15

The Digestive System and Nutrition
The Digestive System and Nutrition

OUTLINE:

- The Gastrointestinal Tract
- Specialized Compartments for Food Processing
- Nerves and Hormones in Digestion
- Planning a Healthy Diet
- Nutrients
- Food Labels
- Energy Balance
- Obesity
- Weight-Loss Programs
- Eating Disorders
The Gastrointestinal Tract

- Function
  - Breaks complex organic molecules in food into smaller subunits that can be absorbed into the bloodstream for delivery to cells
The Gastrointestinal Tract

- Structure
  - Gastrointestinal (GI) tract into which several accessory glands release their secretions
  - Long, hollow tube
    - Lumen—the inner area through which food travels
  - Begins at the mouth and includes the pharynx, esophagus, stomach, small intestine, and large intestine
Figure 15.1 The digestive system.

**ORGANS**

- **Mouth**
  - Entrance to digestive system
  - Teeth chew food
  - Tongue positions and tastes food

- **Pharynx**
  - Passageway for food (and air)
  - Plays a role in swallowing

- **Esophagus**
  - Muscular tube
  - Moves food from pharynx to stomach

- **Stomach**
  - J-shaped muscular sac
  - Stores food
  - Secretes gastric juice (pepsin and HCl)
  - Mixes food with gastric juice
  - Protein digestion begins

- **Small intestine**
  - Long, muscular tube
  - Mixes food with bile and with intestinal and pancreatic enzymes
  - Digests most nutrients
  - Absorbs most nutrients and water

- **Colon**
  - Muscular tube
  - Absorbs water and some nutrients
  - Stores waste materials (feces)

- **Cecum**
  - Blind pouch at junction of small and large intestines

- **Rectum**
  - Region of large intestine
  - Passageway for feces
  - Stretching of wall stimulates the defecation reflex

- **Anal canal**
  - Regulates defecation

- **Anus**
  - Opening at end of system
  - Expels feces

**ACCESSORY STRUCTURES**

- **Salivary glands**
  - Three pairs of glands that secrete saliva
  - Saliva moistens food
  - Enzyme (amylase) in saliva begins starch digestion

- **Liver**
  - Large organ in abdominal cavity
  - Secretes bile, which emulsifies fats
  - Plays role in processing and storing certain nutrients

- **Gallbladder**
  - Small sac
  - Stores bile
  - Releases bile into small intestine

- **Pancreas**
  - Gland located behind stomach
  - Secretes enzymes that digest all major nutrients
  - Secretes buffers that neutralize HCl from stomach
  - Releases secretions into small intestine
The Gastrointestinal Tract

- Along most of its length, the walls of the GI tract have four layers:

  1. Mucosa—innermost, moist, mucus-secreting
  2. Submucosa—connective tissue with nerves and blood and lymph vessels
  3. Muscularis—double layer of smooth muscle, except in the stomach, where there are three layers
  4. Serosa—outermost, epithelial tissue supported by connective tissue
Figure 15.2 Along most of its length, the wall of the GI tract has four basic layers.

- **Lumen**: The central passage through which food and other substances travel.
- **Blood vessels**:供给营养和氧气的血管。
- **Lymphatic vessel**: 被淋巴液填充的血管。
- **Nerve**: 神经。

The **mucosa** is a mucous membrane that lines the GI tract and secretes mucus that lubricates and protects the GI tract.

The **submucosa** is a layer of connective tissue that contains blood vessels, lymph vessels, and nerves.

The **muscularis** is made up of two layers of smooth muscle—one circular and one longitudinal.

The **serosa** is a connective tissue covering that secretes a fluid to lubricate the outside of the GI tract.
The Gastrointestinal Tract

- Regions of the GI tract are specialized to process food
  - Mechanical digestion
    - Physical breaking of food into smaller pieces
  - Chemical digestion
    - Breaking of chemical bonds so that complex molecules are broken into smaller subunits
### Table 15.1 Review of Structures of the Digestive System

<table>
<thead>
<tr>
<th>Structure</th>
<th>Description/Functions</th>
<th>Mechanical Digestion</th>
<th>Chemical Digestion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mouth</td>
<td>Receives food; contains teeth and tongue; tongue manipulates food and monitors quality</td>
<td>Teeth tear and crush food into smaller pieces</td>
<td>Digestion of carbohydrates begins</td>
</tr>
<tr>
<td>Pharynx</td>
<td>Passageway for both food and air</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Esophagus</td>
<td>Tube that transports food from mouth to stomach</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Stomach</td>
<td>J-shaped muscular sac for food storage</td>
<td>Churning of stomach mixes food with gastric juice, creating liquid chyme</td>
<td>Protein digestion begins</td>
</tr>
<tr>
<td>Small intestine</td>
<td>Long tube where digestion is completed and nutrients are absorbed</td>
<td>Segmental contractions mix food with intestinal enzymes, pancreatic enzymes, and bile</td>
<td>Carbohydrate, protein, and fat digestion are completed</td>
</tr>
<tr>
<td>Large intestine</td>
<td>Final tubular region of GI tract; absorbs water and ions; houses bacteria; forms and expels feces</td>
<td>None</td>
<td>Some digestion is carried out by bacteria</td>
</tr>
<tr>
<td>Anus</td>
<td>Terminal outlet of digestive tract</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>
Specialized Compartments for Food Processing

- The digestive organs
  - Mouth
  - Pharynx
  - Esophagus
  - Stomach
  - Small intestine
  - Large intestine
Specialized Compartments for Food Processing

- Aided by several accessory glands and organs
  - Salivary glands
  - Pancreas
  - Liver
  - Gallbladder
Mouth (Oral Cavity)

- Palate
  - Roof of the mouth
  - Hard palate
    - Toward the front
    - Reinforced with bone
  - Soft palate
    - Toward the back
    - Muscle only
    - Prevents food from entering nasal cavities during swallowing
Mouth (Oral Cavity)

- Functions of the mouth
  - Begins mechanical digestion
  - Begins chemical digestion
  - Monitors food quality
  - Prepares (moistens and manipulates) food for swallowing

- Teeth, salivary glands, and tongue contribute to mouth’s functions
Teeth and Mechanical Digestion

- **Function**
  - Mechanical digestion breaks food into smaller pieces
    - Incisors clip and slice
    - Canines puncture and tear
    - Molars and premolars crush
Teeth and Mechanical Digestion

- **Structure**
  - Crown—above the gum
  - Root—below the gum

- **Layers**
  - Pulp—innermost, with blood vessels and nerves (teeth are alive!)
  - Dentin—hard, bonelike
  - Enamel—nonliving, covers crown
Figure 15.3 Adult human teeth.

(a) The teeth slice, tear, and grind food until it can be swallowed.

(b) The structure of the human tooth is suited for its function of breaking food into smaller pieces.
Teeth and Mechanical Digestion

- **Tooth decay**
  - Bacteria digest trapped food and produce acid
  - Acid erodes enamel, causing a cavity
  - Plaque (invisible layer of bacteria, mucus, and food) promotes tooth decay

- **Gingivitis**
  - Inflammation of the gums
  - Can develop into periodontitis
    - Inflammation of the soft tissues around the tooth
    - Tooth may become loose
Salivary Glands and Chemical Digestion

- Three pairs
  - Sublingual (below tongue)
  - Submandibular (below jaw)
  - Parotid (in front of ears)
- Release saliva into mouth
  - Water moistens food
  - Mucus binds food
  - Salivary amylase (enzyme) begins chemical digestion of starch
Figure 15.4 Three pairs of salivary glands.
Tongue: Taste and Food Manipulation

- Large skeletal muscle
  - Movement important in speech
  - Movement important in food manipulation
    - Helps form food into a bolus (soft mass of food suitable for swallowing)
- Studded with taste buds
  - Helps monitor food quality
Pharynx

- Passageway shared by respiratory and digestive systems

Swallowing

- Voluntary component
  - Tongue pushes bolus into pharynx

- Involuntary (reflex) component
  - Soft palate prevents food from entering nasal cavities
  - Larynx moves up, causing epiglottis to cover glottis
    - Prevents food from entering airways
Figure 15.5 Swallowing: (a) voluntary and (b) involuntary phases.

(a) Voluntary phase
- Soft palate
- Bolus
- Hard palate
- The tongue pushes food bolus toward the pharynx.
- Tongue
- Pharynx
- Epiglottis
- Trachea
- The esophagus is closed.

(b) Involuntary phase
- Reflex movement of the soft palate prevents food from entering the nasal cavity.
- Muscles contract, forcing the bolus toward the esophagus.
- The epiglottis closes the opening to the respiratory system, preventing food from entering.
- A muscle ring at the top of the esophagus relaxes, opening the esophagus. Food is pushed into the esophagus.
Esophagus

- Muscular tube that transports food from pharynx to stomach
  - Food moved along esophagus and other regions of the GI tract by peristalsis
    - Rhythmic waves of smooth muscle contraction (muscularis layer)
  - No role in mechanical or chemical digestion
Figure 15.6 *Peristalsis.*

- **Esophagus**
- **Waves of contraction**
- **Bolus**
- **Stomach**
Stomach

- Structure
  - J-shaped expandable sac
  - Band of circular muscle (sphincter) guards opening at each end
    - If sphincter leading from esophagus into stomach is weak, then heartburn can result
  - Wall has three layers of smooth muscle
    - Longitudinal
    - Circular
    - Oblique
Stomach

- Functions
  - Stores food and regulates its release to the small intestine
  - Liquefies food (forms chyme)
  - Begins chemical digestion of proteins
Stomach

- Gastric glands
  - Some secrete hydrochloric acid (HCl)
    - Kills bacteria
    - Breaks down connective tissue of meat
    - Activates pepsinogen, which becomes pepsin
      - Enzyme that digests protein
  - Some secrete intrinsic factor
    - Protein necessary for the absorption of vitamin B\textsubscript{12} from small intestine
### Table 15.2 Major Digestive Enzymes

<table>
<thead>
<tr>
<th>Enzyme</th>
<th>Site of Production</th>
<th>Site of Action</th>
<th>Substrate and Products</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Carbohydrate digestion</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salivary amylase</td>
<td>Salivary glands</td>
<td>Mouth</td>
<td>Polysaccharides into shorter molecules</td>
</tr>
<tr>
<td>Amylase</td>
<td>Pancreas</td>
<td>Small intestine</td>
<td>Polysaccharides into disaccharides</td>
</tr>
<tr>
<td>Maltase</td>
<td>Small intestine</td>
<td>Small intestine</td>
<td>Maltose into glucose units</td>
</tr>
<tr>
<td>Sucrase</td>
<td>Small intestine</td>
<td>Small intestine</td>
<td>Sucrose into glucose and fructose</td>
</tr>
<tr>
<td>Lactase</td>
<td>Small intestine</td>
<td>Small intestine</td>
<td>Lactose into glucose and galactose</td>
</tr>
<tr>
<td><strong>Protein digestion</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pepsin</td>
<td>Stomach</td>
<td>Stomach</td>
<td>Proteins into protein fragments (polypeptides)</td>
</tr>
<tr>
<td>Trypsin</td>
<td>Pancreas</td>
<td>Small intestine</td>
<td>Proteins and polypeptides into smaller fragments</td>
</tr>
<tr>
<td>Chymotrypsin</td>
<td>Pancreas</td>
<td>Small intestine</td>
<td>Proteins and polypeptides into smaller fragments</td>
</tr>
<tr>
<td>Carboxypeptidase</td>
<td>Pancreas</td>
<td>Small intestine</td>
<td>Polypeptides into amino acids</td>
</tr>
<tr>
<td><strong>Lipid digestion</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lipase</td>
<td>Pancreas</td>
<td>Small intestine</td>
<td>Triglycerides (fats) into fatty acids and glycerol</td>
</tr>
</tbody>
</table>
Figure 15.7 *The structure of the stomach.*

(a) The stomach wall has three layers of smooth muscle, each oriented in a different direction, that allow the stomach to churn and mix food with digestive secretions.

(b) Gastric glands in the wall of the stomach produce gastric juice, a mixture of hydrochloric acid and pepsin.

(c) The holes seen in this electron micrograph are the gastric pits, openings in the stomach wall through which gastric glands release their secretions.
The stomach itself is protected from gastric juice by several factors:

- Mucus
- Pepsin produced in an inactive form (pepsinogen)
- Neural and hormonal mechanisms that time release of gastric juice to coincide with food entering stomach: food absorbs and dilutes gastric juice
- Stomach lining replaced rapidly
Small Intestine

- **Structure**
  - Three regions
    - Duodenum
    - Jejunum
    - Ileum

- **Functions**
  - Chemical digestion
  - Absorption
Figure 15.8 The small intestine.
Small Intestine

- Chemical digestion
  - Carbohydrates, proteins, fats, and nucleic acids are broken down into their simplest forms
  - Performed by enzymes of the pancreas and small intestine, aided by bile produced in the liver, stored in the gallbladder, and released into the small intestine
  - Aids in digestion and absorption of fats
Small Intestine

- Absorption: small intestine is the primary site
  - Surface area of small intestine is increased by
    - Pleated lining
    - Villi
    - Microvilli
Small Intestine

- Each villus has a network of capillaries and a lacteal (lymphatic vessel)
  - Capillaries carry away absorbed products of protein and carbohydrate digestion, as well as ions and water
  - Lacteal carries away absorbed products of fat digestion in the form of chylomicrons
    - Chylomicrons: protein-coated products of fat digestion that are soluble in water
Figure 15.9 The small intestine is the primary site for chemical digestion and absorption.
Pancreas (Accessory Organ)

- Pancreatic juice
  - Contains many digestive enzymes, including:
    - Amylase
    - Trypsin
    - Lipase
  - Contains bicarbonate ions important in neutralizing the acid in chyme
  - Drains from pancreas into pancreatic duct, which fuses with the common bile duct before entering small intestine
Figure 15.10 *The pancreas, liver, and gallbladder.*

The liver produces bile, which is stored in the gallbladder before being released into the small intestine.

The pancreas produces several digestive enzymes that act in the small intestine.
Liver (Accessory Organ)

- Largest internal organ
- Nutrient-laden blood from capillaries in villi of the small intestine travels through the hepatic portal vein to the liver
- Portal system: vein linking two capillary beds
  - Hepatic portal system
    - Hepatic portal vein links capillary beds of the villi in the small intestine with capillary beds in the liver
Liver (Accessory Organ)

- Digestive activities of the liver
  - Produces bile
  - Regulates blood glucose levels
  - Packages lipids with proteins to form lipoproteins, which aid transport in the blood
  - Removes poisonous substances
- Once liver adjusts composition of blood, the blood is returned to the general circulation
Figure 15.11 A portal system transports blood from one capillary bed to another.

Step 1: Products of digestion are absorbed into the capillaries within the villi of the small intestine.

Step 2: Digested food molecules then travel through hepatic portal veins to the liver.

Step 3: The liver monitors blood contents.

Step 4: Hepatic veins deliver blood to the circulatory system.
<table>
<thead>
<tr>
<th>Structure</th>
<th>Secretions/Functions</th>
<th>Site of Action of Chemical Secretions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salivary glands (sublingual, submandibular, parotid)</td>
<td>Secrete saliva, a liquid that moistens food and contains an enzyme (amylase) for digesting carbohydrates</td>
<td>Mouth</td>
</tr>
<tr>
<td>Pancreas</td>
<td>Digestive secretions include bicarbonate ions that neutralize acidic chyme and enzymes that digest carbohydrates, proteins, fats, and nucleic acids</td>
<td>Small intestine</td>
</tr>
<tr>
<td>Liver</td>
<td>Digestive function is to produce bile, a liquid that emulsifies fats, making chemical digestion easier and facilitating absorption</td>
<td>Small intestine</td>
</tr>
<tr>
<td>Gallbladder</td>
<td>Stores bile and releases it into small intestine</td>
<td>Small intestine</td>
</tr>
</tbody>
</table>
Liver (Accessory Organ)

- Disorders of the liver
  - Cirrhosis
    - Fat and then scar tissue accumulate in the liver
    - Can be caused by excessive use of alcohol
  - Hepatitis
    - Inflammation of the liver
    - Commonly caused by one of six viruses (A, B, C, D, E, and G)
    - Liver stops filtering bilirubin from the blood, resulting in jaundice (yellowish tint to skin and whites of eyes)
Gallbladder (Accessory Organ)

- **Structure**
  - Muscular, pear-shaped sac

- **Function**
  - Stores, modifies, and concentrates bile produced by the liver

- **Disorder: gallstones**
  - Cholesterol and other substances build up around a particle
  - Can be surgically removed
Figure 15.12 Gallstones.
Large Intestine

- Materials that have not been absorbed by the small intestine move to the large intestine

- Functions
  - Absorbs most of the water remaining in the indigestible food residue
  - Stores and eliminates feces
Large Intestine

- Structure: four regions
  - Cecum
  - Colon
  - Rectum
  - Anal canal
Figure 15.13 *The large intestine.*
Regions of the Large Intestine

- Cecum—pouch at junction of small and large intestines
- Appendix extends from cecum
  - No digestive function
  - May have immune function
- Disorder: appendicitis
  - Inflammation of the appendix
  - Blockage of appendix by stool, food, or tumor allows bacteria to multiply
  - Treatment typically includes antibiotics and surgical removal of the appendix
Regions of the Large Intestine

- Colon
  - Structure
    - Ascending (right)
    - Transverse (top)
    - Descending (left)
  - Functions
    - Absorbs water and ions
    - Contains beneficial bacteria that produce vitamins
    - Material left in the large intestine after passing through the colon is called feces
Large Intestine

- Peristaltic contractions move material through the large intestine
- Feces pushed into rectum, initiating the defecation reflex
  - Feces move into anal canal
  - Two sphincters must relax for defecation
    - Internal sphincter: relaxes automatically as part of the defecation reflex
    - External sphincter: under voluntary control
The Digestive System

Animals do not acquire nutrients as individual molecules but instead must digest their food internally. How and where does digestion occur? This tutorial shows how carbohydrates, proteins, and fats are digested; how nutrients are absorbed from food; and how wastes are formed and eliminated.

Press "PLAY" to begin Animation.
Disorders of the Colon

- Diarrhea: material passes through colon too rapidly and not enough water is absorbed
- Constipation: material passes through colon too slowly and too much water is absorbed
Disorders of the Colon

- Pouches (diverticula) in the intestinal wall
  - Diverticulosis—diverticula do not cause problems
  - Diverticulitis—diverticula become infected and inflamed

- Colorectal cancer
  - Begins with polyp, polyp turns cancerous
  - Detection: sigmoidoscopy (only first third of colon examined) or colonoscopy (entire colon examined)
Figure 15.14 A *diverticulum*.
### Example 15.4 Examples of Neural Controls on Digestive Activity

<table>
<thead>
<tr>
<th>Stimulus</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sight of food, thought of food, presence of</td>
<td>Release of saliva from salivary glands</td>
</tr>
<tr>
<td>food in mouth</td>
<td></td>
</tr>
<tr>
<td>Chewing food</td>
<td>Release of gastric juice (enzymes from stomach and HCl) and mucus from</td>
</tr>
<tr>
<td></td>
<td>cells of stomach lining</td>
</tr>
<tr>
<td>Presence of acidic chyme in small intestine</td>
<td>Release of enzymes from small intestine and pancreas into the small</td>
</tr>
<tr>
<td></td>
<td>intestine; release of bile from gallbladder into small intestine;</td>
</tr>
<tr>
<td></td>
<td>increased motility in small intestine</td>
</tr>
</tbody>
</table>
For digestion to occur, enzymes must be present in the right place at the right time

However, enzymes should not be released until food is present

Nerves and hormones orchestrate the release of digestive secretions

Processes that are quick or anticipatory are controlled by the nervous system

Processes that can take more time are controlled by hormones
Examples

- Salivation is controlled by the nervous system. Food spends little time in the mouth, so neural control, which is faster, works best.

- Release of gastric juice by the stomach is controlled by the nervous system (chewing food is the stimulus) and by the hormone gastrin (distention of the stomach is the stimulus).

- Release of enzymes from the small intestine and pancreas, as well as bile from the gallbladder:
  - Triggered largely by neural reflexes.
  - Hormones released by the small intestine also play a role: vasoactive intestinal peptide, cholecystokinin.
### Table 15.5 Examples of Hormonal Control on Digestive Activity

<table>
<thead>
<tr>
<th>Hormone</th>
<th>Stimulus</th>
<th>Origin</th>
<th>Target</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gastrin</td>
<td>Distention of stomach by food; presence of partially digested proteins in stomach</td>
<td>Stomach</td>
<td>Stomach</td>
<td>Release of gastric juice (enzymes from stomach and HCl)</td>
</tr>
<tr>
<td>Vasoactive intestinal peptide</td>
<td>Presence of acidic chyme in small intestine</td>
<td>Small intestine</td>
<td>Small intestine</td>
<td>Release of enzymes from small intestine</td>
</tr>
<tr>
<td>Secretin</td>
<td>Presence of acidic chyme in small intestine</td>
<td>Small intestine</td>
<td>Pancreas</td>
<td>Release of sodium bicarbonate from pancreas into small intestine to neutralize acidic chyme</td>
</tr>
<tr>
<td>Cholecystokinin</td>
<td>Arrival of chyme-containing lipids</td>
<td>Small intestine</td>
<td>Pancreas</td>
<td>Release of enzymes from pancreas</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gallbladder</td>
<td>Contraction of gallbladder and release of bile</td>
</tr>
</tbody>
</table>
Planning a Healthy Diet

- MyPlate is a useful tool for planning a healthy diet
- Make half your plate fruits and vegetables
- Make half of your grains whole grains
- Choose varied, lean sources of protein and fat-free or 1% fat sources of dairy foods
- Balance caloric intake with energy expenditure
Figure 15.15 MyPlate helps you plan a well-balanced diet.

Balance Calories to Manage Weight
- Prevent and/or reduce overweight and obesity through improved eating and physical activity behaviors.
- Control total calorie intake to maintain body weight. For people who are overweight or obese, this will mean consuming fewer calories from foods and beverages.
- Increase physical activity and reduce time spent in sedentary behaviors.
- Maintain appropriate calorie balance during each stage of life—childhood, adolescence, adulthood, pregnancy and breastfeeding, and older age.

Reduce These Foods
- Reduce daily sodium intake to less than 2,300 milligrams (mg).
- Consume less than 10% of calories from saturated fatty acids by replacing them with monounsaturated and polyunsaturated fatty acids.
- Consume less than 300 mg per day of dietary cholesterol.

Increase These Foods
- Increase vegetable and fruit intake.
- Eat a variety of vegetables, especially dark-green and red and orange vegetables and beans and peas.
- Consume at least half of all grains as whole grains.
- Increase intake of fat-free or low-fat milk and milk products, such as milk, yogurt, cheese, or fortified soy beverages.
- Choose a variety of protein foods, which include seafood, lean meat and poultry, eggs, beans and peas, soy products, and unsalted nuts and seeds.
- Replace protein foods that are higher in solid fats with choices that are lower in solid fats and calories and/or are sources of oils.
- Use oils to replace solid fats where possible.
Nutrients

- Substances in food that provides energy; becomes part of a structure; or performs a function in growth, maintenance, or repair

- Lipids
  - Provide nine calories per gram
  - Include fats, oils, and cholesterol
    - Saturated fat (fat that is solid at room temperature) and trans fats should be reduced in our diet in favor of unsaturated fats or oils (fats that are liquid at room temperature) and omega-3 and omega-6 fats
    - Elevated blood levels of cholesterol increase risk of heart disease
Figure 15.16 Types of dietary fats.

Saturated fats and trans fats raise the risk of atherosclerosis and heart disease.

Most of the fat in the diet should be monounsaturated, polyunsaturated, or omega-3.
Nutrients

- Carbohydrates
  - Provide four calories per gram
  - Complex carbohydrates are healthier than simple carbohydrates
Nutrients

- Proteins are chains of amino acids (aa)
  - Provide four calories per gram
  - Essential aa are the 9 aa out of 20 that the body cannot synthesize and must be obtained in the diet:
    - Complete protein (mostly animal sources), contains all the essential aa
    - Incomplete protein (plant sources) lack one or more of the essential aa
    - Complementary proteins are combinations of incomplete proteins that supply all of the essential aa
Figure 15.17 *Types of carbohydrates.*

Simple carbohydrates are empty calories, because they provide only energy.

Complex carbohydrates provide energy along with other nutrients.
Figure 15.18 Types of protein in the diet.

Complete proteins contain all the essential amino acids and usually come from animal sources.

Incomplete proteins lack one or more of the essential amino acids and usually come from plant sources.
Figure 15.19 Complementary proteins.

Nuts and seeds
- Hummus (chickpeas and sesame seeds)
- Tofu and cashew stir-fry
- Trail mix (roasted soybeans and nuts)
- Tahini (sesame seeds) and peanut sauce

Legumes
- Rice and beans
- Black-eyed peas and corn bread
- Bean burrito in corn tortilla
- Peanut butter on bread
- Rice and tofu
- Rice and lentils

Grains

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Nutrients

- Vitamins
  - Needed in very small amounts, serve as enzyme or coenzyme
  - Water soluble: vitamins C and B
  - Lipid soluble: vitamins A, D, E, and K
Nutrients

- Minerals
  - Inorganic substances needed for a variety of life processes

- Water
  - Transports materials, lubricates and cushions organs, helps in temperature regulation, and provides a medium for many vital chemical reactions
# Table 15.6 Vitamins

<table>
<thead>
<tr>
<th>Vitamin</th>
<th>Good Sources</th>
<th>Function</th>
<th>Effects of Deficiency</th>
<th>Effect of Excess</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fat-soluble vitamins</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>Liver, egg yolk, fat-containing and fortified dairy products; formed from beta-carotene (found in deep yellow and deep green leafy vegetables)</td>
<td>Components of molybdenum, the eye pigment responsible for black-and-white vision; maintains skin and mucous membranes; cell differentiation</td>
<td>Night blindness; dry, scaly skin; dry hair; skin sore; increased respiratory, urogenital, and digestive infections; corneal ulcers; photo-induced keratoconjunctivitis (one of the leading causes of preventable blindness worldwide); most common vitamin deficiency in world</td>
<td>Drowsiness; headache; dry, crusty, scaly skin; hair loss; itching; brittle nails; abdominal and bone pain</td>
</tr>
<tr>
<td>D</td>
<td>Fortified milk, fish liver oil, egg yolk; formed in skin when exposed to ultraviolet light</td>
<td>Increases absorption of calcium; enhances bone growth and calcification</td>
<td>Bone deformities in children; rickets; bone softening in adults</td>
<td>Calcium deposits in soft tissues, kidney damage, vomiting, diarrhea, weight loss</td>
</tr>
<tr>
<td>E</td>
<td>Whole grains, dark green vegetables, vegetable oils, nuts, seeds</td>
<td>May inhibit effects of free radicals; helps maintain cell membranes; prevents oxidation of vitamins A and C in gut</td>
<td>Rare; possible anemia and nerve damage</td>
<td>Muscle weakness, fatigue, nausea</td>
</tr>
<tr>
<td>K</td>
<td>Primary source from bacteria in large intestine; leafy green vegetables, cabbage, cauliflower</td>
<td>Important in forming proteins involved in blood clotting</td>
<td>Easy bruising, abnormal blood clotting; severe bleeding</td>
<td>Liver damage and anemia</td>
</tr>
<tr>
<td><strong>Water-soluble vitamins</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C (ascorbic acid)</td>
<td>Citrus fruits, cantaloupe, strawberries, tomatoes, broccoli, cabbage, green pepper</td>
<td>Collagen synthesis; may inhibit free radicals; improves iron absorption</td>
<td>Scurvy, poor wound healing, impaired immunity</td>
<td>Diarrhea, kidney stones; may alter results of certain diagnostic lab tests</td>
</tr>
<tr>
<td>Thiamin (B₁)</td>
<td>Pork, legumes, whole grains, leafy green vegetables</td>
<td>Coenzyme in energy metabolism; nerve function</td>
<td>Water retention in tissues; nerve changes leading to poor coordination, heart failure, beriberi</td>
<td>None known</td>
</tr>
<tr>
<td>Riboflavin (B₂)</td>
<td>Dairy products such as milk; whole grains, meat, liver, egg whites, leafy green vegetables</td>
<td>Coenzyme used in energy metabolism</td>
<td>Skin lesions</td>
<td>None known</td>
</tr>
<tr>
<td>Niacin (B₃)</td>
<td>Nuts, green leafy vegetables, potatoes; can be formed from tryptophan found in meats</td>
<td>Coenzyme used in energy metabolism</td>
<td>contributes to pellagra (damage to skin, gut, nervous system)</td>
<td>Rashes of skin on face, neck, and hands; possible liver damage</td>
</tr>
<tr>
<td>B₆</td>
<td>Meat, poultry, fish, spinach, potatoes, tomatoes</td>
<td>Coenzyme used in amino acid metabolism</td>
<td>Nervous, skin, and muscular disorders; anemia</td>
<td>Numbness in feet; poor coordination</td>
</tr>
<tr>
<td>Pantothetic acid</td>
<td>Widely distributed in foods, animal products, and whole grains</td>
<td>Coenzyme in energy metabolism</td>
<td>Fatigue, numbness and tingling of hands and feet, headaches, nausea</td>
<td>Diarrhea, water retention</td>
</tr>
<tr>
<td>Folic acid (folate)</td>
<td>Dark green vegetables, orange juice, nuts, legumes, grain products</td>
<td>Coenzyme in nucleic acid and amino acid metabolism</td>
<td>Anemia (megaloablastic and pernicious), gastrointestinal disturbances, nervous system damage, inflamed tongue, neural tube defects</td>
<td>High doses mask vitamin B₁₂ deficiency</td>
</tr>
<tr>
<td>B₁₂</td>
<td>Poultry, fish, red meat, dairy products except butter</td>
<td>Coenzyme in nucleic acid metabolism</td>
<td>Anemia (megaloablastic and pernicious), impaired nerve function</td>
<td>None known</td>
</tr>
<tr>
<td>Biotin</td>
<td>Legumes, egg yolk, widely distributed in foods, bacteria of large intestine</td>
<td>Coenzyme used in energy metabolism</td>
<td>Scaly skin (dermatitis), sore tongue, anemia</td>
<td>None known</td>
</tr>
</tbody>
</table>
## Table 15.7 Selected Minerals

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Good Sources</th>
<th>Function</th>
<th>Effects of Deficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>Milk, cheese, dark green vegetables, legumes</td>
<td>Hardness of bones, tooth formation, blood clotting, nerve and muscle action</td>
<td>Stunted growth, loss of bone mass, osteoporosis, convulsions</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>Milk, cheese, red meat, poultry, whole grains</td>
<td>Bone and tooth formation; components of nucleic acids, ATP and phospholipids; acid-base balance</td>
<td>Weakness, demineralized bone</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Whole grains, green leafy vegetables, milk, dairy products, nuts, legumes</td>
<td>Component of enzymes</td>
<td>Muscle cramps, neurological disturbances</td>
</tr>
<tr>
<td>Potassium</td>
<td>Available in many foods, including meats, fruits, vegetables, and whole grains</td>
<td>Body water balance, nerve function, muscle function, role in protein synthesis</td>
<td>Muscle weakness</td>
</tr>
<tr>
<td>Sulfur</td>
<td>Protein-containing foods, including meat, legumes, milk, and eggs</td>
<td>Component of body proteins</td>
<td>None known</td>
</tr>
<tr>
<td>Sodium</td>
<td>Table salt</td>
<td>Body water balance, nerve function</td>
<td>Muscle cramps, reduced appetite</td>
</tr>
<tr>
<td>Chloride</td>
<td>Table salt, processed foods</td>
<td>Formation of hydrochloric acid in stomach, role in acid-base balance</td>
<td>Muscle cramps, reduced appetite, poor growth</td>
</tr>
</tbody>
</table>

### Trace minerals

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Good Sources</th>
<th>Function</th>
<th>Effects of Deficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>Meat, liver, shellfish, egg yolk, whole grains, green leafy vegetables, nuts, dried fruit</td>
<td>Component of hemoglobin, myoglobin, and cytochrome (transport chain enzyme)</td>
<td>Iron-deficiency anemia, weakness, impaired immune function, liver damage, heart failure, shock</td>
</tr>
<tr>
<td>Iodine</td>
<td>Marine fish and shellfish, iodized salt, dairy products</td>
<td>Thyroid hormone function</td>
<td>Enlarged thyroid</td>
</tr>
<tr>
<td>Fluoride</td>
<td>Treated drinking water, tea, seafood</td>
<td>Bone and tooth maintenance</td>
<td>Tooth decay</td>
</tr>
<tr>
<td>Copper</td>
<td>Nuts, legumes, seafood, drinking water</td>
<td>Synthesis of melanin, hemoglobin, and transport chain components; collagen synthesis; immune function</td>
<td>Rare; anemia, changes in blood vessels, nausea, liver damage</td>
</tr>
<tr>
<td>Zinc</td>
<td>Seafood, whole grains, legumes, nuts, meats</td>
<td>Component of digestive enzymes; required for normal growth, wound healing, and sperm production</td>
<td>Difficulty in walking; slurred speech, scaly skin, impaired immune function</td>
</tr>
<tr>
<td>Manganese</td>
<td>Nuts, legumes, whole grains, leafy green vegetables</td>
<td>Role in synthesis of fatty acids, cholesterol, urea, and hemoglobin; normal neural function</td>
<td>None known, nerve damage</td>
</tr>
</tbody>
</table>
Food Labels

- Can help you choose foods that will help you increase nutrients that are important to consume and limit those that could be harmful

- Note the serving size described on the label

- Notice the number of calories reported per serving

- Note the amount of fat and keep in mind that you should increase unsaturated fat and minimize saturated and trans fat in your diet

- The Percent Daily Values are usually based on a 2000 calorie diet. Your own diet may require more or fewer calories
Figure 15.20 Tips for reading food labels.

<table>
<thead>
<tr>
<th>Nutrition Facts</th>
<th>Note the serving size, because the nutritional information provided is based on serving size.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serving Size</td>
<td>6 Crackers (28g)</td>
</tr>
<tr>
<td>Servings Per Container About 13</td>
<td></td>
</tr>
<tr>
<td>Amount Per Serving</td>
<td></td>
</tr>
<tr>
<td>Calories</td>
<td>120</td>
</tr>
<tr>
<td>Calories from Fat</td>
<td>40</td>
</tr>
<tr>
<td>% Daily Value*</td>
<td></td>
</tr>
<tr>
<td>Total Fat</td>
<td>4.5g 7%</td>
</tr>
<tr>
<td>Saturated Fat</td>
<td>0.5g 4%</td>
</tr>
<tr>
<td>Trans Fat</td>
<td>0g</td>
</tr>
<tr>
<td>Cholesterol</td>
<td>0mg 0%</td>
</tr>
<tr>
<td>Sodium</td>
<td>180mg 7%</td>
</tr>
<tr>
<td>Total Carbohydrate</td>
<td>19g 6%</td>
</tr>
<tr>
<td>Dietary Fiber</td>
<td>3g 13%</td>
</tr>
<tr>
<td>Sugars</td>
<td>0g</td>
</tr>
<tr>
<td>Protein</td>
<td>3g</td>
</tr>
<tr>
<td>Vitamin A</td>
<td>0%</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>0%</td>
</tr>
<tr>
<td>Calcium</td>
<td>0%</td>
</tr>
<tr>
<td>Iron</td>
<td>8%</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>10%</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Calories:</th>
<th>2,000</th>
<th>2,500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Fat</td>
<td>&lt;65g</td>
<td>&lt;80g</td>
</tr>
<tr>
<td>Sat. Fat</td>
<td>&lt;20g</td>
<td>&lt;25g</td>
</tr>
<tr>
<td>Cholesterol</td>
<td>&lt;300mg</td>
<td>&lt;300mg</td>
</tr>
<tr>
<td>Sodium</td>
<td>&lt;2,400mg</td>
<td>&lt;2,400mg</td>
</tr>
<tr>
<td>Total Carbohydrate</td>
<td>300g</td>
<td>375g</td>
</tr>
<tr>
<td>Dietary Fiber</td>
<td>25g</td>
<td>30g</td>
</tr>
</tbody>
</table>

As a general rule, 5% or less for % Daily Value is low, and 20% or more is high.

Limit these nutrients.

Be sure to eat enough of these nutrients.

Note that the daily values are based on a diet of 2000 or 2500 calories. Also note that the goal is to consume less than the daily value of certain nutrients.
Energy Balance

- Basal metabolic rate (BMR): the minimal energy needed to keep an awake, resting person alive
  - Represents 60% to 70% of the body’s energy needs
- Depends on:
  - Sex: male usually higher BMR than female
  - Muscles use more energy than fat does
  - Age: muscle mass and metabolic rate decline
- The sum of your BMR and the number of calories you use in physical activity is the number of calories you should consume to maintain a stable weight
Energy Balance

- Exercise helps keep the body in good working order.
- The Dietary Guide for Americans encourages adults (18 to 64 years) to do at least 2 1/2 hours of moderate-intensity physical activity a week.
- Aerobic exercise reduces the risk of diseases of the heart and blood vessels and lowers blood pressure.
- Weight-bearing exercise reduces the risk of osteoporosis, a loss of bone density.
- Regular physical exercise reduces stress and the risk of certain chronic diseases, including diabetes.
Figure 15.21 The body mass index (BMI).
Obesity

- Weighing more than height–weight charts recommend because of too much body fat; obesity is harmful to your health

- *Overweight and obese generally refer to ranges* of weight that are considered to be unhealthy

- 68% of Americans are overweight and almost 34% are obese

- Leads to disease of the heart and blood vessels
  - Even individuals who are just slightly overweight are at increased risk of having a heart attack

- Can induce diabetes, gallstones, and worsen degenerative joint diseases
Figure 15.22 Obesity trends among adults in the United States.

Obesity Trends* among U.S. Adults
BRFSS, 1990, 2000, 2010

1990

2000

2010

(*BMI ≥ 30, or about 30 lbs. overweight for a 5’4” person)
Weight-Loss Programs

- To maintain a stable weight, balance the number of calories consumed with those used
  - To lose weight, eat fewer calories than you use
- Physical activity is an important part of weight-loss programs
Weight-Loss Programs

- Three components:
  - Reduction in the number of calories consumed, without departing from the recommended nutritional guidelines
  - Increase in energy expenditure
  - Behavior modification
Weight-Loss Programs

- A pound of fat is about 3500 calories
- To lose one pound a week, reduce calorie consumption or increase calorie use by 500 calories a day
- The lowest daily caloric intake recommended is 1200/1500 calories for an adult female/male
- The easiest way is to cut back on fatty foods, especially saturated fat, avoid sugar, and increase the amount of fiber in the diet
- 60% to 90% of dieters who lose weight drastically will later regain all the weight they lost
Eating Disorders

- Obesity can be considered an eating disorder associated with overeating.

- Anorexia nervosa is an eating disorder that is a form of self-starvation with a body weight less than 85% of normal height–weight charts.

- Bulimia nervosa is marked by binge eating huge amount of food (up to 20,000 calories) and then purging it from the body by self-induced vomiting, enemas, laxatives, diuretics, or excessive exercise.

- Thought to be the result of psychological, social, and physiological factors.
  - Anxious depression also seems to play a role.
Eating Disorders

- Many negative effects on the body
  - **Bulimia**: esophageal injuries, tooth decay, and gum disease resulting from frequent vomiting; dehydration, constipation, electrolyte imbalance
  - **Anorexia nervosa**: severe decrease in bone health
    - For example, amenorrhea (cessation of menstruation), malnutrition, and low body weight, particularly low body fat can contribute to poor bone health
  - Without treatment, up to 20% of people with serious eating disorders die (2% to 3% die with treatment)
Figure 15.23 Anorexia.
You Should Now Be Able To:

- Describe the gastrointestinal tract and know all specialized compartments for food processing
- Understand nerves and hormones in digestion
- Know how to plan a healthy diet
  - Nutrients
  - Food labels
  - Energy balance
- Understand the risks associated with obesity
- Describe weight-loss programs
- Know the main eating disorders: anorexia and bulimia and their health effect