate the sequence of a large piece of DNA

sickle cell anemia genetic disorder that affects the shape of red blood cells, and their ability to transport oxygen and move through capillaries

sieve-tube cell phloem cell arranged end to end to form a sieve tube that transports organic substances such as sugars and amino acids

signal integration interaction of signals from two or more different cell-surface receptors that merge to activate the same response in the cell

signal method of communication between animals including those obtained by the senses of smell, hearing, sight, or touch

signal sequence short tail of amino acids that directs a protein to a specific cellular compartment

signal transduction propagation of the signal through the cytoplasm (and sometimes also the nucleus) of the cell

signaling cell cell that releases signal molecules that allow communication with another cell

signaling pathway (also signaling cascade) chain of events that occurs in the cytoplasm of the cell to propagate the signal from the plasma membrane to produce a response

silent mutation mutation that is not expressed

silt soil particles between 0.002 and 0.1 mm in diameter

simple epithelia single layer of epithelial cells

simple fruit fruit that develops from a single carpel or fused carpels

simple leaf leaf type in which the lamina is completely undivided or merely lobed

simulation model ecosystem model that is created with computer programs to holistically model ecosystems and to predict the effects of environmental disturbances on ecosystem structure and dynamics

single nucleotide polymorphism (SNP) variation between individuals in a single nucleotide

single-strand binding protein during replication, protein that binds to the single-stranded DNA; this helps in keeping the two strands of DNA apart so that they may serve as templates

sink growing parts of a plant, such as roots and young leaves, which require photosynthate

sinoatrial (SA) node the heart's internal pacemaker; located near the wall of the right atrium

siphonophore tubular structure that serves as an inlet for water into the mantle cavity

sister taxa two lineages that diverged from the same branch point

skeletal muscle tissue forms skeletal muscles, which attach to bones and control locomotion and any movement that can be consciously controlled

skull bone that supports the structures of the face and protects the brain

S-layer surface-layer protein present on the outside of cell walls of archaea and bacteria

sliding clamp ring-shaped protein that holds the DNA pol on the DNA strand

small 40S ribosomal subunit ribosomal subunit that binds to the RNA to translate it into protein

small intestine organ where digestion of protein, fats, and carbohydrates is completed

small nuclear RNA molecules synthesized by RNA polymerase III that have a variety of functions, including splicing pre-mRNAs and regulating transcription factors

smooth endoplasmic reticulum (SER) region of the endoplasmic reticulum that has few or no ribosomes on its cytoplasmic surface and synthesizes carbohydrates, lipids, and steroid hormones; detoxifies certain chemicals (like pesticides, preservatives, medications, and environmental pollutants), and stores calcium ions

smooth muscle tissue occurs in the walls of hollow organs such as the intestines, stomach, and urinary bladder, and around passages such as the respiratory tract and blood vessels

soil particles between 0.002 and 0.1 mm in diameter

soil profile vertical section of a soil

solar intensity amount of solar power energy the sun emits in a given amount of time

solute substance dissolved in a liquid to form a solution

solvent substance capable of dissolving another substance

somatic cell all the cells of a multicellular organism except the gametes or reproductive cells

somatosensation sense of touch

somatostatin hormone released to stop acid secretion when the stomach is empty

somite group of cells separated by small spaces that form from the mesoderm and give rise to connective tissue

soredia clusters of algal cells and mycelia that allow lichens to propagate

source organ that produces photosynthate for a plant

source water point of origin of a river or stream

Southern blotting transfer of DNA from a gel to a nylon membrane

speciation formation of a new species

species dispersion pattern (also, species distribution pattern) spatial location of individuals of a given species within a habitat at a particular point in time

species group of populations that interbreed and produce fertile offspring

species richness number of different species in a community

species-area relationship relationship between area surveyed and number of species encountered; typically measured by incrementally increasing the area of a survey and determining the cumulative numbers of species

specific heat capacity the amount of heat one gram of a substance must absorb or lose to change its temperature by one degree Celsius

spectrophotometer instrument that can measure transmitted light and compute the absorption

spermatheca specialized sac that stores sperm for later use

spermatogenesis process of producing haploid sperm

spermatophyte seed plant; from the Greek *sperm* (seed) and *phyte* (plant)

Sphenodontia clade of tuataras

sphere of hydration when a polar water molecule surrounds charged or polar molecules thus keeping them dissolved and in solution

sphincter band of muscle that controls movement of materials throughout the digestive tract

spicule structure made of silica or calcium carbonate that provides structural support for sponges

spinal cord thick fiber bundle that connects the brain with peripheral nerves; transmits sensory and motor information; contains neurons that control motor reflexes

spinal nerve nerve projecting between skin or muscle and spinal cord

spiral cleavage cells of one pole of the embryo are rotated or misaligned with respect to the cells of the opposite pole

spirometry method to measure lung volumes and to diagnose lung diseases

splicing process of removing introns and reconnecting exons in a pre-mRNA

spongocoel central cavity within the body of some sponges

spongy bone tissue forms the inner layer of all bones

spontaneous mutation mutation that takes place in the cells as a result of chemical reactions taking place naturally without exposure to any external agent

sporangium reproductive sac that contains spores

spore a haploid cell that can undergo mitosis to form a multicellular, haploid individua

spore haploid cell that can produce a haploid multicellular organism or can fuse with another spore to form a diploid cell

sporocyte diploid cell that produces spores by meiosis

sporophyll leaf modified structurally to bear sporangia

sporophyte a multicellular diploid life-cycle stage that produces haploid spores by meiosis

sporophyte multicellular diploid stage in plants that is formed after the fusion of male and female gametes

sporopollenin tough polymer surrounding the spore

Squamata clade of lizards and snakes

squamous epithelia type of epithelia made of flat cells, specialized in aiding diffusion or preventing abrasion

S-shaped growth curve shape of a logistic growth curve

stabilizing selection selection that favors average phenotypes

stamen structure that contains the male reproductive organs

standard metabolic rate (SMR) metabolic rate at rest in ectothermic animals

stapes (also, stirrup) third of the three bones of the middle ear

starch storage carbohydrate in plants

start codon AUG (or rarely, GUG) on an mRNA from which translation begins; always specifies methionine

statolith (also, **amyloplast**) plant organelle that contains heavy starch granules

stele inner portion of the root containing the vascular tissue; surrounded by the endodermis

stereocilia in the auditory system, hair-like projections from hair cells that help detect sound waves

stereoscopic vision two overlapping fields of vision from the eyes that produces depth perception

sternum (also, breastbone) long, flat bone located at the front of the chest

steroid type of lipid composed of four fused hydrocarbon rings forming a planar structure

stigma uppermost structure of the carpel where pollen is deposited

stipule small green structure found on either side of the leaf stalk or petiole

stolon modified stem that runs parallel to the ground and can give rise to new plants at the nodes

stoma opening that regulates gas exchange and water evaporation between leaves and the environment, typically situated on the underside of leaves

stomach saclike organ containing acidic digestive juices

stratified epithelia multiple layers of epithelial cells

streptophytes group that includes green algae and land plants

strigolactone hormone that promotes seed germination in some species and inhibits lateral apical development in the absence of auxins

strobili cone-like structures that contain the sporangia

strobilus plant structure with a tight arrangement of sporophylls around a central stalk, as seen in cones or flowers; the male strobilus produces pollen, and the female strobilus produces eggs

stroke volume> - the volume of blood pumped into the aorta per contraction of the left ventricle

stroma fluid-filled space surrounding the grana inside a chloroplast where the light-independent reactions of photosynthesis take place

stromatolite layered sedimentary structure formed by precipitation of minerals by prokaryotes in microbial mats

structural isomers molecules that share a chemical formula but differ in the placement of their chemical bonds

style long, thin structure that links the stigma to the ovary

subduction movement of one tectonic plate beneath another

substituted hydrocarbon hydrocarbon chain or ring containing an atom of another element in place of one of the backbone carbons

substrate molecule on which the enzyme acts

substrate-level phosphorylation production of ATP from ADP using the excess energy from a chemical reaction and a phosphate group from a reactant

sucrase enzyme that breaks down sucrose into glucose and fructose

sulcus (plural: sulci) indents or “valleys” in the cortex

sum rule probability of the occurrence of at least one of two mutually exclusive events is the sum of their individual probabilities

summation process of multiple presynaptic inputs creating EPSPs around the same time for the postsynaptic neuron to be sufficiently depolarized to fire an action potential

superior colliculus paired structure in the top of the midbrain, which manages eye movements and auditory integration

superior vena cava drains blood from the jugular vein that comes from the brain and from the veins that come from the arms

supination movement of the radius and ulna bones of the forearm so that the palm faces forward

suprachiasmatic nucleus cluster of cells in the hypothalamus that plays a role in the circadian cycle

surface tension tension at the surface of a body of liquid that prevents the molecules from separating; created by the attractive cohesive forces between the molecules of the liquid

surfactant detergent-like liquid in the airways that lowers the surface tension of the alveoli to allow for expansion

survivorship curve graph of the number of surviving population members versus the relative age of the member

suspensor part of the growing embryo that makes connection with the maternal tissues

suture bone small, flat, irregularly shaped bone that forms between the flat bones of the cranium

suture short fiber of connective tissue that holds the skull bones tightly in place; found only in the skull

swim bladder in fishes, a gas filled organ that helps to control the buoyancy of the fish

symbiont plant in a symbiotic relationship with bacteria or fungi

symbiosis close interaction between individuals of different species over an extended period of time that impacts the abundance and distribution of the associating populations

sympathetic nervous system division of autonomic nervous system activated during stressful "fight or flight" situations

sympatric speciation speciation that occurs in the same geographic space

symphysis hyaline cartilage covers the end of the bone, but the connection between bones occurs through fibrocartilage; symphyses are found at the joints between vertebrae

symporter transporter that carries two different ions or small molecules, both in the same direction

synapse junction between two neurons where neuronal signals are communicated

synapsid mammal having one temporal fenestra

synapsis formation of a close association between homologous chromosomes during prophase I

synaptic cleft space between the presynaptic and postsynaptic membranes

synaptic signal chemical signal (neurotransmitter) that travels between nerve cells

synaptic vesicle spherical structure that contains a neurotransmitter

synaptonemal complex protein lattice that forms between homologous chromosomes during prophase I, supporting crossover

synarthrosis joint that is immovable

synchondrosis bones joined by hyaline cartilage; synchondroses are found in the epiphyseal plates of growing bones in children

syndesmosis joint in which the bones are connected by a band of connective tissue, allowing for more movement than in a suture

synergid type of cell found in the ovule sac that secretes chemicals to guide the pollen tube towards the egg

synovial joint only joint that has a space between the adjoining bones

systematics field of organizing and classifying organisms based on evolutionary relationships

systemic circulation flow of blood away from the heart to the brain, liver, kidneys, stomach, and other organs, the limbs, and the muscles of the body, and then the return of this blood to the heart

systems biology study of whole biological systems (genomes and proteomes) based on interactions within the system

systole contraction phase of cardiac cycle when the ventricles are pumping blood into the arteries

T cell lymphocyte that matures in the thymus gland; one of the main cells involved in the adaptive immune system

Tachyglossidae clade that includes the echidna or spiny anteater

tadpole larval stage of a frog

tap root system type of root system with a main root that grows vertically with few lateral roots; found in dicots

target cell cell that has a receptor for a signal or ligand from a signaling cell

tarsal one of the seven bones of the ankle

tastant food molecule that stimulates gustatory receptors

taste bud clusters of taste cells

TATA box conserved promoter sequence in eukaryotes and prokaryotes that helps to establish the initiation site for transcription

taxis directed movement in response to a stimulus

taxon (plural: taxa) single level in the taxonomic classification system

taxonomy science of classifying organisms

TCA cycle (also, citric acid cycle) alternate name for the citric acid cycle, named after the group name for citric acid, tricarboxylic acid (TCA); see citric acid cycle

tectorial membrane cochlear structure that lies above the hair cells and participates in the transduction of sound at the hair cells

tegmen inner layer of the seed coat

teichoic acid polymer associated with the cell wall of Gram-positive bacteria

telomerase enzyme that contains a catalytic part and an inbuilt RNA template; it functions to maintain telomeres at chromosome ends

telomere DNA at the end of linear chromosomes

telophase stage of mitosis during which chromosomes arrive at opposite poles, decondense, and are surrounded by a new nuclear envelope

template strand strand of DNA that specifies the complementary mRNA molecule

temporal fenestra non-orbital opening in the skull that may allow muscles to expand and lengthen

temporal isolation differences in breeding schedules that can act as a form of prezygotic barrier leading to reproductive isolation

temporal lobe part of the cerebral cortex that processes auditory input; parts of the temporal lobe are involved in speech, memory, and emotion processing

tendril modified stem consisting of slender, twining strands used for support or climbing

terminal bronchiole region of bronchiole that attaches to the respiratory bronchioles

tertiary consumer carnivore that eat other carnivores

tertiary structure three-dimensional conformation of a protein, including interactions between secondary structural elements; formed from interactions between amino acid side chains

test porous shell of a foram that is built from various organic materials and typically hardened with calcium carbonate

test cross cross between a dominant expressing individual with an unknown genotype and a homozygous recessive individual; the offspring phenotypes indicate whether the unknown parent is heterozygous or homozygous for the dominant trait

testa outer layer of the seed coat

testes pair of reproductive organs in males

testosterone reproductive hormone in men that assists in sperm production and promoting secondary sexual characteristics

Testudines order of turtles

tetrad two duplicated homologous chromosomes (four chromatids) bound together by chiasmata during prophase I

tetrapod phylogenetic reference to an organism with a four-footed evolutionary history; includes amphibians, reptiles, birds, and mammals

thalamus brain area that relays sensory information to the cortex

thalassemia rare genetic disorder that results in mutation of the alpha or beta subunits of hemoglobin, creating smaller red blood cells with less hemoglobin

thallus vegetative body of a fungus

theory tested and confirmed explanation for observations or phenomena

thermocline layer of water with a temperature that is significantly different from that of the surrounding layers

thermodynamics study of energy and energy transfer involving physical matter

thermophile organism that lives at temperatures between 60–80 °C

thermoregulation regulation of body temperature

theropod dinosaur group ancestral to birds

thick filament a group of myosin molecules

thigmomorphogenesis developmental response to touch

thigmonastic directional growth of a plant independent of the direction in which contact is applied

thigmotropism directional growth of a plant in response to constant contact

thin filament two polymers of actin wound together along with tropomyosin and troponin

thoracic cage (also, ribcage) skeleton of the chest, which consists of the ribs, thoracic vertebrae, sternum, and costal cartilages

thorn modified stem branch appearing as a sharp outgrowth that protects the plant

thought to be a major cause of the global amphibian decline

threshold of excitation level of depolarization needed for an action potential to fire

thylakoid disc-shaped, membrane-bound structure inside a chloroplast where the light-dependent reactions of photosynthesis take place; stacks of thylakoids are called grana

thylakoid lumen aqueous space bound by a thylakoid membrane where protons accumulate during light-driven electron transport

thymus gland located behind the sternum that produces thymosin hormones that contribute to the development of the immune system

thyroglobulin glycoprotein found in the thyroid that is converted into thyroid hormone

thyroid gland endocrine gland located in the neck that produces thyroid hormones thyroxine and triiodothyronine

thyroid-stimulating hormone (TSH) hormone produced by the anterior pituitary that controls the release of T_3 and T_4 from the thyroid gland

thyroxine (tetraiodothyronine, T_4) thyroid hormone that controls the basal metabolic rate

Ti plasmid plasmid system derived from *Agrobacterium tumifaciens* that has been used by scientists to introduce foreign DNA into plant cells

tibia (also, shinbone) large bone of the leg that is located directly below the knee

tidal volume (TV) amount of air that is inspired and expired during normal breathing

tight junction firm seal between two adjacent animal cells created by protein adherence

tissue group of similar cells carrying out related functions

tonic activity in a neuron, slight continuous activity while at rest

tonicity amount of solute in a solution

topoisomerase enzyme that causes underwinding or overwinding of DNA when DNA replication is taking place

torpor decrease in activity and metabolism that allows an animal to survive adverse conditions

total lung capacity (TLC) sum of the residual volume, expiratory reserve volume, tidal volume, and inspiratory reserve volume

trabecula tiny plate that makes up spongy bone and gives it strength

trabeculae lamellae that are arranged as rods or plates

trachea cartilaginous tube that transports air from the larynx to the primary bronchi

tracheid xylem cell with thick secondary walls that helps transport water

tracheophyte vascular plant

tragedy of the commons economic principle that resources held in common will inevitably be overexploited

trait variation in the physical appearance of a heritable characteristic

trans fat fat formed artificially by hydrogenating oils, leading to a different arrangement of double bond(s) than those found in naturally occurring lipids

***trans*-acting element** transcription factor binding site found outside the promoter or on another chromosome that influences the transcription of a particular gene

transcription bubble region of locally unwound DNA that allows for transcription of mRNA

transcription factor binding site sequence of DNA to which a transcription factor binds

transcription factor protein that binds to the DNA at the promoter or enhancer region and that influences transcription of a gene

transcription process through which messenger RNA forms on a template of DNA

transcriptional start site site at which transcription begins

transduction process by which a bacteriophage moves DNA from one prokaryote to another

transfer RNA (tRNA) RNA that carries activated amino acids to the site of protein synthesis on the ribosome

transformation process by which a prokaryote takes in DNA found in its environment that is shed by other prokaryotes

transformation process in which external DNA is taken up by a cell

transgenic organism that receives DNA from a different species

transition state high-energy, unstable state (an intermediate form between the substrate and the product) occurring during a chemical reaction

transition substitution when a purine is replaced with a purine or a pyrimidine is replaced with another pyrimidine

transitional epithelia epithelia that can transition for appearing multilayered to simple; also called uroepithelial

translation process through which RNA directs the formation of protein

translocation mass transport of photosynthates from source to sink in vascular plants

translocation process by which one segment of a chromosome dissociates and reattaches to a different, nonhomologous chromosome

transpiration loss of water vapor to the atmosphere through stomata

transport maximum maximum amount of solute that can be transported out of the renal tubules during reabsorption

transport protein membrane protein that facilitates passage of a substance across a membrane by binding it

transporter specific carrier proteins or pumps that facilitate movement

transverse (horizontal) plane plane cutting through an animal separating the individual into upper and lower portions

transversion substitution when a purine is replaced by a pyrimidine or a pyrimidine is replaced by a purine

triacylglycerol (also, triglyceride) fat molecule; consists of three fatty acids linked to a glycerol molecule

trichome hair-like structure on the epidermal surface

tricuspid valve one-way membranous flap of connective tissue between the atrium and the ventricle in the right side of the heart; also known as atrioventricular valve

triiodothyronine (T3) thyroid hormone that controls the basal metabolic rate

triploblast animal that develops from three germ layers

trisomy otherwise diploid genotype in which one entire chromosome is duplicated

trochophore first of the two larval stages in mollusks

trophic level position of a species or group of species in a food chain or a food web

trophic level transfer efficiency (TLTE) energy transfer efficiency between two successive trophic levels

trophoblast outer layer of cells in the blastocyst

tropomyosin acts to block myosin binding sites on actin molecules, preventing cross-bridge formation and preventing contraction until a muscle receives a neuron signal

troponin binds to tropomyosin and helps to position it on the actin molecule, and also binds calcium ions

trp operon series of genes necessary to synthesize tryptophan in prokaryotic cells

trypsin pancreatic protease that breaks down protein

tryptophan amino acid that can be synthesized by prokaryotic cells when necessary

tuber modified underground stem adapted for starch storage; has many adventitious buds

tubular reabsorption reclamation of water and solutes that got filtered out in the glomerulus

tubular secretion process of secretion of wastes that do not get reabsorbed

tumor suppressor gene segment of DNA that codes for regulator proteins that prevent the cell from undergoing uncontrolled division

tunicate sessile chordate that is a member of Urochordata

tympanum (also, tympanic membrane or ear drum) thin diaphragm between the outer and middle ears

ubiquinone soluble electron transporter in the electron transport chain that connects the first or second complex to the third

ulna bone located on the medial aspect (pinky-finger side) of the forearm

ultrasound sound frequencies above the human detectable ceiling of approximately 20,000 Hz

umami one of the five basic tastes, which is described as “savory” and which may be largely the taste of L-glutamate

unidirectional circulation flow of blood in a single circuit; occurs in fish where the blood flows through the gills, then past the organs and the rest of the body, before returning to the heart

unified cell theory a biological concept that states that all organisms are composed of one or more cells; the cell is the basic unit of life; and new cells arise from existing cells

uniporter transporter that carries one specific ion or molecule

uniramous referring to one branch per appendage

unsaturated fatty acid long-chain hydrocarbon that has one or more double bonds in the hydrocarbon chain

untranslated region segment of the RNA molecule that are not translated into protein. These regions lie before (upstream or 5') and after (downstream or 3') the protein-coding region

up-regulation an increase in the number of hormone receptors in response to increased hormone levels

upstream nucleotides preceding the initiation site; in general, sequences toward the 5' end relative to a site on the mRNA

urea cycle pathway by which ammonia is converted to urea

ureotelic describes animals that secrete urea as the primary nitrogenous waste material

ureter urine-bearing tube coming out of the kidney; carries urine to the bladder

uric acid byproduct of ammonia metabolism in birds, insects, and reptiles

urinary bladder structure that the ureters empty the urine into; stores urine

urine filtrate produced by kidneys that gets excreted out of the body

Urochordata clade composed of tunicates

Urodela salamanders

uterus environment for developing embryo and fetus

vaccine weakened solution of virus components, viruses, or other agents that produce an immune response

vacuole membrane-bound sac, somewhat larger than a vesicle, which functions in cellular storage and transport

vagina muscular tube for the passage of menstrual flow, copulation, and birth of offspring

valence shell outermost shell of an atom

van der Waals interaction very weak interaction between molecules due to temporary charges attracting atoms that are very close together

variable number of tandem repeats (VNTRs) variation in the number of tandem repeats between individuals in the population

variable part of an experiment that the experimenter can vary or change

variation genetic differences among individuals in a population

vasa recta peritubular network that surrounds the loop of Henle of the juxtamedullary nephrons

vascular bundle strands of stem tissue made up of xylem and phloem

vascular plant plant containing a network of cells that conducts water and solutes through the organism

vascular stele strands of root tissue made up of xylem and phloem

vascular tissue tissue made up of xylem and phloem that transports food and water throughout the plant

vasoconstriction narrowing of a blood vessel

vasodilation widening of a blood vessel

vasodilator compound that increases the diameter of blood vessels

vasopressin another name for anti-diuretic hormone

vein blood vessel that brings blood back to the heart

vein bundle of vascular tissue made of xylem and phloem

veliger second of the two larval stages in mollusks

vena cava major vein of the body returning blood from the upper and lower parts of the body; see the superior vena cava and inferior vena cava

venation pattern of veins in a leaf; may be parallel (as in monocots), reticulate (as in dicots), or dichotomous (as in *Gingko biloba*)

venous P_{CO_2} partial pressure of carbon dioxide in the veins (40 mm Hg in the pulmonary veins)

venous P_{O_2} partial pressure of oxygen in the veins (100 mm Hg in the pulmonary veins)

ventilation/perfusion (V/Q) mismatch region of the lung that lacks proper alveolar ventilation (V) and/or arterial perfusion (Q) C

ventral cavity body cavity on the anterior or front portion of an animal that includes the thoracic cavities and the abdominopelvic cavities

ventricle (heart) large inferior chamber of the heart that pumps blood into arteries

ventricle cavity within brain that contains cerebrospinal fluid

venule blood vessel that connects a capillary bed to a vein

vernalization exposure to cold required by some seeds before they can germinate

vertebral column (also, spine) surrounds and protects the spinal cord, supports the head, and acts as an attachment point for ribs and muscles of the back and neck

vertebral column series of separate bones joined together as a backbone

Vertebrata members of the phylum Chordata that possess a backbone

vertical transmission transmission of disease between unrelated individuals

vesicle small, membrane-bound sac that functions in cellular storage and transport; its membrane is capable of fusing with the plasma membrane and the membranes of the endoplasmic reticulum and Golgi apparatus

vessel element xylem cell that is shorter than a tracheid and has thinner walls

vestibular sense sense of spatial orientation and balance

vestigial structure physical structure present in an organism but that has no apparent function and appears to be from a functional structure in a distant ancestor

viable-but-non-culturable (VBNC) state survival mechanism of bacteria facing environmental stress conditions

vicariance allopatric speciation that occurs when something in the environment separates organisms of the same species into separate groups

villi folds on the inner surface of the small intestine whose role is to increase absorption area

viral receptor glycoprotein used to attach a virus to host cells via molecules on the cell

virion individual virus particle outside a host cell

viroid plant pathogen that produces only a single, specific RNA

virus core contains the virus genome

vision sense of sight

vitamin organic substance necessary in small amounts to sustain life

viviparity process in which the young develop within the female, receiving nourishment from the mother's blood through a placenta

water potential (Ψ_W) the potential energy of a water solution per unit volume in relation to pure water at atmospheric pressure and ambient temperature

water vascular system system in echinoderms where water is the circulatory fluid

wavelength distance between consecutive points of equal position (two crests or two troughs) of a wave in a graphic representation; inversely proportional to the energy of the radiation

wax lipid made of a long-chain fatty acid that is esterified to a long-chain alcohol; serves as a protective coating on some feathers, aquatic mammal fur, and leaves

weather conditions of the atmosphere during a short period of time

web of life phylogenetic model that attempts to incorporate the effects of horizontal gene transfer on evolution

whisk fern seedless vascular plant that lost roots and leaves by reduction

white blood cell large (30 μm) cell with nuclei of which there are many types with different roles including the protection of the body from viruses and bacteria, and cleaning up dead cells and other waste

white-nose syndrome disease of cave-hibernating bats in the eastern United States and Canada associated with the fungus *Geomyces destructans*

whole-genome sequencing process that determines the DNA sequence of an entire genome

whorled pattern of leaf arrangement in which three or more leaves are connected at a node

with a start codon, binds directly to the ribosome P site, and links to a special methionine to begin a polypeptide chain

X inactivation condensation of X chromosomes into Barr bodies during embryonic development in females to compensate for the double genetic dose

X-linked gene present on the X, but not the Y chromosome

xylem tissue responsible for long-distance transport of water and nutrients

yeast general term used to describe unicellular fungi

zero population growth steady population size where birth rates and death rates are equal

zoea larval stage in the early development of crustaceans

zona pellucida protective layer of glycoproteins on the mammalian egg

zoology study of animals

zoonosis disease that primarily infects animals that is transmitted to humans

Zygomycota (also, conjugated fungi) phylum of fungi that form a zygote contained in a zygospore

zygospore structure with thick cell wall that contains the zygote in zygomycetes

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