



Hole's Human Anatomy & Physiology, Texas Edition

Program Overview



A Student and Teacher Favorite with Dynamic Digital Tools

Engaging and Effective Student Resources

Hole's Human Anatomy & Physiology assumes no prior science knowledge by students and places an emphasis on the fundamentals. Full integration of robust print and digital resources helps students grow in their understanding of anatomy and physiology while ensuring coverage of the Anatomy and Physiology Texas Essential Knowledge and Skills (TEKS).


The integrated learning system, **Learn, Practice, Assess**, helps students master anatomy and physiology. Each chapter opens with Learning Outcomes, contains many opportunities to Practice throughout, and closes with Assessments that are closely tied to the Learning Outcomes.



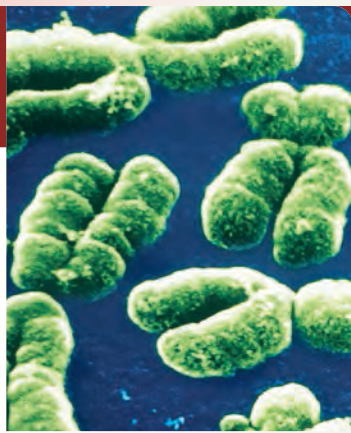
This icon designates the **TEKS** covered in this chapter.

Learning Outcomes open the chapters and link closely to Chapter Assessments and Integrative Assessments/Critical Thinking questions found at the end of each chapter.

Each **Study Strategy** gives students learning strategies, that include listening, speaking, reading and peer interactions.



4



Cellular Metabolism

TEKS 5(A), 5(B), 7(A), 10(A), 11(B)

LEARNING OUTCOMES

After you have studied this chapter, you should be able to:


- 4.1 Metabolic Processes**
1 Compare and contrast anabolism and catabolism. (pp. 121–123)
- 4.2 Control of Metabolic Reactions**
2 Describe the role of enzymes in metabolic reactions. (p. 123)
3 Explain how metabolic pathways are regulated. (pp. 124–125)
- 4.3 Energy for Metabolic Reactions**
4 Explain how ATP stores chemical energy and makes it available to a cell. (p. 126)
- 4.4 Cellular Respiration**
5 Analyze how the reactions of cellular respiration release chemical energy that is used by the body. (p. 127)
6 Describe the general metabolic pathways of carbohydrate metabolism. (pp. 127–131)
- 4.5 Nucleic Acids and Protein Synthesis**
7 Describe how DNA molecules store genetic information. (p. 132)
8 Describe how DNA molecules are replicated. (p. 134)
9 Explain how protein synthesis relies on genetic information. (p. 136)
10 Compare and contrast DNA and RNA. (p. 136)
11 Describe the steps of protein synthesis. (pp. 139–142)
- 4.6 Changes in Genetic Information**
12 Describe how genetic information can be altered. (p. 142)
13 Explain how a mutation may or may not affect an organism. (p. 143)

STUDY STRATEGY

Discussion Group As a group, brainstorm ways that you could explain the role of enzymes in an enzyme-catalyzed reaction to a sixth-grade science class. Prepare a short presentation and present it to a group of students.

THE WHOLE PICTURE

In every human cell, even in the most sedentary individual, thousands of chemical reactions essential to life take place every second. Many metabolic reactions occur one after the other in a sequence, with the products of one reaction serving as starting materials for the next. These reactions form pathways and cycles that intersect where they share intermediate compounds. Special types of proteins called enzymes control the rate of each reaction, enabling them to proceed fast enough to sustain life. The sum total of chemical reactions in the cell constitutes cellular metabolism.



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Learn, Practice, Assess



Learning tools to help the student succeed . . .

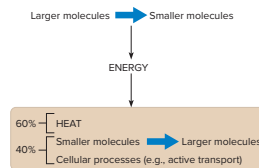
Understanding Words helps the student remember scientific word meanings as well as examine root words, stems, prefixes, suffixes, pronunciations, and build a solid anatomy and physiology vocabulary.

UNDERSTANDING WORDS

- aer-**, air; aerobic respiration—respiratory process that requires oxygen.
- an-**, without; anaerobic respiration—respiratory process that does not require oxygen.
- ana-**, up; anabolism—cellular processes in which smaller molecules are built up into larger ones.
- cata-**, down; catabolism—cellular processes that break down larger molecules into smaller ones.
- co-**, with; coenzyme—substance that unites with a protein to complete the structure of an active enzyme molecule.
- de-**, undoing; deamination—process that removes nitrogen-containing portions of amino acid molecules.
- mut-**, change; mutation—change in genetic information.
- strat**, spread out; substrate—substance upon which an enzyme acts.
- sub-**, under; substrate—substance upon which an enzyme acts.
- zym**, causing to ferment; enzyme—protein that speeds up a chemical reaction without itself being consumed.

4.1 | Metabolic Processes

Metabolic reactions and pathways are of two types: anabolism and catabolism. In **anabolism** (ă-h-năb'ŏ-līz"ē-m), small molecules are built up into larger ones, requiring energy. In **catabolism** (kă-tab'ŏ-līz"ē-m), larger molecules are broken down into smaller ones, releasing energy. About 60% of the energy released as large molecules are dismantled escapes as heat. The rest of the energy is used to build molecules and to drive various activities of the cell.



Anabolism

Anabolism provides all the materials a cell requires for maintenance, growth, and repair. For example, a type of anabolic process called **dehydration synthesis** (de'hi-dra'shun sin'the-sis) joins many simple sugar molecules (monosaccharides) to form larger molecules of glycogen, which store energy in their chemical bonds. When a runner eats pasta the night before a race, digestion breaks down the plant-based complex carbohydrates in the food to monosaccharides. These smaller molecules are absorbed into the bloodstream, which carries the energy-rich molecules to body cells. Here, dehydration synthesis joins the monosaccharides to form glycogen, which stores energy that the runner may need later, as the finish line nears. First, two monosaccharides join to form a disaccharide. When monosaccharide units join, an -OH (hydroxyl group) from one monosaccharide molecule and an -H (hydrogen atom) from an -OH group of another are removed. As the -H and -OH react to produce a water molecule, the monosaccharides are

joined by a shared oxygen atom, as **figure 4.1** shows (read from left to right). As the process repeats, the molecular chain extends, forming a polysaccharide.

Dehydration synthesis also links glycerol and fatty acid molecules in fat cells (adipose tissue) to form triglyceride molecules. **Figure 4.2** shows (read from left to right) how a triglyceride forms as three hydrogen atoms are removed from a glycerol molecule



CAREER CORNER Personal Trainer

The 45-year-old man's physician advised him to start an exercise program to lose weight, so the man joined a gym. But he hadn't been to one in many years, and the rows of machines looked daunting. So he hired a personal trainer to develop an exercise routine that would be just what the doctor ordered.

A personal trainer assesses a client's fitness level and guides the client in using specific machines and doing mat exercises. The trainer offers advice on which weight-lifting machines to use, how many repetitions to begin with, and how often to increase repetitions. The trainer might advise the client to lift weights only every other day, so that muscles will have time to recover from the microscopic tears caused by weight lifting. Using a mat, a trainer might lead a client through a series of exercises to strengthen the core abdominal muscles.

The personal trainer is part coach, part cheerleader, encouraging exercisers to push their limits. Trainers work in athletic clubs, at corporate fitness centers, in senior centers, and at other types of facilities that have exercise equipment. Some personal trainers even train clients at their homes.

Minimal requirements to become a personal trainer include a high school diploma, cardiopulmonary resuscitation (CPR) training, and completion of a personal trainer course, which generally takes from a few months to a year. Passing a certification exam is required. Personal trainers tend to be outgoing, friendly people who enjoy helping others become physically fit.

The Whole Picture provides an introduction to the chapter. It answers the question: "What is the big picture of how this chapter relates to human anatomy and physiology"?

Career Corner features provide background on a variety of career opportunities available to those interested in anatomy and physiology.



Interesting applications allow students to practice and apply knowledge . . .

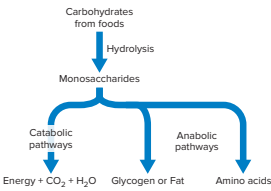


FIGURE 4.15 Hydrolysis breaks down carbohydrates from foods into monosaccharides. The resulting molecules may enter catabolic pathways and be used as energy sources, or they may enter anabolic pathways and be stored as glycogen or fat, or react to yield amino acids.

synthesize glycogen. Between meals, when blood glucose concentration is lower, the reaction reverses, and glucose is released into the blood. This mechanism ensures that cells throughout the body have a continual supply of glucose to support cellular respiration.

Glucose can also react to form fat molecules, which are later deposited in adipose tissue. This happens when a person takes in more carbohydrates than can be stored as glycogen or are required for normal activities. The body has an almost unlimited capacity to perform this type of anabolism. This is why overeating carbohydrates can increase body fat.

This section has considered the metabolism of glucose. Lipids and proteins can also be broken down to release energy for ATP synthesis. For all three, the final process is aerobic respiration, and the most common entry point is into the citric acid cycle as acetyl CoA (fig. 4.16). These pathways are described in detail in chapter 18 (pp. 697–699).

PRACTICE

- 17 State the products of the aerobic reactions.
- 18 List the products of the citric acid cycle.
- 19 Explain the function of the electron transport chain.
- 20 Discuss fates of glucose other than cellular respiration.

4.5 | Nucleic Acids and Protein Synthesis

Enzymes control the metabolic pathways essential for cell survival. They oversee the use of all four major groups of organic molecules—carbohydrates, lipids, nucleic acids, and many other proteins important in physiology, such as blood proteins, the proteins that form muscle and connective tissues, and the antibodies that protect against infection.

The information that instructs a cell to synthesize a particular protein is held in the sequence of building blocks of **deoxyribonucleic acid (DNA)**, the genetic material. The correspondence between a unit of DNA information and a particular amino acid constitutes the **genetic code** (jĕ-ne'tĭk kôd).

Genetic Information

Children resemble their parents because of inherited traits, but what passes from parents to a child is genetic information, in the form of DNA molecules from the parents' sex cells. Long molecules of DNA and associated proteins are organized into chromosomes. The opening image for this chapter (p. 120) shows human chromosomes. As an offspring develops, mitosis passes the information in the DNA sequences of the chromosomes to new cells. Genetic information "tells" cells how to construct a great variety of protein molecules, each with a specific function. A DNA sequence that contains the information for making a particular polypeptide is called a **gene** (jĕn).

RECONNECT

To Chapter 3, Mitosis, page 108.

The complete set of genetic instructions in a cell, including the genes as well as other sequences, constitutes the **genome** (jĕnôm'). Only a small part of the human genome encodes protein and it is called the **exome** (x-ôm). Much of the rest of the genome controls which proteins are produced in a particular cell under particular circumstances and the amounts produced, which is called **gene expression**. Studies of gene expression can reveal molecules and pathways that are part of physiological processes. Chapter 24 (pp. 906–907) discusses the human genome.

The human genome includes about 20,325 protein-encoding genes among 3.2 billion DNA nucleotides in each set of 23 chromosomes. Most cells have two chromosome sets. Sequencing the first human genomes took fifteen years and billions of dollars. Tens of thousands of people have had their genomes sequenced. It takes less than a day, but interpretation of the findings takes longer. Health-care professionals are learning how to incorporate information from the human genome into clinical practice.

Nucleotides are the building blocks of nucleic acids, as discussed in chapter 2 (pp. 75–76). A nucleotide consists of a 5-carbon sugar (ribose or deoxyribose), a phosphate group, and one of several nitrogenous bases (fig. 4.17). DNA and RNA nucleotides form long strands (polynucleotide chains) as dehydration synthesis alternately joins their sugars and phosphates, forming a "backbone" structure (fig. 4.18).

A DNA molecule is double-stranded, consisting of two polynucleotide chains. The nitrogenous bases project from the sugar-phosphate backbone of one strand and bind, or pair, by hydrogen bonding to the nitrogenous bases of the second strand (fig. 4.19). The resulting molecular structure is like a ladder in which the rails represent the alternating sugar and phosphate backbones of the two strands and the rungs represent the paired nitrogenous bases. The sugars forming the two backbones point in opposite directions. For this reason, the two strands are called **antiparallel**.

A DNA molecule has a highly regular structure because the bases pair in only two combinations. A DNA base is one of four types: adenine (A), thymine (T), cytosine (C), or guanine (G).

Reconnect directs students back to a related concept discussed in an earlier chapter to help them better understand the new concept being explained.

Boxed information applies ideas and facts in the narrative to clinical situations.

After each major section, a question or series of questions gauge student understanding of the material and enable them to practice the information they've just learned.



CLINICAL APPLICATION 4.1
Inborn Errors of Metabolism

In a type of inherited disease called an inborn error of metabolism, a deficient or absent enzyme causes a block in the biochemical pathway that it catalyzes. As a result, the biochemical that the enzyme normally acts upon builds up, and the biochemical resulting from the enzyme's normal action becomes scarce. The effect of an impaired enzyme in a metabolic pathway is like a twist in a garden hose that cuts off the flow of water; pressure builds behind the block, but no water comes out after the block.

Inborn errors of metabolism were initially described with the help of a mother of two young physically and intellectually disabled children in Norway, in 1931. The mother noted a musty odor to the children's urine, and her husband then mentioned it to an acquaintance who was a physician interested in biochemistry. Intrigued, the doctor analyzed the foul urine in a lab at the University of Oslo, with help from the mother, who brought him samples. The physician identified the problem in the children's metabolism—later named phenylketonuria (PKU)—and then found it among people in mental institutions.

In PKU, a missing or nonworking enzyme blocks the metabolic pathway that converts the amino acid phenylalanine into another amino acid, tyrosine. Excess phenylalanine spills into the urine and the blood, and poisons the brain. In the early 1960s a physician and microbiologist who had PKU in his family developed a test to detect the disease using drops of blood taken from a newborn's heel. It was the first newborn screening test to identify biochemicals in blood (using an analytical chemistry technique called mass spectrometry) to detect inborn errors of metabolism. Understanding PKU enabled researchers to develop a "medical food" that severely restricts phenylalanine, countering the biochemical abnormality. If begun very soon after birth, this special diet, followed for many years and sometimes for life, can completely prevent the symptoms of intellectual disability.

Today newborns are screened for dozens of inborn errors of metabolism. Some of these disorders, such as PKU, have dietary treatments, and others may respond better to different treatments if they are begun early.

Clinical Applications present disorders, physiological responses to environmental factors, and other topics of general interest.

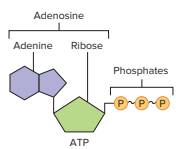


FIGURE 4.7 ATP is the currency for cellular energy. An ATP (adenosine triphosphate) molecule consists of an adenine, a ribose, and three phosphates. The wavy lines connecting the last two phosphates represent high-energy chemical bonds.

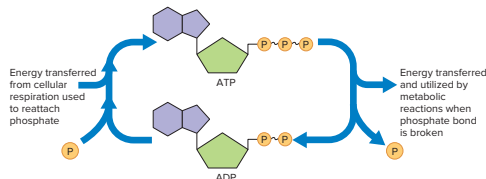
energy released from cellular respiration to attach a third phosphate, in a process called **phosphorylation** (fos'fō-rī-lā'shun). As figure 4.8 shows, ATP and ADP molecules shuttle back and forth between the energy-releasing reactions of cellular respiration and the energy-utilizing reactions of the cell.

Release of Chemical Energy

Most metabolic processes require chemical energy stored in ATP. This form of energy is initially held in the chemical bonds that link atoms into molecules and is released when these bonds break. Burning a marshmallow over a campfire releases the chemical energy held in the bonds of the molecules that make up the marshmallow as heat and light. Similarly, when we eat a marshmallow, the digestive system first breaks the sweet-tasting sugar sucrose into its constituent molecules of glucose and fructose. Inside cells, fructose ultimately reacts to form glucose. A process called **oxidation** (ok'sī-dā'shun) releases the energy from the glucose, which is harnessed to power cellular metabolism.

in one or both high-energy bonds may be quickly transferred to another molecule in a metabolic reaction. Energy from the breakdown of ATP powers cellular work such as skeletal muscle contraction, active transport across cell membranes, secretion, and many other functions.

An ATP molecule that loses its terminal (end) phosphate becomes an **adenosine diphosphate (ADP)** molecule, which has only two phosphates. ADP can be converted back into ATP using



From Science to Technology features explore the molecular underpinnings of familiar as well as not so familiar illnesses. Students will read about topics such as ion channel disorders, muscular dystrophy, and cystic fibrosis.

FROM SCIENCE TO TECHNOLOGY 4.2
DNA Profiling Frees a Prisoner

The human genome sequence differs from person to person because it includes 3.2 billion bits of information. Techniques called **DNA profiling** (or **fingerprinting**) compare the most variable parts of the genome among individuals for several purposes—to identify remains at crime scenes or after natural disasters; to confirm or rule out "blood" relationships; and, increasingly, to establish innocence when other types of evidence are questionable. The Innocence Project is a national litigation and public policy organization that provides DNA testing to people who claim that they have been wrongfully convicted. The Innocence Project has exonerated hundreds of people since it began in 1992.

One exonerated man had served four and a half years of a twenty-five-year sentence for rape when DNA profiling established his innocence. He and a friend had become suspects after a woman in Houston identified them as the men who had raped and threatened her with a gun, leaving her in a field. The two young men supplied saliva and blood samples, from which DNA profiles were

done and compared to DNA profiles from semen found in the victim and in her car. At the trial, an employee of the crime lab doing the DNA analysis testified that the probability that the suspect's DNA matched that of the evidence by chance was 1 in 694,000—a number that led jurors to convict him, even though he did not fit the victim's description of her assailant.

A DNA profile analyzes thirteen parts of the genome that vary in most populations. Usually this is sufficient information to rule out a suspect. Using these criteria, the suspect's DNA at first seemed to match the evidence. The problem, though, wasn't in the DNA, but in the population to which it was compared.

Proclaiming his innocence all along, the man had asked right away for an independent DNA test, but was told he couldn't afford one. Two journalists began investigating the Houston crime laboratory. They sent information on a few cases to a professor of criminology, who immediately saw the errors made in the suspect's DNA analysis. Retesting his DNA, and comparing it to a relevant population, proved his innocence.

of sequences of three nucleotides. That is, the sequence C, G, T in a DNA strand represents one type of amino acid; the sequence G, C, A represents another type. Other sequences encode instructions for beginning or ending the synthesis of a protein molecule, and for determining which genes are accessed for their information.

The genetic code is said to be universal because all species use the same DNA base triplets to specify the same amino acids. Researchers deciphered the code in the 1960s. When the media mentions an individual's genetic code, they really are referring to the sequence of DNA bases comprising a certain gene or genome—not the genetic code (the correspondence between DNA triplet and amino acid).

DNA is in the nucleus, and protein synthesis occurs in the cytoplasm. Because the cell must keep a permanent copy of the genetic instructions, a copy of the genetic information must move from the nucleus into the cytoplasm for the cell to use it. This copying and

are part of both DNA and RNA, thymine nucleotides are only in DNA. In place of thymine nucleotides, RNA molecules have uracil (U) nucleotides (fig. 4.22 and Appendix F, **A Closer Look at DNA and RNA Structures**). In RNA U pairs with A (fig. 4.23). Different types of RNA have different size ranges and functions. The process of copying DNA information into an RNA sequence is called **transcription** (trans-krip-'shun).

The first step in delivering information from the nucleus to the cytoplasm is the synthesis of **messenger RNA (mRNA)**. As its name suggests, this form of RNA carries a gene's information on how to build a specific polypeptide. As mRNA is synthesized, its nucleotides form complementary base pairs with one of the two strands of DNA that encodes a particular protein. However, just as the words in a sentence must be read in the correct order to make sense, the base sequence of a strand of DNA must be "read" in the correct direction and from the correct starting point. Furthermore, only one of the two antiparallel strands of DNA contains the genetic message. An enzyme called RNA polymerase recognizes the correct DNA strand and the right direction for RNA synthesis. The "sentence" always begins with the mRNA base sequence AUG (fig. 4.24).



Tools to help make the connection and master anatomy & physiology!

Chapter Summary provides outlines for reviewing the chapter's main ideas.



Chapter Summary

4.1 Metabolic Processes (page 121)

Metabolic reactions and pathways are of two types: **anabolism** and **catabolism**.

- Anabolism
 - Anabolism builds molecules.
 - In **dehydration synthesis**, hydrogen atoms and hydroxyl groups are removed, water forms, and smaller molecules bind by sharing atoms.
 - Anabolic reactions include complex carbohydrates synthesized from monosaccharides, fats synthesized from glycerol and fatty acids, and proteins synthesized from amino acids.
- Catabolism
 - Catabolism breaks down molecules.
 - In **hydrolysis**, a water molecule adds a hydrogen atom to one portion of a molecule and a hydroxyl group to a second portion, breaking the bond between these parts.
 - Catabolic reactions include complex carbohydrates decomposed into monosaccharides, fats decomposed into glycerol and fatty acids, and proteins broken down into amino acids.

4.2 Control of Metabolic Reactions (page 123)

Metabolic processes have many steps that occur in a specific sequence and are interconnected.

- Enzyme action
 - Metabolic reactions require energy to start.
 - Most enzymes are proteins that increase the rate of (catalyze) specific metabolic reactions.
 - Enzymes are usually named according to their substrates, with **-ase** at the end.
 - An enzyme acts when its **active site** temporarily combines with the **substrate**, altering its chemical structure. This enables the substrate to react, forming a product. The enzyme is released in its original form.
 - The rate of enzyme-controlled reactions depends upon the numbers of enzyme and substrate molecules and the efficiency of the enzyme.
 - Enzymes can be denatured by heat, radiation, electricity, chemicals, and extreme pH values.
- Metabolic pathways
 - A sequence of enzyme-controlled reactions is a **metabolic pathway**.
 - Enzyme-catalyzed reactions form pathways when a reaction's product is another's substrate.
 - A **rate-limiting enzyme** may regulate a metabolic pathway.
 - A negative feedback mechanism in which the product of a pathway inhibits the regulatory enzyme may control the regulatory enzyme.
 - The rate of product formation usually remains stable in a pathway because of feedback mechanisms.

STUDY STRATEGY

Clarifying Use this summary to set up an outline. Add additional notes during class discussions and while you read.

- Cofactors and coenzymes
 - Cofactors** are additions to some enzymes that are necessary for their function.
 - A cofactor may be an ion or a small organic molecule called a **coenzyme**.
 - Some vitamins, the sources of coenzymes, cannot be synthesized by human cells in adequate amounts.

4.3 Energy for Metabolic Reactions (page 125)

Energy is a capacity to produce change or to do work. Forms of energy include heat, light, sound, and electrical, mechanical, and chemical energies. The reactions of **cellular respiration** use and release chemical energy.

- ATP molecules
 - Energy is captured in the bond of the terminal phosphate of ATP.
 - Captured energy is released when the terminal phosphate bond of an ATP molecule breaks.
 - ATP that loses its terminal phosphate becomes **ADP**.
 - ADP can become ATP by capturing energy and a phosphate.
 - ATP is the primary energy-carrying molecule in a cell.
- Release of chemical energy
 - Most metabolic processes use chemical energy released when molecular bonds break.
 - The energy liberated from glucose during cellular respiration is used for metabolism.
 - Enzymes in the cytoplasm and mitochondria control cellular respiration.

4.4 Cellular Respiration (page 127)

Cellular respiration transfers energy from molecules such as glucose and makes it available for cellular use. This process occurs in three distinct, interconnected series of reactions: **glycolysis**, the **citric acid cycle**, and the **electron transport chain**. Some of the steps require oxygen (**aerobic**) and some do not (**anaerobic**). Up to 38 ATPs form from breakdown of one glucose molecule.

- Glycolysis
 - Glycolysis, the first step of glucose catabolism, occurs in the cytosol and does not require oxygen.
 - The three stages of glycolysis release and transfer some energy to ATP.
 - Some of the energy is in the form of high-energy electrons attached to hydrogen carriers.
- Anaerobic reactions (absence of oxygen)
 - In the anaerobic reactions, NADH and H⁺ donate electrons and hydrogens to pyruvic acid, generating **lactic acid**.
 - Lactic acid builds up, eventually inhibiting glycolysis and ATP formation.
 - When oxygen returns, in liver cells lactic acid reacts to form pyruvic acid.

**CHAPTER ASSESSMENTS**

- 4.1 Metabolic Processes**
- Distinguish between anabolism and catabolism. (p. 121)
 - Distinguish between dehydration synthesis and hydrolysis. (pp. 121–122)
 - Give examples of a dehydration synthesis reaction and a hydrolysis reaction. (pp. 121–123)
- 4.2 Control of Metabolic Reactions**
- Describe how an enzyme interacts with its substrate. (pp. 123–124)
 - Define *active site*. (p. 123)
 - State two factors that influence the rate of an enzyme-catalyzed reaction. (p. 124)
 - A cell has _____ types of enzymes. (p. 124)
 - 3
 - hundreds of
 - thousands of
 - millions of
 - Explain the importance of a rate-limiting enzyme. (p. 125)
 - Describe how negative feedback involving a rate-limiting enzyme controls a metabolic pathway. (p. 125)
 - Define *cofactor*. (p. 125)
 - Discuss the relationship between a coenzyme and a vitamin. (p. 125)
- 4.3 Energy for Metabolic Reactions**
- Define *energy*. (p. 125)
 - Analyze the importance of ATP and its relationship to ADP. (pp. 125–126)
 - Explain how the oxidation of molecules inside cells differs from the burning of substances outside cells. (pp. 126–127)
- 4.4 Cellular Respiration**
- State the overall function of cellular respiration. (p. 127)
 - Distinguish between anaerobic and aerobic phases of cellular respiration. (p. 127)
 - Analyze the role of each of the three main chemical reactions in cellular respiration in ultimately providing energy for the body. Assume aerobic respiration occurs. (pp. 127–131)
 - Identify the final acceptor of the electrons released in the reactions of cellular respiration. (p. 131)
 - Evaluate the function of the liver in the storage and release of excess glucose. (pp. 131–132)
- 4.5 Nucleic Acids and Protein Synthesis**
- The genetic code is _____. (p. 132)
 - the bonding of purine to pyrimidine
 - the correspondence between DNA triplet and amino acid
 - the correspondence between DNA triplet and RNA triplet
 - the controls that determine where the instructions for a polypeptide chain start and stop
 - DNA information provides instructions for the cell to _____. (p. 132)
 - manufacture carbohydrate molecules
 - extract energy
 - manufacture RNA from amino acids
 - synthesize protein molecules
 - Distinguish among a gene, an exome, and a genome. (p. 132)
 - Define *gene expression*. (p. 132)
 - If a DNA strand has the sequence ATGCCGATCCGC then the sequence on the complementary DNA strand is _____. (pp. 133–134)
 - ATGCCGATCCGC
 - TACCGTAGGGC
 - UACGCUAGGGC
 - AUGCGAUCCGC
 - Explain why DNA replication is essential. (p. 134)
 - Describe the events of DNA replication. (p. 134)
 - Identify the part of a DNA molecule that encodes information. (pp. 134–136)
 - Calculate the number of amino acids that a DNA sequence of twenty-seven nucleotides encodes. (p. 136)
 - List three ways that RNA differs from DNA. (p. 136)
 - If one strand of a DNA molecule has the sequence ATTCTCGACTAT, the complementary mRNA has the sequence _____. (p. 136)
 - ATTCTCGACTAT
 - AUUCUCGACUUAU
 - TAAGAGCTGATATA
 - UAGAGCUGAUA
 - Distinguish between transcription and translation. (pp. 136–138)
 - Distinguish the functions of mRNA, rRNA, and tRNA. (pp. 136–141)
 - Describe the function of a ribosome in protein synthesis. (p. 141)
 - List the steps of protein synthesis. (pp. 136–141)
- 4.6 Changes in Genetic Information**
- Explain how a mutation can alter the sequence of amino acids in a polypeptide. (p. 142)
 - Discuss two major ways that mutation occurs. (p. 142)
 - Identify the effects of prolonged exposure to ultraviolet radiation on DNA. (p. 142)
 - Explain why DNA repair is necessary. (p. 143)
 - Discuss three ways that the genetic code protects against the effects of a mutation. (p. 143)

Chapter Assessments

check understanding of the chapter's learning outcomes.

**INTEGRATIVE ASSESSMENTS/CRITICAL THINKING****Outcomes 2.2, 4.1**

- How can the same molecule be both a reactant (starting material) and a product of a biochemical pathway?

Outcomes 2.3, 3.2, 4.2

- What effect might changes in the pH of body fluids or body temperature that accompany illness have on cells?

Outcomes 2.3, 4.1, 4.4

- Michael P was very weak from birth, with poor muscle tone, difficulty breathing, and great fatigue. By his third month, he began having seizures. Michael's medical tests were normal except for one: his cerebrospinal fluid (the fluid that bathes the brain and spinal cord) was unusually high in glucose. Hypothesizing that the boy could not produce enough ATP, doctors gave him a diet rich in certain fatty acids that caused the cellular respiration pathway to resume at the point of acetyl CoA formation. Michael rapidly improved. Explain what caused his symptoms.

Outcomes 4.3, 4.4

- Use the example of PKU to evaluate the causes and effects of congenital defects on the function of cells.
- Investigate and describe how the disruption of cellular respiration due to cyanide poisoning leads to a disruption of homeostasis. Use the information you find to describe why cellular respiration is critical to the body being able to maintain homeostasis.

- A student is accustomed to running 3 miles at a leisurely jogging pace. In a fitness class, she has to run a mile as fast as she can. Afterward, she is winded and has sharp pains in her chest and leg muscles. What has she experienced, in terms of energy metabolism?

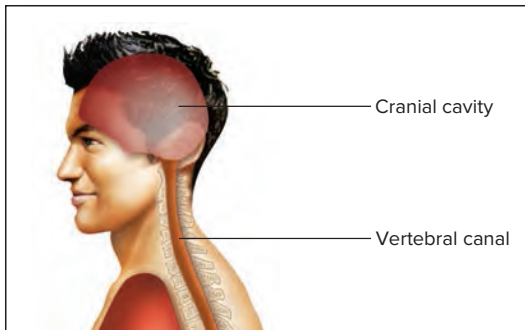
Outcome 4.5

- Consider the following DNA sequence: CATGTGTAGTCTAATA
 - Write the sequence of the DNA strand that would be replicated from this one.
 - Write the sequence of the RNA molecule that would be transcribed from the DNA strand.
 - State how many codons the sequence specifies.
 - State how many amino acids the sequence specifies.
 - Use table 4.2 to write the sequence of amino acids that this DNA sequence encodes.
- Some antibiotic drugs fight infection by interfering with DNA replication, transcription, or translation in bacteria. Indicate whether each of the following effects is on replication, transcription, or translation:
 - Rifampin binds to bacterial RNA polymerase.
 - Streptomycin binds bacterial ribosomes, disabling them.
 - Quinolone blocks an enzyme that prevents bacterial DNA from unwinding.

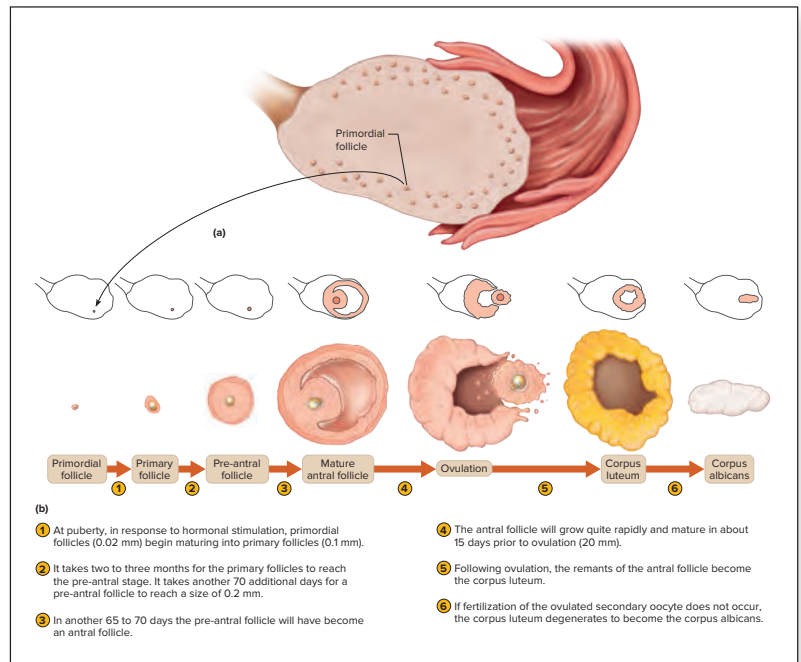
Integrative Assessments/Critical Thinking questions connect and apply information from previous chapters as well as information within the current chapter.

Dynamic Art Program

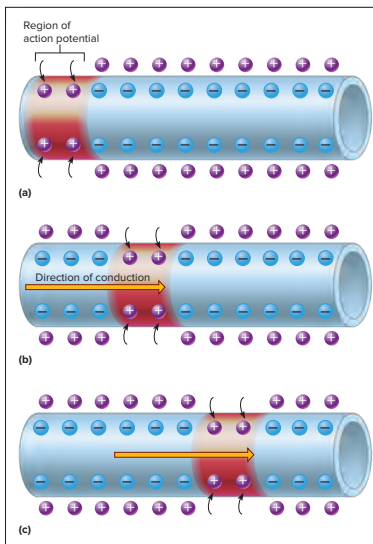
A dynamic and vibrant three-dimensional art program provides visual and contextual support to help students derive meaning.



Realistic, three-dimensional figures provide depth and orientation.

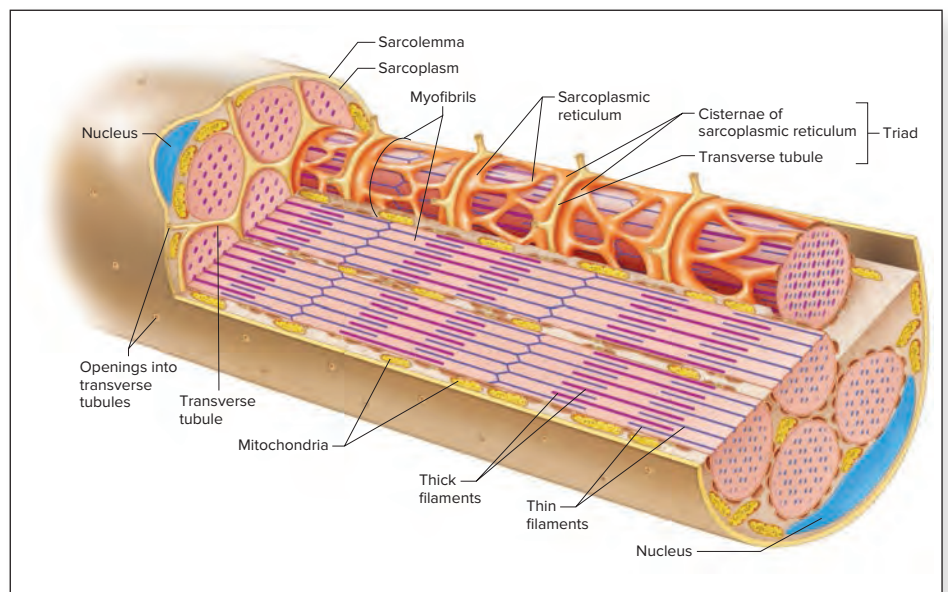


Bodily processes are portrayed accurately and in detail.



Color follows the movement of the action potential.

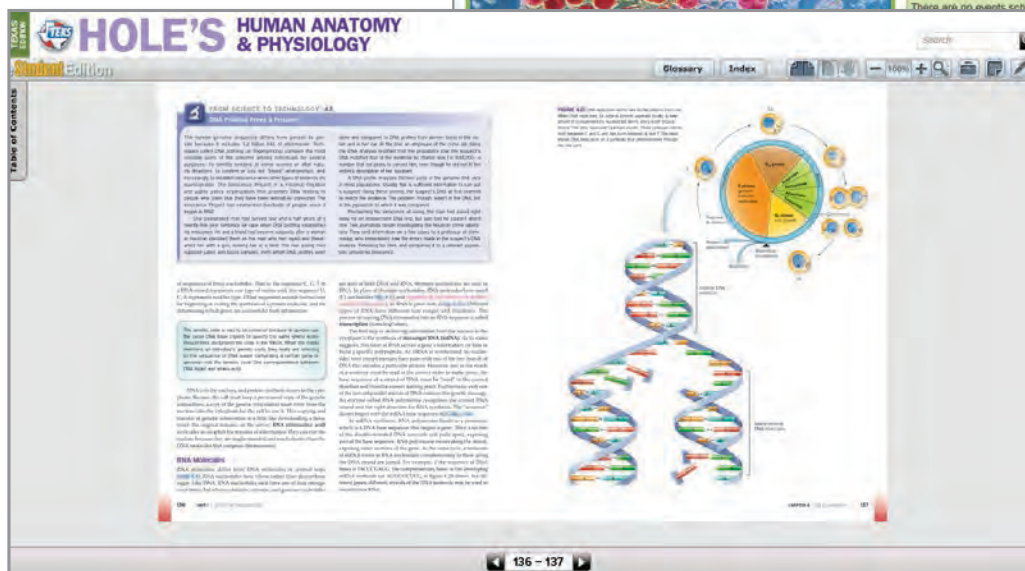
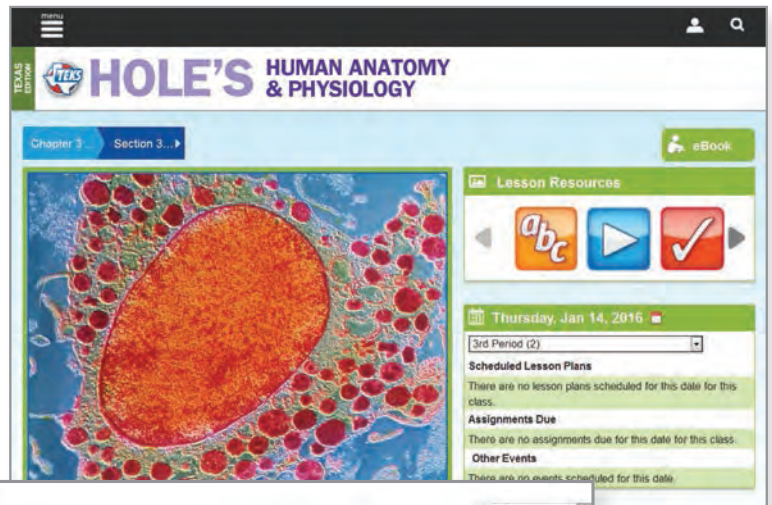
This longitudinal section shows the interior structures of a muscle fiber revealing more detail of the myofibrils, and thick and thin filaments.



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Hole's Human Anatomy & Physiology Texas Edition is supported by **ConnectED®**, a digital teaching and learning platform that makes it easy and convenient to customize lessons, review assignments, and communicate with students. This one-stop-shop allows students and teachers to access eBooks, assessment tools, classroom resources, messaging tools, and so much more!

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A&P - Hole's Human Anatomy & Physiology - Shier, Butler, Lewis, 14e, Muscular System

9.1 | Structure of a Skeletal Muscle

This chapter focuses mostly on skeletal muscles, which attach to bones and to the skin of the face and are under conscious control. A skeletal muscle is an organ of the muscular system. It is composed primarily of skeletal muscle tissue, nervous tissue, blood, and other connective tissues.

Connective Tissue Coverings

An individual skeletal muscle is separated from adjacent muscles and held in position by layers of dense connective tissue called **fascia** (fash'e-ah). This connective tissue surrounds each muscle and may project beyond the ends of its muscle fibers, forming a cordlike **tendon**. Fibers in a tendon may intertwine with those in the periosteum of a bone, attaching the muscle to the bone. Or, the connective tissues associated with a muscle form broad, fibrous sheets called **aponeuroses** (ap'o-nu-ro'seéz), which may attach to bone or the coverings of adjacent muscles (figs. 9.1 and 9.2).

A tendon or the connective tissue sheath of a tendon (tenosynovium) may become painfully inflamed and swollen following an injury or the repeated stress of athletic activity. *Tendinitis* affects the tendon and *tenosynovitis* affects the connective tissue sheath of the tendon. Most commonly affected are the tendons associated with the joint capsules of the shoulder, elbow, hip, and knee and those involved with moving the wrist, hand, thigh, and foot.

The layer of connective tissue that closely surrounds a skeletal muscle is called the *epimysium*, which in some areas of the body may merge with the surrounding deep fascia. Another layer of connective tissue, called the *perimysium*, extends inward from the epimysium and separates the muscle tissue into small sections. These sections contain bundles of skeletal muscle fibers called *fascicles* (fasciculi). Each muscle fiber within a fascicle (fasciculus)

FIGURE 9.1 Tendons attach muscles to bones, whereas aponeuroses attach muscles to other muscles or to bone.

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Powerful Teaching and Learning Supplements

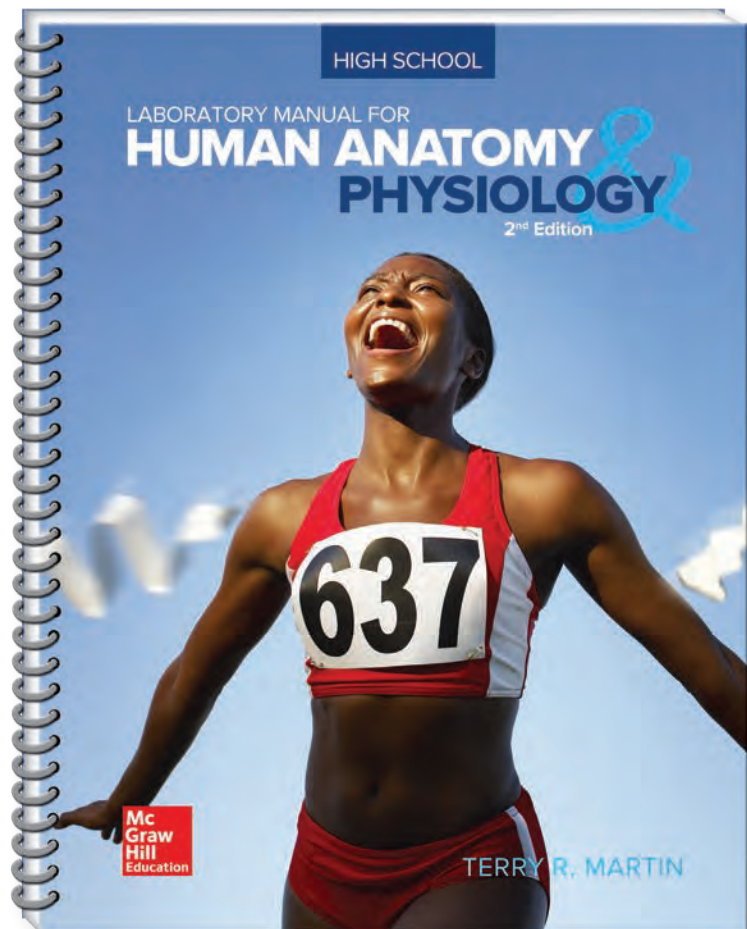
High School Laboratory Manual for Human Anatomy & Physiology, Second Edition

The *High School Laboratory Manual for Human Anatomy & Physiology* by Terry R. Martin is a streamlined lab manual ideal for the high school classroom. 34 hands-on laboratory activities complement any anatomy and physiology course.

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Hole's Human Anatomy & Physiology Texas Edition includes a teacher website with a wealth of valuable resources that augment the chapter content and bolster student learning and engagement.

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