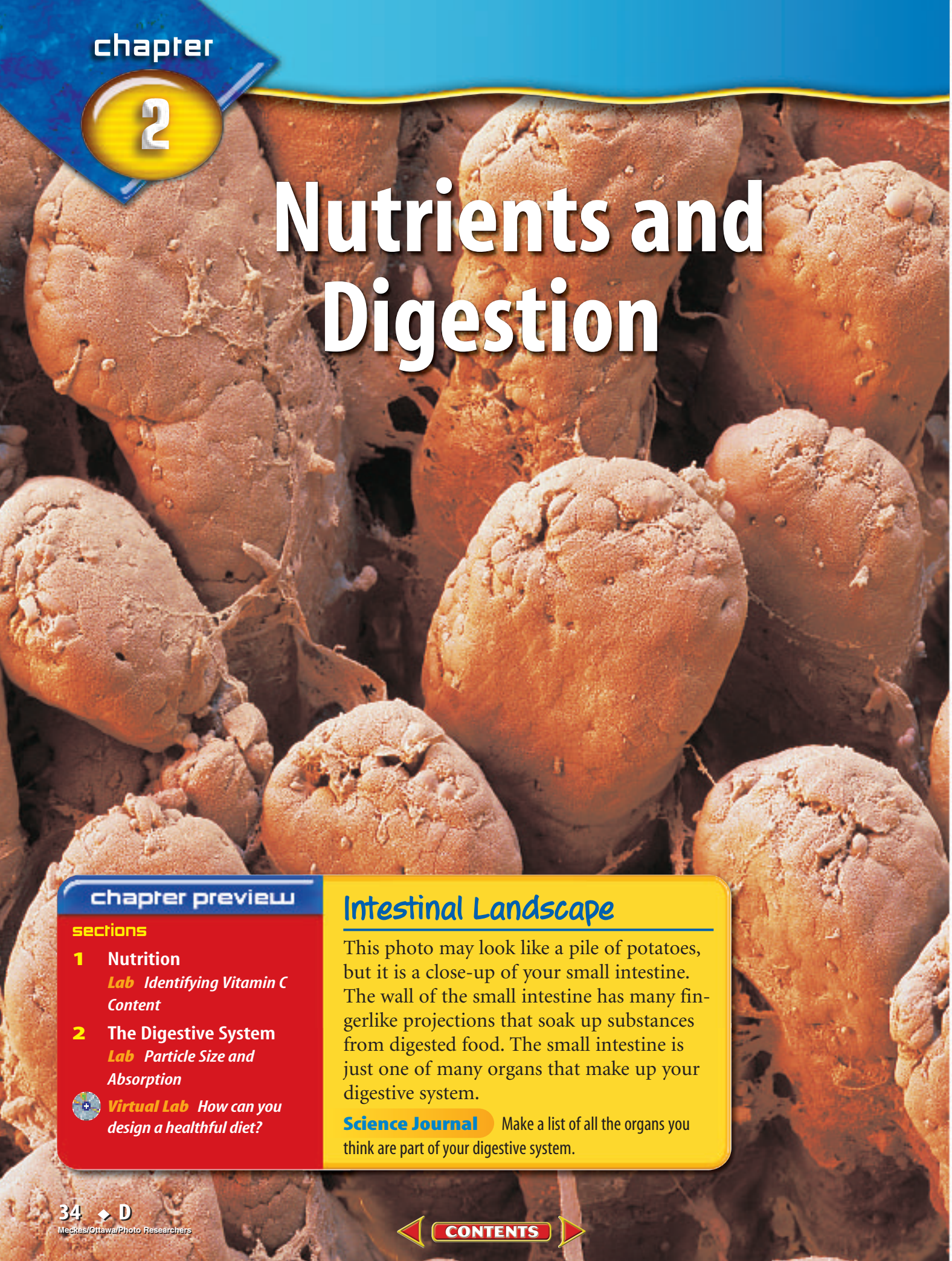
chapter 2

Nutrients and Digestion



chapter preview

sections

Intestinal Landscape

This photo may look like a pile of potatoes, but it is a close-up of your small intestine. The wall of the small intestine has many fingerlike projections that soak up substances from digested food. The small intestine is just one of many organs that make up your digestive system.

Science Journal Make a list of all the organs you think are part of your digestive system.

Meckes/Ottawa/Photo Researchers

CONTENTS

Start-Up Activities

Launch LAB

Model the Digestive Tract

Imagine taking a bite of your favorite food. When you eat, your body breaks down food to release energy. How long does it take?

Organs of the Digestive System

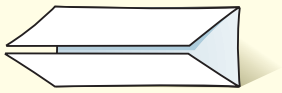
Organ	Length	Time
Mouth	8 cm	5 s to 30 s
Pharynx and esophagus	25 cm	10 s
Stomach	16 cm	2 h to 4 h
Small intestine	4.75 m	3 h
Large intestine	1.25 m	2 days

1. Make a label for each of the digestive organs listed here. Include the organ's name, length, and the time it takes for food to pass through it.
2. Working with a partner, place a piece of masking tape that is 6.5 m long on the classroom floor.
3. Beginning at one end of the tape, and in the same order as they are listed in the table, mark the length for each organ. Place each label next to its section.
4. **Think Critically** In your Science Journal, suggest reasons why food spends a different amount of time in each organ.

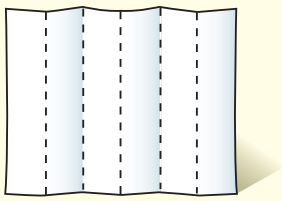
FOLDABLES™ Study Organizer

Nutrients in Foods Make the following Foldable to help you organize foods based on the nutrients that they contain.

STEP 1 **Fold** the top of a vertical piece of paper down and the bottom up to divide the paper into thirds. Then, **fold** the paper in half from top to bottom.



STEP 2 **Turn** the paper horizontally, **unfold and label** the six columns as follows: *Proteins, Carbohydrates, Lipids, Water, Vitamins,* and *Minerals.*



Read for Main Ideas As you read the chapter, list foods you eat that provide each of these nutrients in the proper columns.

section 1

Nutrition

as you read

What You'll Learn

- **Distinguish** among the six classes of nutrients.
- **Identify** the importance of each type of nutrient.
- **Explain** the relationship between diet and health.

Why It's Important

You can make healthful food choices if you know what nutrients your body uses daily.

Review Vocabulary

molecule: the smallest particle of a substance that retains the properties of the substance and is composed of one or more atoms

New Vocabulary

- nutrient
- protein
- amino acid
- carbohydrate
- fat
- vitamin
- mineral
- food group

Why do you eat?

You're listening to a favorite song on the radio, maybe even singing along. Then all of a sudden, the music stops. You examine the radio to see what happened. The batteries died. You hunt for more batteries and quickly put in the new ones. In the same way that the radio needs batteries to work, you need food to carry out your daily activities—but not just any food. When you are hungry, you probably choose food based on taste and the amount of time you have to eat it. However, as much as you don't want to admit it, the nutritional value of the food you choose is more important than the taste. A chocolate-iced donut might be tasty and quick to eat, yet it provides few of the nutrients your body needs. **Nutrients** (NEW tree unts) are substances in foods that provide energy and materials for cell development, growth, and repair.

Energy Needs Your body needs energy for every activity that it performs. Muscle activities such as the beating of your heart, blinking your eyes, and lifting your backpack require energy. How much energy you need depends on several factors, such as body mass, age, and activity level. This energy comes from the foods you eat. The amount of energy available in food is measured in Calories. A Calorie (Cal) is the amount of heat necessary to raise the temperature of 1 kg of water 1°C. As shown in **Figure 1,** different foods contain different numbers of Calories. A raw carrot may have 30 Cal. This means that when you eat a carrot, your body has 30 Cal of energy available to use. A slice of cheese pizza might have 170 Cal, and one hamburger might have 260 Cal. The number of Calories varies due to the kinds of nutrients a food provides.

Figure 1 Foods vary in the number of Calories they contain. A hamburger has the same number of Calories as 8.5 average-sized carrots.

Classes of Nutrients

Six kinds of nutrients are available in food—proteins, carbohydrates, fats, vitamins, minerals, and water. Proteins, carbohydrates, vitamins, and fats all contain carbon and are called organic nutrients. In contrast, inorganic nutrients, such as water and minerals, do not contain carbon. Foods containing carbohydrates, fats, and proteins need to be digested or broken down before your body can use them. Water, vitamins, and minerals don't require digestion and are absorbed directly into your bloodstream.

Figure 2 Meats, poultry, eggs, fish, peas, beans, and nuts are all rich in protein.

Proteins Your body uses proteins for replacement and repair of body cells and for growth. **Proteins** are large molecules that contain carbon, hydrogen, oxygen, nitrogen and sometimes sulfur. A molecule of protein is made up of a large number of smaller units, or building blocks, called **amino acids.** In **Figure 2** you can see some sources of proteins. Different foods contain different amounts of protein, as shown in **Figure 3.**

Your body needs only 20 amino acids in various combinations to make the thousands of proteins used in your cells. Most of these amino acids can be made in your body's cells, but eight of them cannot. These eight are called essential amino acids. They have to be supplied by the foods you eat. Complete proteins provide all of the essential amino acids. Eggs, milk, cheese, and meat contain complete proteins. Incomplete proteins are missing one or more of the essential amino acids. If you are a vegetarian, you can get all of the essential amino acids by eating a wide variety of protein-rich vegetables, fruits, and grains.

Figure 3 The amount of protein in a food is not the same as the number of Calories in the food. A taco has nearly the same amount of protein as a slice of pizza, but it usually has about 100 fewer Calories.

CONTENTS

Science Online

Topic: Dietary Fiber

Visit bookd.msscience.com for Web links to recent news or magazine articles about the importance of fiber in your diet.

Activity In your Science Journal, classify your favorite foods into two groups—*Good source of fiber* and *Little or no fiber.*

INTEGRATE Chemistry

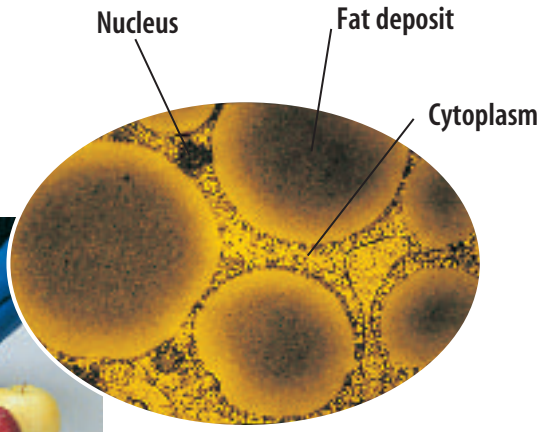
Carbohydrates Study the nutrition label on several boxes of cereal. You'll notice that the number of grams of carbohydrates found in a typical serving of cereal is higher than the amounts of the other nutrients. **Carbohydrates** (kar boh HI drayts) usually are the main sources of energy for your body. Each carbohydrate molecule is made of carbon, hydrogen, and oxygen atoms. Energy holds the atoms together. When carbohydrates are broken down in the presence of oxygen in your cells, this energy is released for use by your body.

Three types of carbohydrates are sugar, starch, and fiber, as shown in **Figure 4.** Sugars are called *simple carbohydrates.* You're probably most familiar with table sugar. However, fruits, honey, and milk also contain forms of sugar. Your cells break down glucose, a simple sugar. The other two types of carbohydrates—starch and fiber—are called *complex carbohydrates.* Starch is found in potatoes and foods made from grains such as pasta. Starches are made up of many simple sugars in long chains. Fiber, such as cellulose, is found in the cell walls of plant cells. Foods like whole-grain breads and cereals, beans, peas, and other vegetables and fruits are good sources of fiber. Because different types of fiber are found in foods, you should eat a variety of fiber-rich plant foods. You cannot digest fiber, but it is needed to keep your digestive system running smoothly.

Nutritious snacks can help your body get the nutrients it needs, especially when you are growing rapidly and are physically active. Choose snacks that provide nutrients such as complex carbohydrates, proteins, and vitamins, as well as fiber. Foods high in sugar and fat can have lots of Calories that supply energy, but they provide only some of the nutrients your body needs.

Figure 4 These foods contain carbohydrates that provide energy for all the things that you do. **List** *the carbohydrates that you've eaten today.*

Figure 5 Fat is stored in certain cells in your body. The cytoplasm and nucleus are pushed to the edge of the cell by the fat deposits.



Fats The term fat has developed a negative meaning for some people. However, **fats,** also called lipids, are necessary because they provide energy and help your body absorb vitamins. Fat tissue cushions your internal organs. A major part of every cell membrane is made up of fat. A gram of fat can release more than twice as much energy as a gram of carbohydrate can. During the digestion process, fat is broken down into smaller molecules called fatty acids and glycerol (GLIH suh rawl). Because fat is a good storage unit for energy, excess energy from the foods you eat is converted to fat and stored for later use, as shown in **Figure 5.**

Reading Check ***Why is fat a good storage unit for energy?***

Fats are classified as unsaturated or saturated based on their chemical structure. Unsaturated fats are usually liquid at room temperature. Vegetable oils as well as fats found in seeds are unsaturated fats. Saturated fats are found in meats, animal products, and some plants and are usually solid at room temperature. Although fish contains saturated fat, it also has some unsaturated fats that your body needs. Saturated fats have been associated with high levels of blood cholesterol. Your body makes cholesterol in your liver. Cholesterol is part of the cell membrane in all of your cells. However, a diet high in cholesterol may result in deposits forming on the inside walls of blood vessels. These deposits can block the blood supply to organs and increase blood pressure. This can lead to heart disease and strokes.

Mini LAB

Comparing the Fat Content of Foods

Procedure

1. Collect three pieces of each of the following foods: **potato chips; pretzels; peanuts;** and **small cubes of fruits, cheese, vegetables, and meat.**
2. Place the food items on a piece of **brown grocery bag.** Label the paper with the name of each food. Do not taste the foods.
3. Allow foods to sit for 30 min.
4. Remove the items, properly dispose of them, and observe the paper.

Analysis

1. Which items left a translucent (greasy) mark? Which left a wet mark?
2. How are the foods that left a greasy mark on the paper alike?
3. Use this test to determine which other foods contain fats. A greasy mark means the food contains fat. A wet mark means the food contains a lot of water.

CONTENTS

Vitamins Organic nutrients needed in small quantities for growth, regulating body functions, and preventing some diseases are called **vitamins.** For instance, your bone cells need vitamin D to use calcium, and your blood needs vitamin K in order to clot.

Most foods supply some vitamins, but no food has them all. Some people feel that taking extra vitamins is helpful, while others feel that eating a well-balanced diet usually gives your body all the vitamins it needs.

Vitamins are classified into two groups, as shown in **Figure 6.** Some vitamins dissolve easily in water and are called water-soluble vitamins. They are not stored by your body so you have to take them daily. Other vitamins dissolve only in fat and are called fat-soluble vitamins. These vitamins are stored by your body. Although you eat or drink most vitamins, some are made by your body. Vitamin D is made when your skin is exposed to sunlight. Some vitamin K and two of the B vitamins are made with the help of bacteria that live in your large intestine.

Applying Science

Is it unhealthy to snack between meals?

Most children eat three meals each day accompanied by snacks in between. Grabbing a bite to eat to satisfy you until your next meal is a common occurrence in today's society, and 20 percent of our energy and nutrient needs comes from snacking. While it would be best to select snacks consisting of fruits and vegetables, most children prefer to eat a bag of chips or a candy bar. Although these quick snacks are highly convenient, many times they are high in fat, as well.

Identifying the Problem

The table on the right lists several snack foods that are popular among adolescents. They are listed alphabetically, and the grams of fat per individual serving is shown. As you examine the chart, can you conclude which snacks would be a healthier choice based on their fat content?

Fat in Snack Foods

One Serving	Fat (g)
Candy bar	12
Frozen pizza	30
Ice cream	8
Potato chips	10
Pretzels	1

Solving the Problem

1. Looking at the data, what can you conclude about the snack foods you eat? What other snack foods do you eat that are not listed on the chart? How do you think they compare in nutritional value? Which snack foods are healthiest?
2. Pizza appears to be the unhealthiest choice on the chart because of the amount of the fat it contains. Why do you think pizza contains so much fat? List at least three ways to make pizza a healthier snack food.

Figure 6

Vitamins come in two groups—water soluble, which should be replaced daily, and fat soluble, which can be stored in the body. The sources and benefits of both groups are shown below.

Aids in growth, healthy nervous system, use of carbohydrates, and red blood cell production

B

(B_6, B_{12}, riboflavin, niacin, thiamine, etc.)

Aids in growth, healthy bones and teeth, wound recovery

C

WATER SOLUBLE

Need to be replenished every day because they are excreted by the body

Aids in growth, eyesight, healthy skin

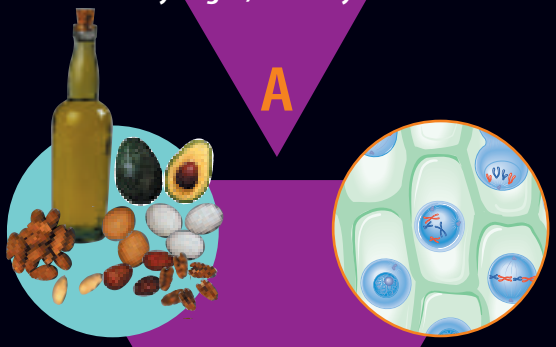
A

Aids in absorption of calcium and phosphorus by bones and teeth

D

FAT SOLUBLE

Stored in the body in fatty tissue



Aids in formation of cell membranes

E

Aids in blood clotting and wound recovery

K

Minerals Inorganic nutrients—nutrients that lack carbon and regulate many chemical reactions in your body—are called **minerals.** Your body uses about 14 minerals. Minerals build cells, take part in chemical reactions in cells, send nerve impulses throughout your body, and carry oxygen to body cells. In **Figure 7,** you can see how minerals can get from the soil into your body. Of the 14 minerals, calcium and phosphorus are used in the largest amounts for a variety of body functions. One of these functions is the formation and maintenance of bone. Some minerals, called trace minerals, are required only in small amounts. Copper and iodine usually are listed as trace minerals. Several minerals, what they do, and some food sources for them are listed in **Table 1.**

Reading Check *Why is copper considered a trace mineral?*

Phosphorus

Wheat being harvested

Figure 7 The roots of the wheat take in phosphorus from the soil. Then the mature wheat is harvested and used in bread and cereal. Your body gets phosphorus when you eat the cereal.

Table 1 Minerals

Mineral	Health Effect	Food Sources
Calcium	strong bones and teeth, blood clotting, muscle and nerve activity	dairy products, eggs, green leafy vegetables, soy
Phosphorus	strong bones and teeth, muscle contraction, stores energy	cheese, meat, cereal
Potassium	balance of water in cells, nerve impulse conduction, muscle contraction	bananas, potatoes, nuts, meat, oranges
Sodium	fluid balances in tissues, nerve impulse conduction	meat, milk, cheese, salt, beets, carrots, nearly all foods
Iron	oxygen is transported in hemoglobin by red blood cells	red meat, raisins, beans, spinach, eggs
Iodine (trace)	thyroid activity, metabolic stimulation	seafood, iodized salt

Gary Kreyer from Grant Heilman
CONTENTS

Figure 8 About two-thirds of your body water is located within your body cells. Water helps maintain the cells' shapes and sizes. The water that is lost through perspiration and respiration must be replaced.

Water Loss

Method of Loss	Amount (mL/day)
Exhaled air	350
Feces	150
Skin (mostly as sweat)	500
Urine	1,500

Water Have you ever gone on a bike ride on a hot summer day without a bottle of water? You probably were thirsty and maybe you even stopped to get some water. Water is important for your body. Next to oxygen, water is the most important factor for survival. Different organisms need different amounts of water to survive. You could live for a few weeks without food but for only a few days without water because your cells need water to carry out their work. Most of the nutrients you have studied in this chapter can't be used by your body unless they are carried in a solution. This means that they have to be dissolved in water. In cells, chemical reactions take place in solutions.

The human body is about 60 percent water by weight. About two thirds of your body water is located in your body cells. Water also is found around cells and in body fluids such as blood. As shown in **Figure 8,** your body loses water as perspiration. When you exhale, water leaves your body as water vapor. Water also is lost every day when your body gets rid of wastes. To replace water lost each day, you need to drink about 2 L of liquids. However, drinking liquids isn't the only way to supply cells with water. Most foods have more water than you realize. An apple is about 80 percent water, and many meats are 90 percent water.

INTEGRATE Social Studies

Salt Mines The mineral halite is processed to make table salt. In the United States, most salt comes from underground mines. Research to find the locations of these mines, then label them on a map.

CONTENTS

Why do you get thirsty? Your body is made up of systems that operate together. When your body needs to replace lost water, messages are sent to your brain that result in a feeling of thirst. Drinking water satisfies your thirst and usually restores the body's homeostasis (hoh mee oh STAY sus). Homeostasis is the regulation of the body's internal environment, such as temperature and amount of water. When homeostasis is restored, the signal to the brain stops and you no longer feel thirsty.

Food Groups

Because no naturally occurring food has every nutrient, you need to eat a variety of foods. Nutritionists have developed a simple system, called the food pyramid, shown in **Figure 9,** to help people select foods that supply all the nutrients needed for energy and growth.

Foods that contain the same type of nutrient belong to a **food group.** Foods have been divided into five groups—bread and cereal, vegetable, fruit, milk, and meat. The recommended daily amount for each food group will supply your body with the nutrients it needs for good health. Using the food pyramid to make choices when you eat will help you maintain good health.

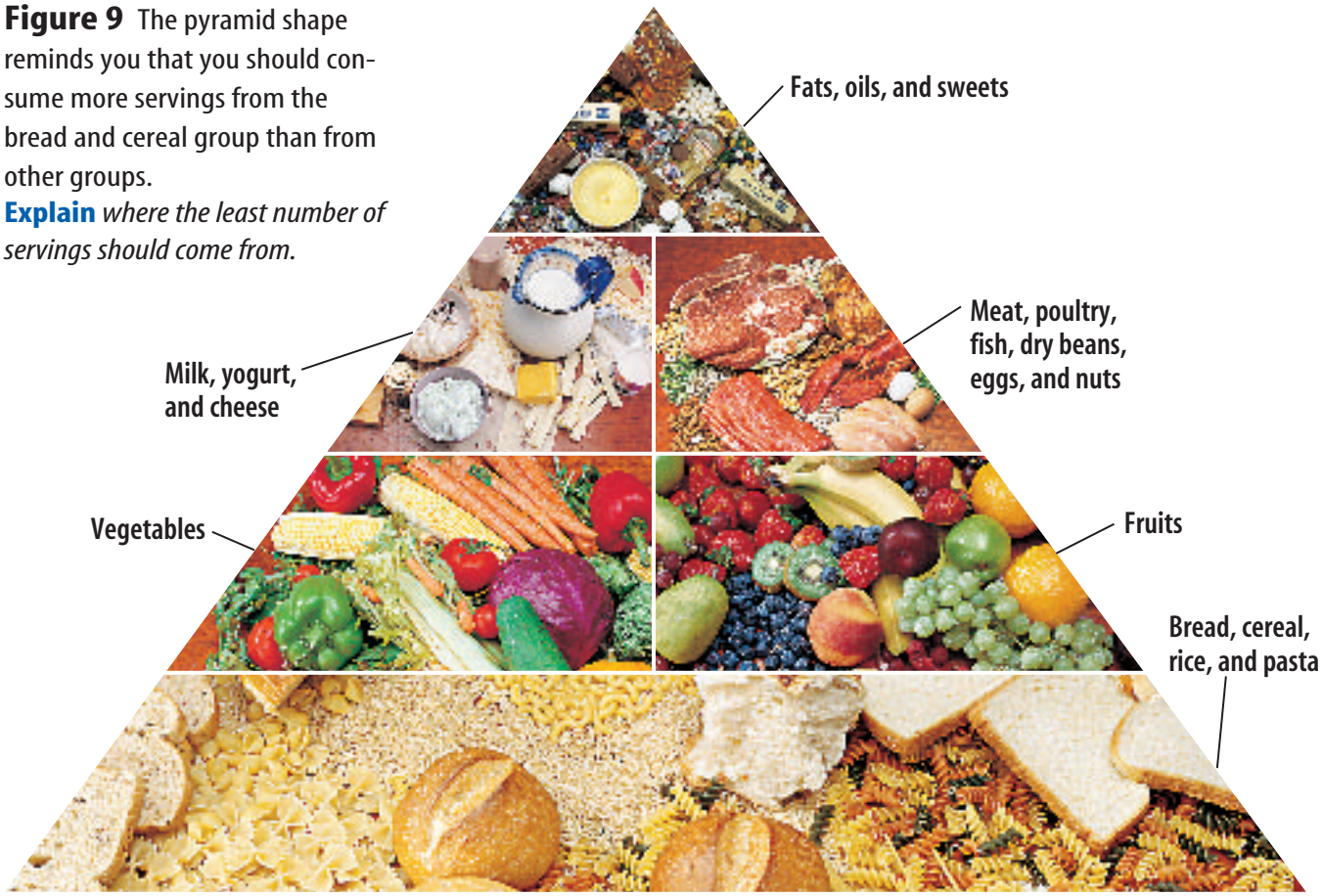


Figure 9 The pyramid shape reminds you that you should consume more servings from the bread and cereal group than from other groups.
Explain *where the least number of servings should come from.*

Daily Servings Each day you should eat six to eleven servings from the bread and cereal group, three to five servings from the vegetable group, two to four servings from the fruit group, two to three servings from the milk group, and two to three servings from the meat group. Only small amounts of fats, oils, and sweets should be consumed.

The size of a serving is different for different foods. For example, a slice of bread or one ounce of ready-to-eat cereal is a bread and cereal-group serving. One cup of raw leafy vegetables or one-half cup of cooked or chopped raw vegetables make a serving from the vegetable group. One medium apple, banana, or orange is a fruit serving. A serving from the milk group can be one cup of milk or yogurt. Two ounces of cooked lean meat or one egg is a serving from the meat group.

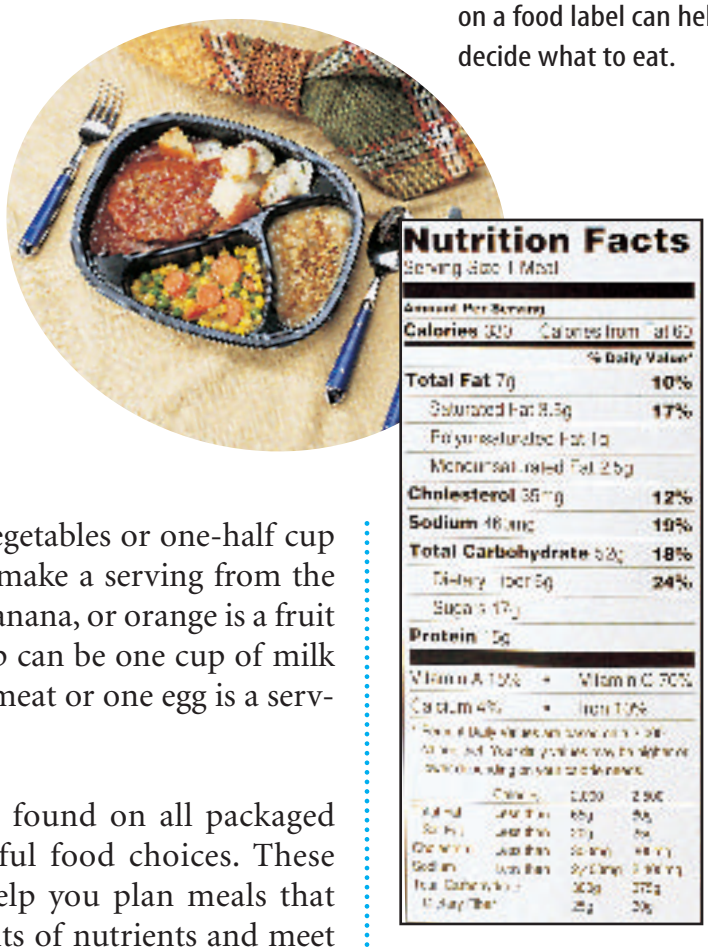


Figure 10 The information on a food label can help you decide what to eat.

Food Labels The nutritional facts found on all packaged foods make it easier to make healthful food choices. These labels, as shown in **Figure 10,** can help you plan meals that supply the daily recommended amounts of nutrients and meet special dietary requirements (for example, a low-fat diet).

section 1 review

Summary

Why do you eat?

- Food provides the energy for your body.

Classes of Nutrients

- The nutrients in food fall into six classes.
- Organic nutrients—proteins, vitamins, fats, and carbohydrates—contain carbon.
- Inorganic nutrients—water and minerals—do not contain carbon.

Food Groups

- Foods are divided into groups based on the type of nutrient in the foods.
- The five food groups are bread and cereal, vegetable, fruit, milk, and meat.

Self Check

1. **List** the six classes of nutrients. Give one example of a food source for each class.
2. **Describe** a major function of each class of nutrient.
3. **Discuss** how food choices can positively and negatively affect your health.
4. **Explain** the importance of water in the body.
5. **Think Critically** What foods from each food group would provide a balanced breakfast? Explain.

Applying Skills

6. **Interpret Data** Nutritional information can be found on the labels of most foods. Interpret the labels found on three different types of food products.

Identifying Vitamin C Content

Vitamin C is found in many fruits and vegetables. Oranges have a high vitamin C content. Try this lab to test which orange juice has the highest vitamin C content.

Real-World Question

Which orange juice contains the most vitamin C?

Goals

- **Observe** the vitamin C content of different orange juices.

Materials

test tubes (4)
**paper cups*
test-tube rack
masking tape
wooden stirrers (13)
graduated cylinder
**graduated container*
2% tincture of iodine
dropper
cornstarch
triple-beam balance
weighing paper
water (50 mL)
glass-marking pencil

dropper bottles (4) containing:
(1) freshly squeezed orange juice
(2) orange juice made from frozen concentrate
(3) canned orange juice
(4) dairy carton orange juice

**Alternate materials*

Safety Precautions

WARNING: *Do not taste any of the juices. Iodine is poisonous, can stain skin and clothing, and is an irritant that can cause damage if it comes in contact with your eyes. Notify your teacher if a spill occurs.*

Drops of Iodine Needed to Change Color

Juice	Trial 1	Trial 2	Trial 3	Average
1 Fresh juice				
2 Frozen juice				
3 Canned juice				
4 Carton juice				

Procedure

1. Copy the data table shown above.
2. Label four test tubes as shown in the table above and place them in the test-tube rack.
3. **Measure** and pour 5 mL of juice from each bottle into its labeled test tube.
4. **Measure** 0.3 g of cornstarch, then put it in a container. Slowly mix in 50 mL of water until the cornstarch completely dissolves.
5. Add 5 mL of the cornstarch solution to each of the four test tubes. Stir well.
6. Add iodine to test tube 1, one drop at a time. Stir after each drop. Record the number of drops needed to change the juice to purple. The more vitamin C, the more drops needed.
7. Repeat step 6 with test tubes 2, 3, and 4.
8. Empty and clean the test tubes. Repeat steps 3 through 7 two more times, then average your results.

Conclude and Apply

1. **Compare and contrast** the amount of vitamin C in the orange juices tested.
2. **Infer** why the amount of vitamin C varied.

section 2

The Digestive System

Functions of the Digestive System

You are walking through a park on a cool, autumn afternoon. Birds are searching in the grass for insects. A squirrel is eating an acorn. Why are the animals so busy? Like you, they need food to supply their bodies with energy. Food is processed in your body in four stages—ingestion, digestion, absorption, and elimination. Whether it is a piece of fruit or an entire meal, all the food you eat is treated to the same processes in your body. As soon as food enters your mouth, or is ingested as shown in **Figure 11,** breakdown begins. **Digestion** is the process that breaks down food into small molecules so that they can be absorbed and moved into the blood. From the blood, food molecules are transported across the cell membrane to be used by the cell. Unused molecules pass out of your body as wastes.

Digestion is mechanical and chemical. **Mechanical digestion** takes place when food is chewed, mixed, and churned. **Chemical digestion** occurs when chemical reactions occur that break down large molecules of food into smaller ones.

as you read

What You'll Learn

- **Distinguish** the differences between mechanical digestion and chemical digestion.
- **Identify** the organs of the digestive system and what takes place in each.
- **Explain** how homeostasis is maintained in digestion.

Why It's Important

The processes of the digestive system make the food you eat available to your cells.

Review Vocabulary

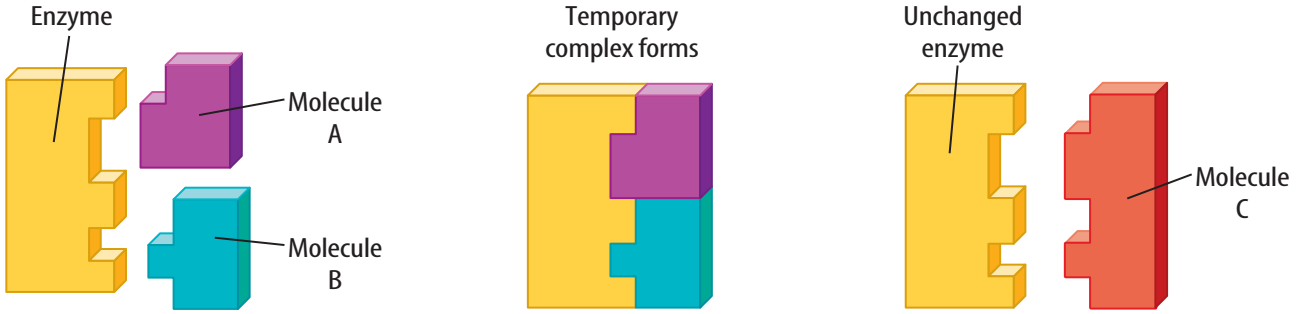
bacteria: one-celled organism without membrane-bound organelles

New Vocabulary

- digestion
- mechanical digestion
- chemical digestion
- enzyme
- peristalsis
- chyme
- villi

Figure 11 Humans have to chew solid foods before swallowing them, but snakes have adaptations that allow them to swallow their food whole.

CONTENTS



The surface shape of an enzyme fits the shape of specific molecules that take part in the reaction.

The enzyme and the molecules join and the reaction occurs between the two molecules.

Following the reaction, the enzyme and the new molecule separate. The enzyme is not changed by the reaction. The resulting new molecule has a new chemical structure.

Figure 12 Enzymes speed up the rate of certain body reactions. During these reactions, the enzymes are not used up or changed in any way.
Explain *what happens to the enzyme after it separates from the new molecule.*

Enzymes

Chemical digestion is possible only because of enzymes (EN zimez). An **enzyme** is a type of protein that speeds up the rate of a chemical reaction in your body. One way enzymes speed up reactions is by reducing the amount of energy necessary for a chemical reaction to begin. If enzymes weren't there to help, the rate of chemical reactions would slow down. Some might not even happen at all. As shown in **Figure 12,** enzymes work without being changed or used up.

Enzymes in Digestion Many enzymes help you digest carbohydrates, proteins, and fats. Amylase (AM uh lays) is an enzyme produced by glands near the mouth. This enzyme helps speed up the breakdown of complex carbohydrates, such as starch, into simpler carbohydrates—sugars. In your stomach, the enzyme pepsin aids the chemical reactions that break down complex proteins into less complex proteins. In your small intestine, a number of other enzymes continue to speed up the breakdown of proteins into amino acids.

The pancreas, an organ on the back side of the stomach, releases several enzymes through a tube into the small intestine. Some of these enzymes continue to aid the process of starch breakdown that started in the mouth. The resulting sugars are turned into glucose and are used by your body's cells. Different enzymes from the pancreas are involved in the breakdown of fats into fatty acids. Others help in the reactions that break down proteins.

Reading Check ***What is the role of enzymes in the chemical digestion of food?***

Other Enzyme Actions Enzyme-aided reactions are not limited to the digestive process. Enzymes also help speed up chemical reactions responsible for building your body. They are involved in the energy production activities of your muscle and nerve cells. Enzymes also aid in the blood-clotting process. Without enzymes, the chemical reactions of your body would not happen. In fact, you would not exist.

Organs of the Digestive System

Your digestive system has two parts—the digestive tract and the accessory organs. The major organs of your digestive tract—mouth, esophagus (ih SAH fuh guhs), stomach, small intestine, large intestine, rectum, and anus—are shown in **Figure 13.** Food passes through all of these organs. The tongue, teeth, salivary glands, liver, gallbladder, and pancreas, also shown in **Figure 13,** are the accessory organs. Although food doesn't pass through them, they are important in mechanical and chemical digestion. Your liver, gallbladder, and pancreas produce or store enzymes and chemicals that help break down food as it passes through the digestive tract.

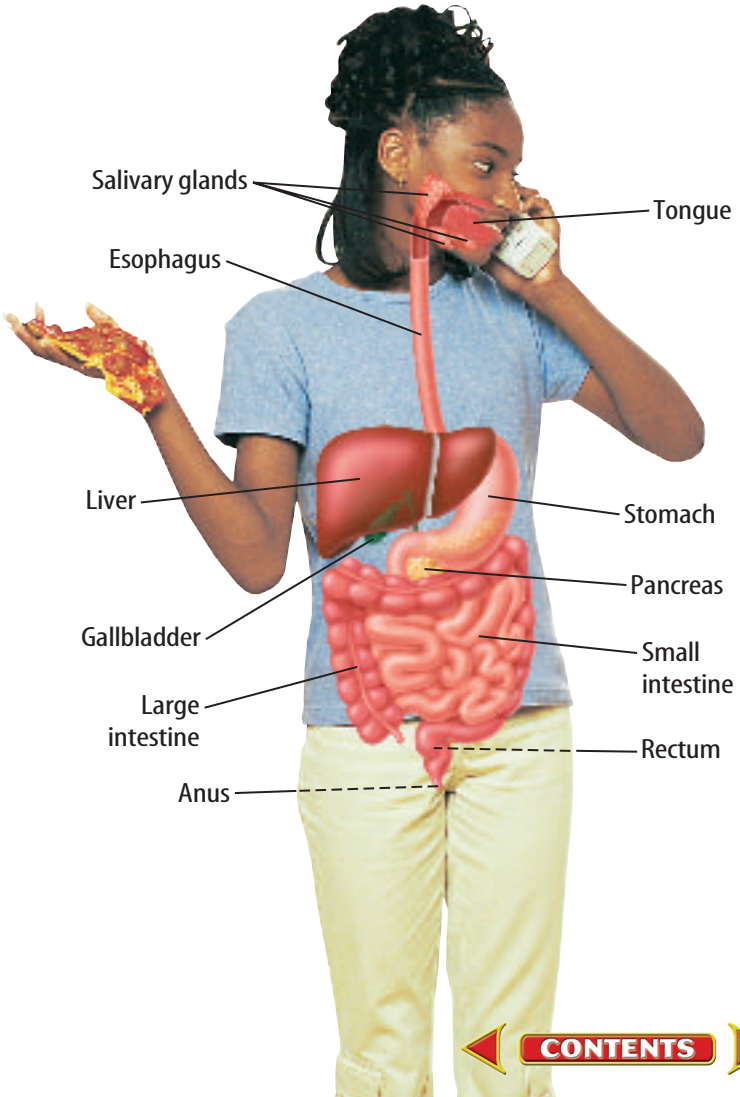
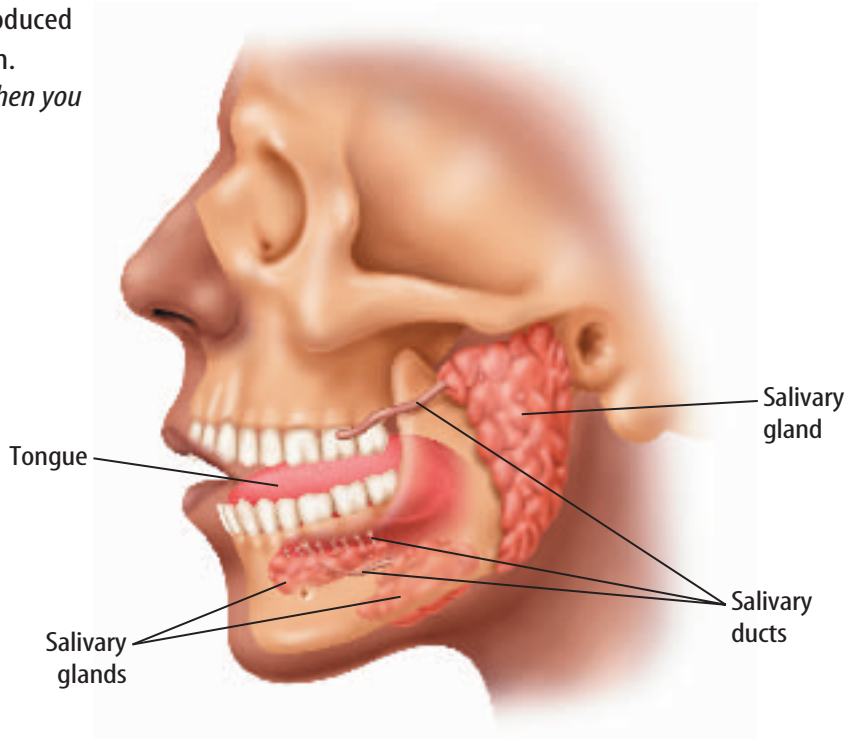


Figure 13 The human digestive system can be described as a tube divided into several specialized sections. If stretched out, an adult's digestive system is 6 m to 9 m long.

Figure 14 About 1.5 L of saliva are produced each day by salivary glands in your mouth. **Describe** *what happens in your mouth when you think about a food you like.*



Science Online

Topic: The Stomach

Visit bookd.msscience.com for Web links to information about the role of the stomach during digestion.

Activity Research to find out how antacids provide relief from stomach discomfort.

The Mouth Mechanical and chemical digestion begin in your mouth. Mechanical digestion happens when you chew your food with your teeth and mix it with your tongue. Chemical digestion begins with the addition of a watery substance called saliva (suh LI vuh). As you chew, your tongue moves food around and mixes it with saliva. Saliva is produced by three sets of glands near your mouth, as shown in **Figure 14.** Although saliva is mostly water, it also contains mucus and an enzyme that aids in the breakdown of starch into sugar. Food mixed with saliva becomes a soft mass and is moved to the back of your mouth by your tongue. It is swallowed and passes into your esophagus. Now ingestion is complete, but the process of digestion continues.

The Esophagus Food moving into the esophagus passes over the epiglottis (ep uh GLAH tus). This structure automatically covers the opening to the windpipe to prevent food from entering it, otherwise you would choke. Your esophagus is a muscular tube about 25 cm long. It takes about 4 s to 10 s for food to move down the esophagus to the stomach. No digestion takes place in the esophagus. Mucous glands in the wall of the esophagus keep the food moist. Smooth muscles in the wall move food downward with a squeezing action. These waves of muscle contractions, called **peristalsis** (per uh STAHL sus), move food through the entire digestive tract.

The Stomach The stomach, shown in **Figure 15,** is a muscular bag. When empty, it is somewhat sausage shaped with folds on the inside. As food enters from the esophagus, the stomach expands and the folds smooth out. Mechanical and chemical digestion take place in the stomach. Mechanically, food is mixed in the stomach by peristalsis. Chemically, food is mixed with enzymes and strong digestive solutions, such as hydrochloric acid solution, to help break it down.

Specialized cells in the walls of the stomach release about 2 L of hydrochloric acid solution each day. The acidic solution works with the enzyme pepsin to digest protein. The acidic solution has another important purpose—it destroys bacteria that are present in the food. The stomach also produces mucus, which makes food more slippery and protects the stomach from the strong, digestive solutions. Food moves through your stomach in 2 hours to 4 hours and is changed into a thin, watery liquid called **chyme** (KIME). Little by little, chyme moves out of your stomach and into your small intestine.

Reading Check *Why isn't your stomach digested by the acidic digestive solution?*

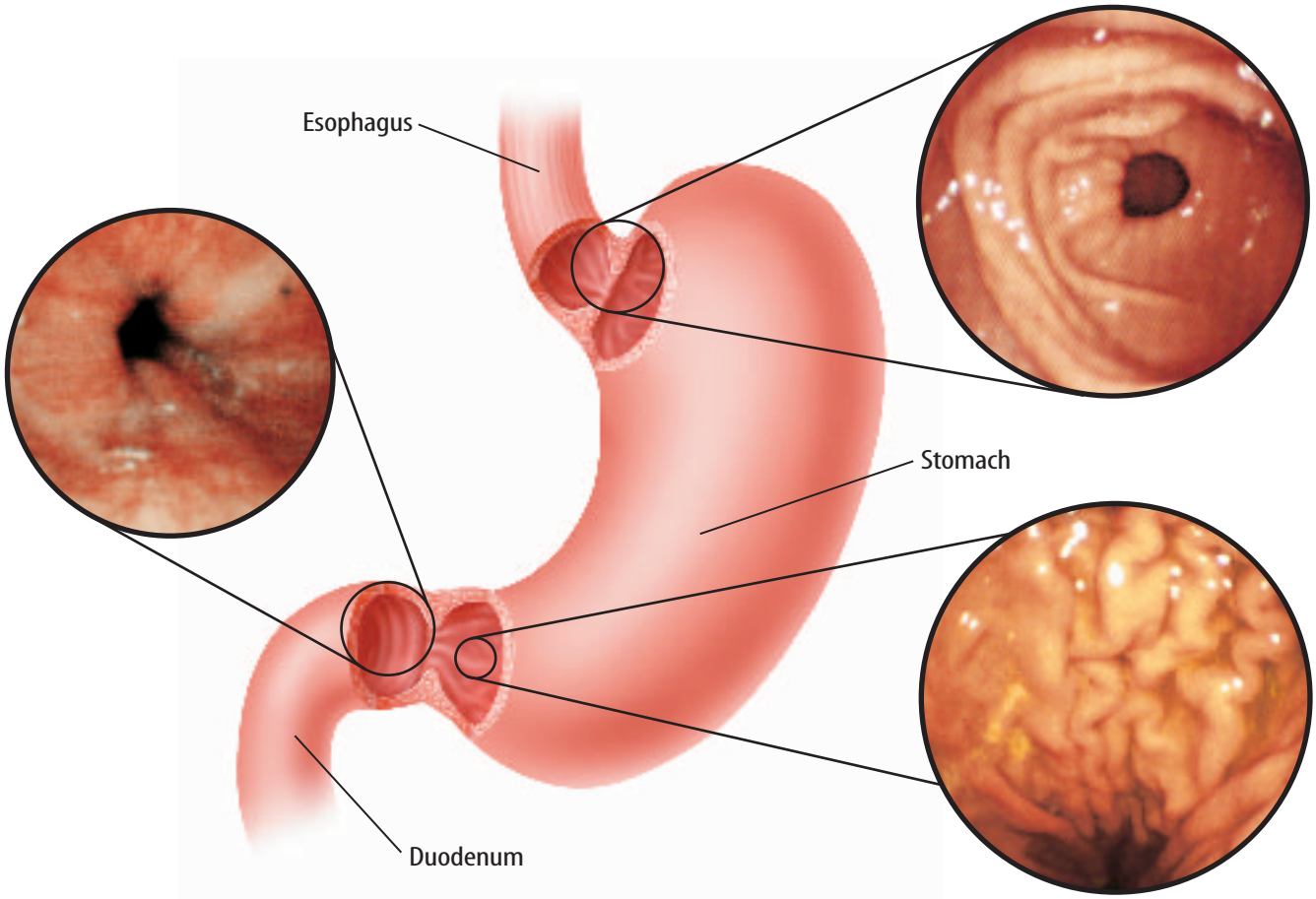
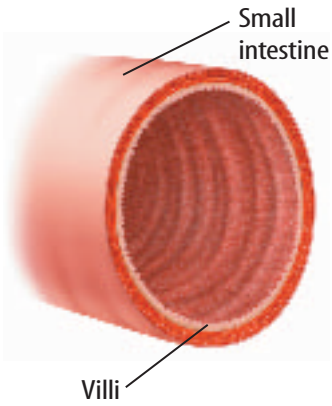


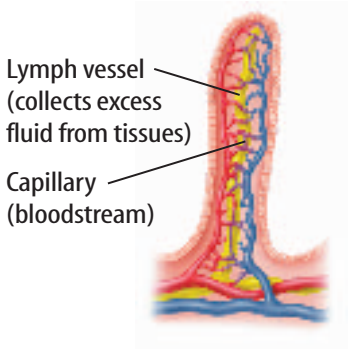
Figure 15 A band of muscle is at the entrance of the stomach to control the entry of food from the esophagus. Muscles at the end of the stomach control the flow of the partially digested food into the first part of the small intestine.

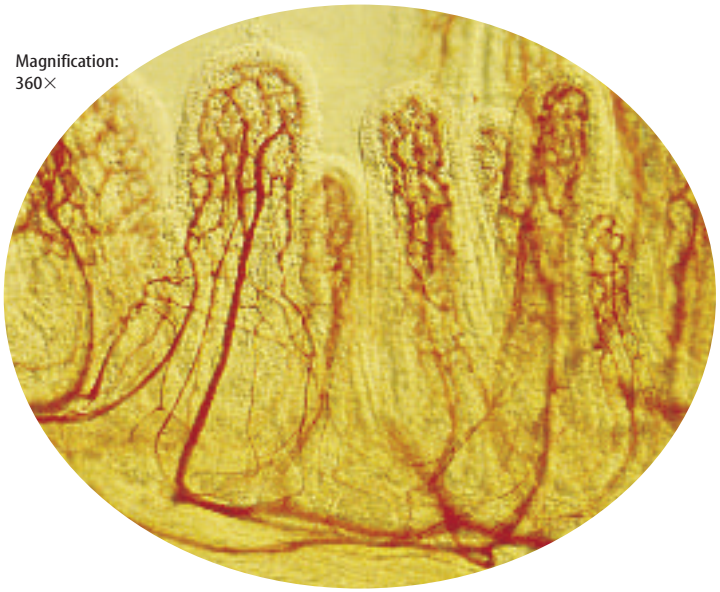
CONTENTS

Figure 16 Hundreds of thousands of densely packed villi give the impression of a velvet cloth surface. If the surface area of your villi could be stretched out, it would cover an area the size of a tennis court.

Infer *what would happen to a person's weight if the number of villi were drastically reduced. Why?*







Biophoto Associates/Photo Researchers

Mini LAB

Modeling Absorption in the Small Intestine

Procedure

1. Place one piece of smooth **cotton cloth** (about 25 cm × 25 cm) and a similar-sized piece of **cotton terry cloth** into a **bowl of water.**
2. Soak each for 30 s.
3. Remove the cloths and drain for 1 minute.
4. Wring out each cloth into different containers. Measure the amount of water collected in each.

Analysis

1. Which cloth absorbed the most water?
2. How does the surface of the terry cloth compare to the internal surface of the small intestine?

Try at Home

The Small Intestine Your small intestine is small in diameter, but it measures 4 m to 7 m in length. As chyme leaves your stomach, it enters the first part of your small intestine, called the duodenum (doo AH duh num). Most digestion takes place in your duodenum. Here, a greenish fluid from the liver, called bile, is added. The acid from the stomach makes large fat particles float to the top of the liquid. Bile breaks up the large fat particles, similar to the way detergent breaks up grease.

Chemical digestion of carbohydrates, proteins, and fats occurs when a digestive solution from the pancreas is mixed in. This solution contains bicarbonate ions and enzymes. The bicarbonate ions help neutralize the stomach acid that is mixed with chyme. Your pancreas also makes insulin, a hormone that allows glucose to pass from the bloodstream into your cells.

Absorption of food takes place in the small intestine. Look at the wall of the small intestine in **Figure 16.** The wall has many ridges and folds that are covered with fingerlike projections called **villi** (VIH li). Villi increase the surface area of the small intestine so that nutrients in the chyme have more places to be absorbed. Peristalsis continues to move and mix the chyme. The villi move and are bathed in the soupy liquid. Nutrients move into blood vessels within the villi. From here, blood transports the nutrients to all cells of your body. Peristalsis continues to force the remaining undigested and unabsorbed materials slowly into the large intestine.

The Large Intestine When the chyme enters the large intestine, it is still a thin, watery mixture. The main job of the large intestine is to absorb water from the undigested mass. This keeps large amounts of water in your body and helps maintain homeostasis. Peristalsis usually slows down in the large intestine. The chyme might stay there for as long as three days. After the excess water is absorbed, the remaining undigested materials become more solid. Muscles in the rectum, which is the last section of the large intestine, and the anus control the release of semisolid wastes from the body in the form of feces (FEE seez).

Bacteria Are Important

Many types of bacteria live in your body. Bacteria live in many of the organs of your digestive tract including your mouth and large intestine. Some of these bacteria live in a relationship that is beneficial to the bacteria and to your body. The bacteria in your large intestine feed on undigested material like cellulose. In turn, bacteria make vitamins you need—vitamin K and two B vitamins. Vitamin K is needed for blood clotting. The two B vitamins, niacin and thiamine, are important for your nervous system and for other body functions. Bacterial action also converts bile pigments into new compounds. The breakdown of intestinal materials by bacteria produces gas.

Bacteria The species of bacteria that live in your large intestine are adapted to their habitat. What do you think would happen to the bacteria if their environment were to change? How would this affect your large intestine? Discuss your ideas with a classmate and write your answers in your Science Journal.

Summary

Functions of the Digestive System

- To process food, your body must ingest, digest, absorb, and eliminate it.

Enzymes

- Enzymes aid the chemical reactions of digestion.

Organs of the Digestive System

- The mouth, esophagus, stomach, small intestine, large intestine, rectum, and anus are the major organs of this system.
- The digestive system also has accessory organs that are important to mechanical and chemical digestion.

Bacteria Are Important

- Bacteria help break down intestinal materials and make vitamins.

Self Check

1. **Compare and contrast** mechanical digestion and chemical digestion.
2. **Explain** how activities in the large intestine help maintain homeostasis.
3. **Describe** the function of each of the organs in the digestive tract.
4. **Explain** how the accessory organs aid digestion.
5. **Think Critically** A cracker contains starch. Explain why a cracker begins to taste sweet after it is in your mouth for five minutes without being chewed.

Applying Skills

6. **Recognize Cause and Effect** What would happen to some of the nutrients in chyme if the pancreas did not secrete its solution into the small intestine?

LAB

Particle Size and Absorption

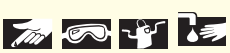
Goals

- **Compare** the dissolving rates of different sized particles.
- **Predict** the dissolving rate of sugar particles larger than sugar cubes.
- **Predict** the dissolving rate of sugar particles smaller than particles of ground sugar.
- Using the lab results, infer why the body must break down and dissolve food particles.

Materials

250-mL beakers or jars (3)
thermometers (3)
sugar granules
mortar and pestle
triple-beam balance
stirring rod
sugar cubes
weighing paper
warm water
stopwatch

Safety Precautions



WARNING: *Do not taste, eat, or drink any materials used in the lab.*

Real-World Question

Before food reaches the small intestine, it is digested mechanically in the mouth and the stomach. The food mass is reduced to small particles. You can chew an apple into small pieces, but you would feed applesauce to a small child who didn't have teeth. What is the advantage of reducing the size of the food material? How does reducing the size of food particles aid the process of digestion?

Procedure

1. Copy the data table below into your Science Journal.

Dissolving Time of Sugar Particles

Size of Sugar Particles	Mass	Time Until Dissolved
Sugar cube	Do not write in this book.	
Sugar granules		
Ground sugar particles		

2. Place a sugar cube into your mortar and grind up the cube with the pestle until the sugar becomes powder.
3. Using the triple-beam balance and weighing paper, measure the mass of the powdered sugar from your mortar. Using separate sheets of weighing paper, measure the mass of a sugar cube and the mass of a sample of the granular sugar. The masses of the powdered sugar, sugar cube, and granular sugar should be approximately equal to each other. Record the three masses in your data table.
4. Place warm water into the three beakers. Use the thermometers to be certain the water in each beaker is the same temperature.

Matt Meadows

5. Place the sugar cube in a beaker, the powdered sugar in a second beaker, and the granular sugar in the third beaker. Place all the sugar samples in the beakers at the same time and start the stopwatch when you put the sugar samples in the beaker.
6. Stir each sample equally.
7. **Measure** the time it takes each sugar sample to dissolve and record the times in your data table.

Analyze Your Data

1. **Identify** the experiment's constants and variables.
2. **Compare** the rate at which the sugar samples dissolved. What type of sugar dissolved most rapidly? Which was the slowest to dissolve?

Conclude and Apply

1. **Predict** how long it would take sugar particles larger than the sugar cubes to dissolve. Predict how long it would take sugar particles smaller than the powdered sugar to dissolve.
2. **Infer and explain** the reason why small particles dissolve more rapidly than large particles.
3. **Infer** why you should thoroughly chew your food.
4. **Explain** how reducing the size of food particles aids the process of digestion.

Communicating Your Data

Write a news column for a health magazine explaining to health-conscious people what they can do to digest their food better.

Eating Well

Does the same diet work for everyone?

Growing up in India in the first half of the twentieth century, R. Rajalakshmi (RAH jah lok shmee) saw many people around her who did not get enough food. Breakfast for a poor child might have been a cup of tea. Lunch might have consisted of a slice of bread. For dinner, a child might have eaten a serving of rice with a small piece of fish. This type of diet, low in calories and nutrients, produced children who were often sick and died young.

Good Diet, Wrong Place

R. Rajalakshmi studied biochemistry and nutrition at universities in India and in Canada. In the 1960s, she was asked to help manage a program to improve nutrition in her country. At that time, North American and European nutritionists suggested foods that were common and worked well for people who lived in these nations.

Thanks to R. Rajalakshmi and other nutritionists, many children in India are eating well and staying healthy.

Goldwater/Network/Saba Press Photos

For example, they told poor Indian women to eat more meat and eggs and drink more orange juice. But Rajalakshmi knew this advice was useless in a country such as India. People there didn't eat such foods. They weren't easy to find. And for the poor, such foods were too expensive.

The Proper Diet for India

Rajalakshmi knew that for the program to work, it had to fit Indian culture. So she decided to restructure the nutrition program. She first found out what healthy middle class people in India ate. She took note of the nutrients available in those foods. Then she looked for cheap, easy-to-find foods that would provide the same nutrients.

Rajalakshmi created a balanced diet of cheap, locally grown fruits, vegetables, and grains. Legumes (plants related to peas and peanuts), vegetables, and an Indian food called dhokla (DOH kluh) were basics. Dhokla is made of grains, legumes, and leafy vegetables. The grains and legumes provided protein, and the vegetables added vitamins and minerals.

Rajalakshmi's ideas were thought unusual in the 1960s. For example, she insisted that a diet without meat could provide all major nutrients. Now we know she was right. But it took persistence to get others to accept her diet about 40 years ago. Because of Rajalakshmi's program, Indian children almost doubled their food intake. And many children who would have been hungry and ill grew healthy and strong.

Report **Choose a continent and research what foods are native to that area. Share your findings with your classmates and compile a list of the foods and where they originated. Using the class list, mark the origins of the different foods on a world map.**

Reviewing Main Ideas

Section 1 Nutrition

1. Proteins, carbohydrates, fats, vitamins, minerals, and water are the six nutrients found in foods.
2. Carbohydrates provide energy, proteins are needed for growth and repair, and fats store energy and cushion organs. Vitamins and minerals regulate functions. Water makes up about 60 percent of your body's mass and is used for a variety of homeostatic functions.
3. Health is affected by the combination of foods that make up a diet.

Section 2 The Digestive System

1. Mechanical digestion breaks down food through chewing and churning.
2. Enzymes and other chemicals aid chemical digestion.
3. Digestion breaks down food into substances that cells can absorb and use. Carbohydrates break down into simple sugars; proteins into amino acids; and fats into fatty acids and glycerol.
4. Food is ingested in the mouth. Digestion occurs in the mouth, stomach, and small intestine, with absorption occurring in the small and large intestines. Wastes are excreted through the anus.
5. The accessory digestive organs move and cut up food and supply digestive enzymes and other chemicals, such as bile, needed for digestion.
6. The large intestine absorbs water, which helps the body maintain homeostasis.

Visualizing Main Ideas

Copy and complete the following table indicating good sources of vitamins and minerals.

Vitamin and Mineral Sources

Food Type	Source of Vitamin	Source of Mineral
Milk	D	
Spinach		iron
Meat		calcium, potassium
Eggs	E	
Carrots		sodium

chapter 2 Review

Using Vocabulary

amino acid p. 37
carbohydrate p. 38
chemical digestion p. 47
chyme p. 51
digestion p. 47
enzyme p. 48
fat p. 39
food group p. 44
mechanical digestion p. 47
mineral p. 42
nutrient p. 36
peristalsis p. 50
protein p. 37
villi p. 52
vitamin p. 40

Fill in the blanks with the correct vocabulary word or words.

1. _____ is the muscular contractions of the esophagus.
2. The _____ increase the surface area of the small intestine.
3. The building blocks of proteins are _____.
4. The liquid product of digestion is called _____.
5. _____ is the breakdown of food.
6. Your body's main source of energy is _____.
7. _____ are inorganic nutrients.
8. Pears and apples belong to the same _____.
9. _____ is when food is chewed and mixed.
10. A(n) _____ is a nutrient needed in small quantities for growth and for regulating body functions.

Checking Concepts

Choose the word or phrase that best answers the question.

11. In which organ is water absorbed?
A) liver **C)** small intestine
B) esophagus **D)** large intestine

12. What beneficial substances are produced by bacteria in the large intestine?
A) fats **C)** vitamins
B) minerals **D)** proteins

13. Which organ makes bile?
A) gallbladder **C)** stomach
B) liver **D)** small intestine

14. Where in humans does most chemical digestion occur?
A) duodenum **C)** liver
B) stomach **D)** large intestine

15. Which of these organs is an accessory organ?
A) mouth **C)** small intestine
B) stomach **D)** liver

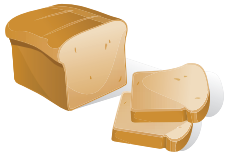
16. Which vitamin is found most abundantly in citrus fruits?
A) A **C)** C
B) B **D)** K

17. Where is hydrochloric acid solution added to the food mass?
A) mouth **C)** small intestine
B) stomach **D)** large intestine

18. Which of the following is in the same food group as yogurt and cheese?

A) 

C) 

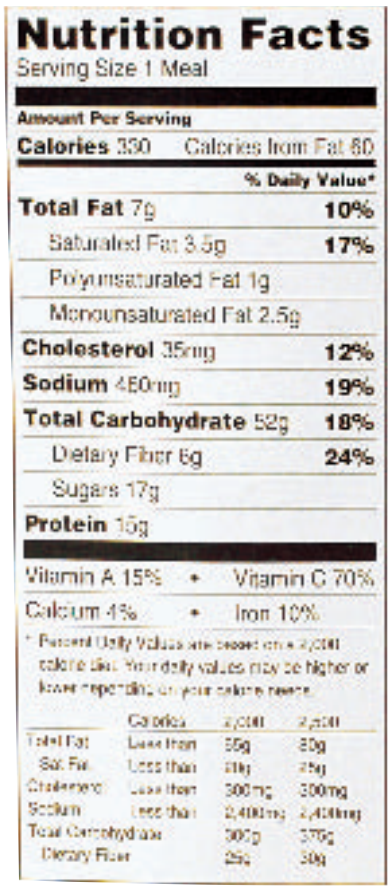
B) 

D) 

19. Which organ produces enzymes that help in digestion of proteins, fats, and carbohydrates?
A) mouth **C)** large intestine
B) pancreas **D)** gallbladder

Thinking Critically

Use the figure below to answer question 20.



Nutrition Facts
Serving Size 1 Meal

Amount Per Serving

Calories 330 Calories from Fat 80

% Daily Value*

Total Fat 7g **10%**
Saturated Fat 3.5g **17%**
Polyunsaturated Fat 1g
Monounsaturated Fat 2.5g
Cholesterol 35mg **12%**
Sodium 480mg **19%**
Total Carbohydrate 52g **18%**
Dietary Fiber 6g **24%**
Sugars 17g
Protein 15g

Vitamin A 15% • Vitamin C 70%
Calcium 4% • Iron 10%

* Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs.

	Calories	2,000	2,500
Total Fat	Less than	65g	80g
Sat Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g

20. Explain how the information on the food label above can help you make healthful food choices.

21. Infer Food does not enter your body until it is absorbed into the blood. Explain why.

22. Discuss the meaning of the familiar statement "You are what you eat." Base your answer on your knowledge of food groups and nutrients.

23. Explain Bile's action is similar to that of soap. Use this information to explain how bile works on fats.

24. Compare and contrast the three types of carbohydrates—sugar, starch, and fiber.

Performance Activities

25. Project Research the ingredients used in antacid medications. Identify the compounds used to neutralize the excess stomach acid. Note the time, and then place an antacid tablet in a glass of vinegar—an acid. Using pH paper, check when the acid is neutralized. Record the time it took for the antacid to neutralize the vinegar. Repeat this procedure with different antacids. Compare your results.

Applying Math

26. Villi Surface Area The surface area of the villi in your small intestine is comparable to the area of a tennis court. A tennis court measures 11.0 m by 23.8 m. What is the area of a tennis court—and the surface area of the small intestine's villi—in square meters?

Use the table below to answer question 27.

Recommended Dietary Allowances

Nutrient	Percent U.S. RDA
Protein	2
Vitamin A	20
Vitamin C	25
Vitamin D	15
Calcium (Ca)	less than 2
Iron (Fe)	25
Zinc (Zn)	15
Total fat	5
Saturated fat	3
Cholesterol	0
Sodium	3

27. Nutrients A product nutrient label is shown above. Make a bar graph of this information.

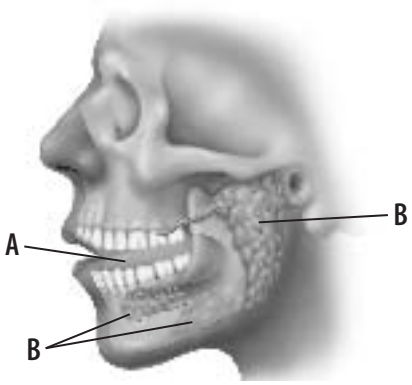
Part 1 Multiple Choice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

1. How many amino acids are required by your body?

A. 5 **C.** 20
B. 12 **D.** 50

Use the illustration below to answer questions 2 and 3.



2. How does the organ labeled "A" help break down food?

A. produces enzymes
B. produces saliva
C. moves food around
D. produces mucus

3. Which of the following is produced by the organs labeled "B"?

A. saliva **C.** hydrochloric acid
B. bile **D.** chyme

Test-Taking Tip

Using Tables Concentrate on what the question is asking from a table, not all the information in the table.

Question 4 Look in the column titled *DV (Daily Values)* to find what the question asks, then follow the row to the *Item* column to find the answer.

Use the table below to answer questions 4 and 5.

Nutrition Facts of Vanilla Ice Cream		
Item	**Amount**	**DV (Daily Values)**
Serving Size	112 g	0
Calories	208	0
Total Fat	19 g	29%
Saturated Fat	11 g	55%
Cholesterol	0.125 g	42%
Sodium	0.90 g	4%
Total Carbohydrates	22 g	7%
Fiber	0 g	0%
Sugars	22 g	n/a
Protein	5 g	n/a
Calcium	0.117 g	15%
Iron	n/a	0%

4. According to the table above, which mineral has the greatest DV?

A. sodium **C.** iron
B. cholesterol **D.** calcium

5. If you had two servings of this vanilla ice cream, how many grams of saturated fat and Daily Value (DV) percentage would you eat?

A. 11 g, 110% **C.** 21 g, 55%
B. 22 g, 110% **D.** 5.5 g, 110%

6. Which of the following is the correct sequence of the organs of the digestive tract?

A. mouth, stomach, esophagus, small intestine, large intestine
B. esophagus, mouth, stomach, small intestine, large intestine
C. mouth, esophagus, small intestine, stomach, large intestine
D. mouth, esophagus, stomach, small intestine, large intestine

CONTENTS

Part 2 Short Response/Grid In

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

7. Explain the difference between organic and inorganic nutrients. Name a class of nutrients for each.

Use the photos below to answer questions 8 and 9.

8. During the activity shown above, which of the two teens is losing more body water? Why?

9. Based on the activity shown above, which teen may need more food energy (Calories)? Why?

10. Name three food sources that contain complete proteins.

11. How does bile help in digestion?

12. What is meant by an "essential amino acid"?

13. How do bacteria that live in the large intestine help your body?

14. Explain the importance of fats in the body.

15. Enzymes play an important role in the digestive process. But enzyme-aided reactions are also involved in other body systems. Give an example of how enzymes are used by the body in a way that does not involve the digestive system.

16. A taco has 180 Calories (Cal) and an ice cream sundae has 540 Cal. How many tacos could you eat to equal the number of Calories in the ice cream sundae?

Part 3 Open Ended

Record your answers on a sheet of paper.

17. Explain what might happen to a child who is deficient in vitamin D. What foods should be eaten to prevent a deficiency in vitamin D?

18. Certain bacteria that do not normally live in the body can make toxins that affect intestinal absorption. Explain what might happen if these bacteria were present in the small and large intestines.

Use the illustration below to answer questions 19 and 20.

19. Identify the food group shown at the base of the food pyramid. Explain why the greatest number of servings should come from this group.

20. Identify the food group at the top of the pyramid. Explain why the least number of servings should come from this group.

21. Antibiotics may be given to help a person fight off a bacterial infection. If a person is taking antibiotics, what might happen to the normal bacteria living in the large intestine? How would this affect the body?

22. Sometimes the esophagus can be affected by a disease in which peristalsis is not normal and the band of muscle at the entrance to the stomach does not work properly. What do you think would happen to food that the person swallowed?