Chapter 6

Digestion

6.1 – The Molecules of Living Systems

- In this section we will:

1. Describe the nature of carbohydrates, lipids & proteins
2. Explain how carbohydrates, lipids & proteins are synthesized and broken down
3. Describe and perform tests to identify macromolecules

Macromolecules

- Macromolecules are large, complex organic molecules
- These include carbohydrates, lipids, proteins, and nucleic acids
- These macromolecules are all created from smaller subunits

Assembling & Disassembling Molecules

- Macromolecules are assembled through dehydration synthesis
- They are broken down through hydrolysis reactions

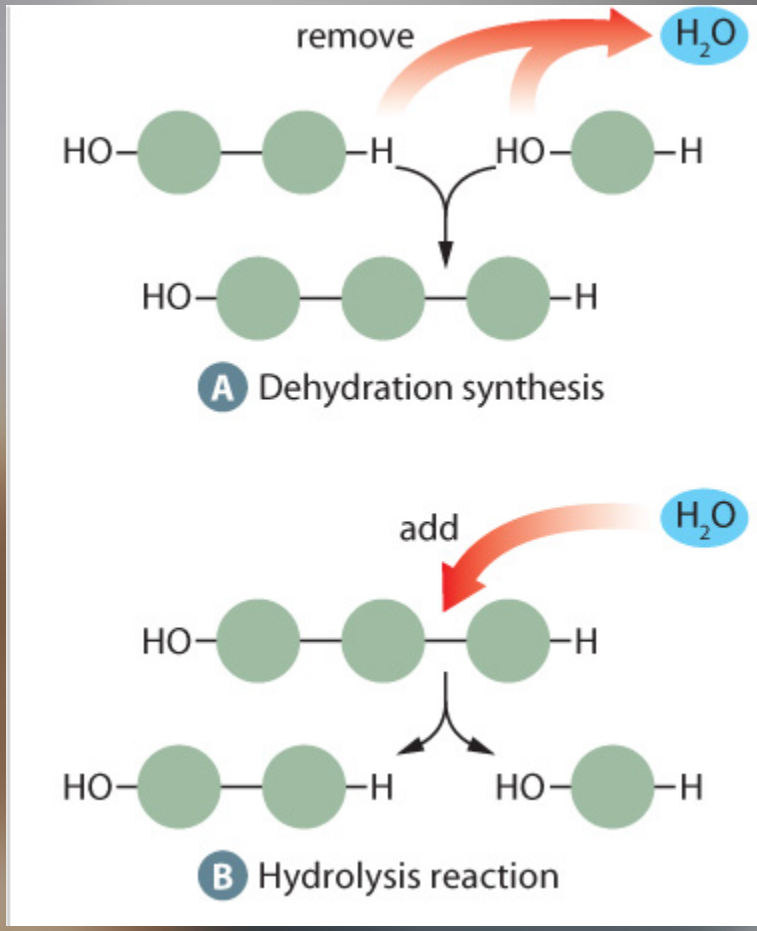


Figure 6.2 This simplified diagram shows how molecular subunits are put together (synthesized) to form macromolecules and broken apart through hydrolysis.

Carbohydrates

- Carbohydrates contain carbon, oxygen and hydrogen
- PRIMARY source of our body's energy
- They can be classified as simple sugars (made up of one or two individual sugar units), or polysaccharides (which are long chains of simple sugars)

mono and di - saccharides

- Monosaccharides are simple sugars such as glucose (blood sugar), fructose, and galactose (sweetest tasting)
- Disaccharides are 2 monosaccharides bonded together- examples are:
  - glucose+fructose - sucrose
  - glucose+galactose - lactose
  - glucose+glucose - maltose

Production of a Disaccharide

- Note that this is a form of dehydration synthesis

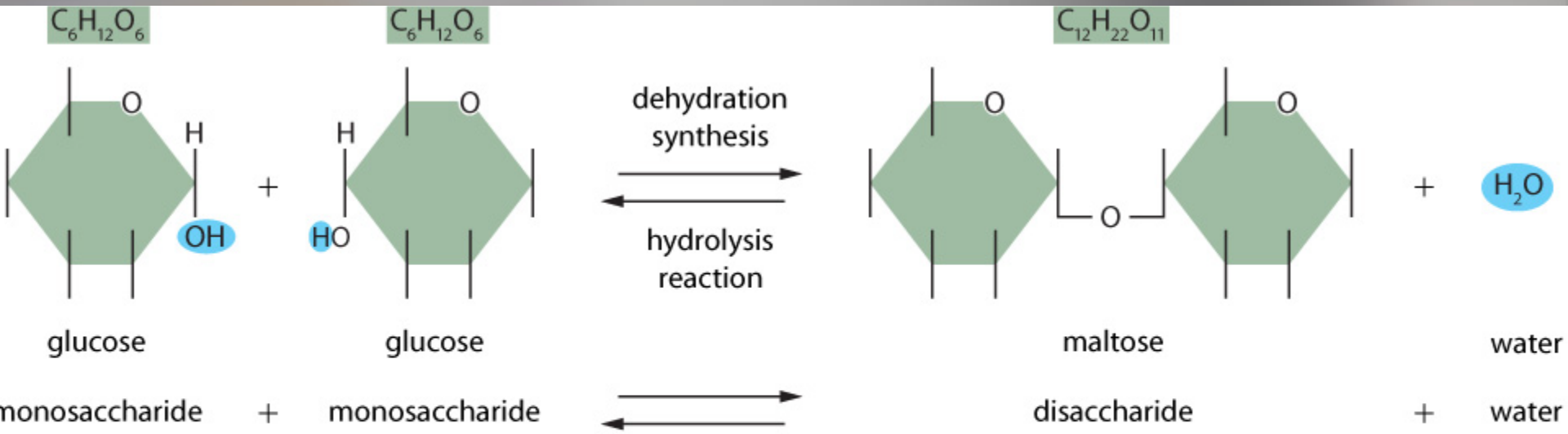


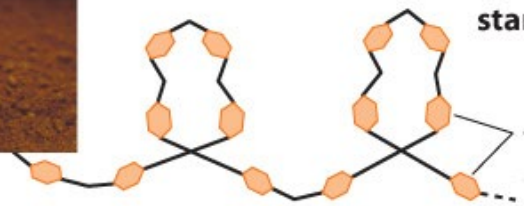
Figure 6.3 During the synthesis of maltose, a chemical bond forms between two glucose molecules, and the components of one water molecule are removed. During the hydrolysis of maltose, the components of one water molecule are added and the bond is broken, yielding two glucose molecules. (The double arrow indicates that the chemical reaction, represented by the chemical equation, can proceed in both directions—from left to right and from right to left.)

Examples of Polysaccharides

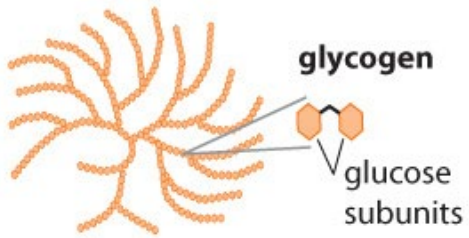
- All of these are examples of polysaccharides
- The way that the individual sugar units are arranged determines their shape and function

Figure 6.4 Compare the structural differences among starch, glycogen, and cellulose. Notice that all three polysaccharides consist of glucose subunits.

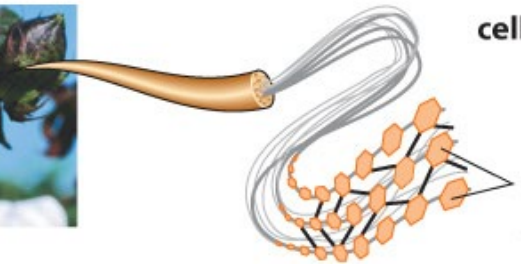
potato



liver



cotton



Carbohydrates

- Polysaccharides - large polymers of monosaccharaides (lots of monomers)
- Cellulose
  - Plant “fiber”
  - Indigestible by human enzymes
- Starches and glycogen
  - Quick energy storage
  - Starches are long chains of glucose in plant cells
  - glycogen is “animal starch”, composed of long chains of glucose stored in animal cells (muscle and liver)

Lipids

- General characteristics
  - Extremely diverse group including fats, oils, steroids, waxes, phospholipids
  - Common characteristic- nonpolar molecules which are insoluble in water (non-polar covalent bond of H and C)
  - Energy storage molecules
  - Also function as structural components (building membranes), insulation, cushioning of organs, and hormones

Lipids

- Lipids consist of glycerol (a 3-carbon chain) and fatty acids (whose composition may vary)

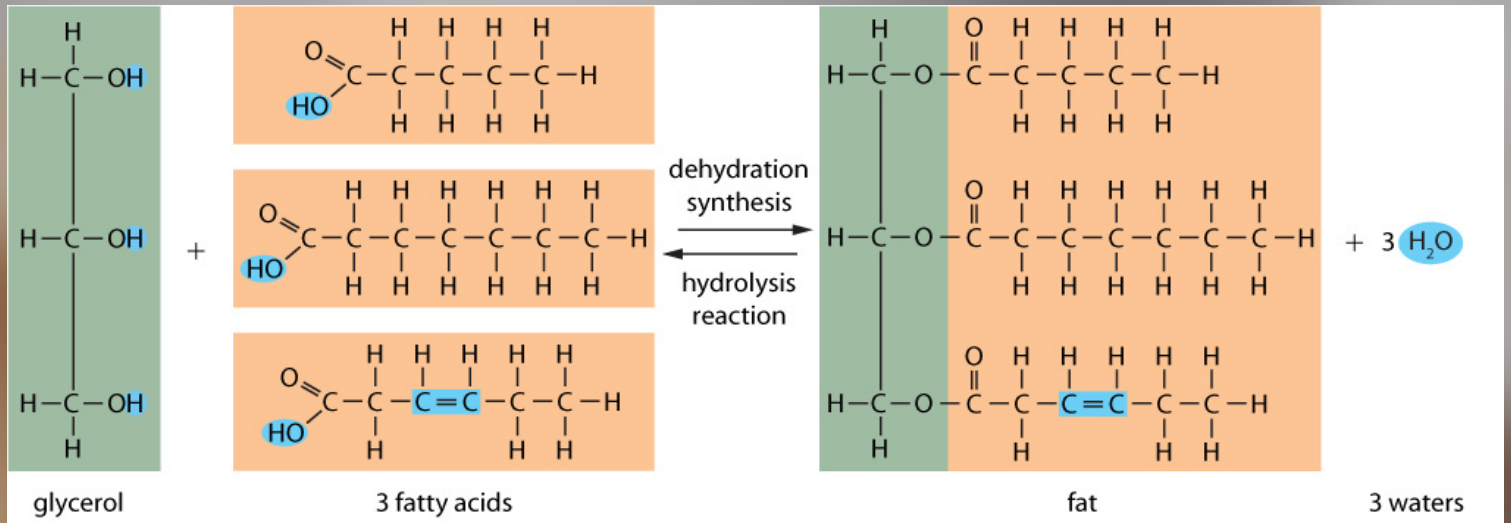


Figure 6.5 During the synthesis of a fat molecule, three fatty acid molecules bond with one glycerol molecule, and three water molecules are produced. What happens during the hydrolysis of a fat molecule?

Lipids

- Emulsification
  - Fats are nonpolar; they do not dissolve in water and tend to form “globules” (think of oil and vinegar salad dressing)
  - Emulsifiers break down the globules of fat into smaller droplets
  - Emulsifiers have a nonpolar end which attaches to the fat, and a polar end which interacts with water molecules so that the droplets can disperse
- Saturated and unsaturated fatty acids
  - Saturated have no double bonds between carbon atoms in the chain (all bonded to hydrogen), and tend to be more solid at room temperature and harder to break down
  - Rigid & straight (animal fat)
  - Unsaturated have at least one double bond between carbons
  - Polyunsaturated have multiple double bonds- the more polyunsaturated the fatty acids, the more liquid the fat will be at room temperature due to kinks in the chain and the easier it is to break down

AVOCADO: Hello I'm good fat

BACON: *lights cigarette* *punches avocado*

Proteins

- General characteristics
  - Composed of amino acids
  - An amino acid has a central carbon atom with a carboxyl group (COOH) at one end and an amino group at the other (NH_2)
  - There are 20 different amino acids
  - The portion of the molecule that varies between the different types is called the R group (“remainder”) which classifies the amino
  - Essential amino acids (9 out of 20) cannot be made by the body and must be consumed through food (histidine, isoleucine, valine)

Representative amino acids

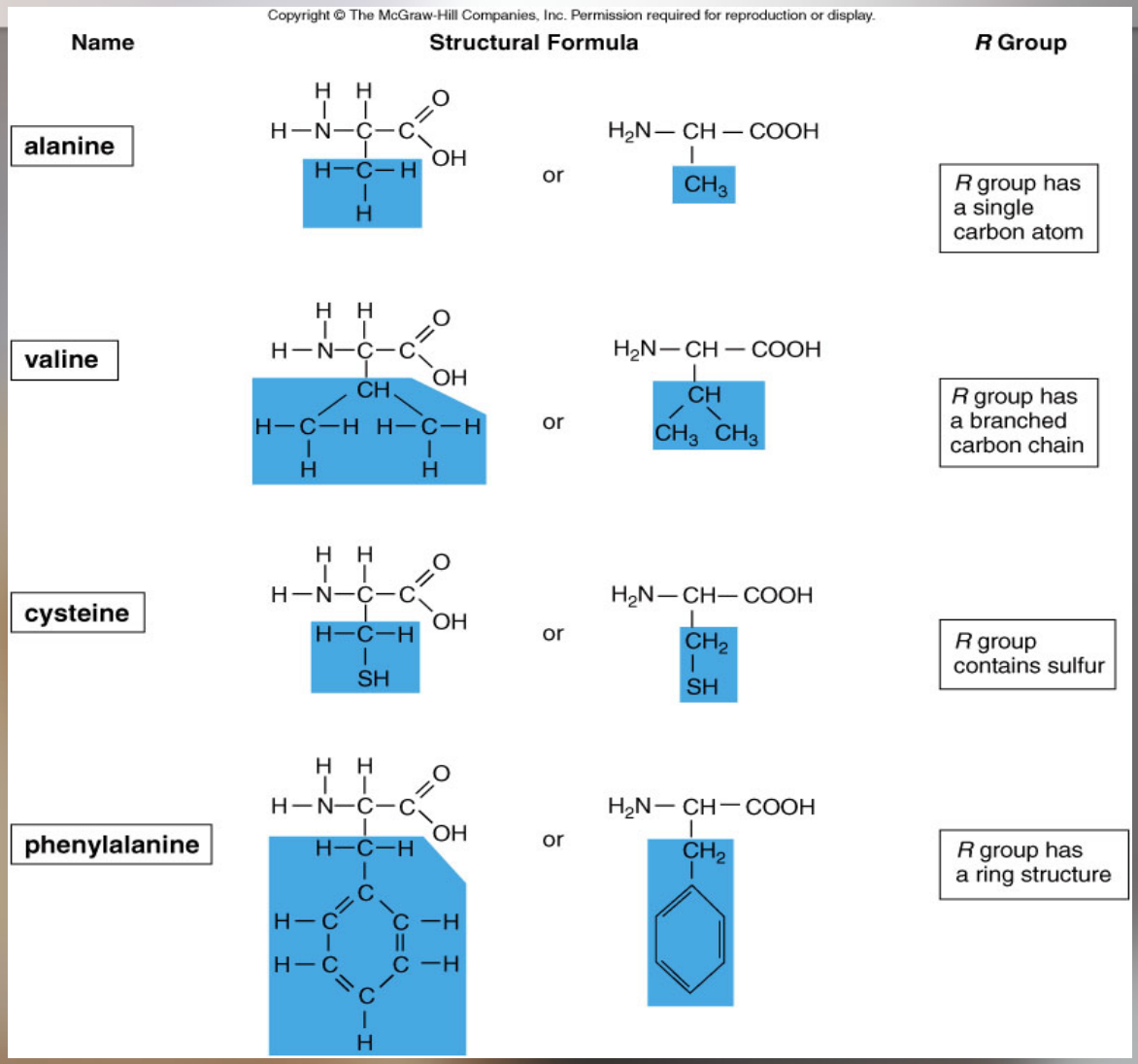


Fig. 2.24

Peptide Bonds (2:38)

Protein Synthesis

- The human body can synthesize 11 of the 20 amino acids
- We must then obtain the other 9 (known as essential amino acids) from our diet

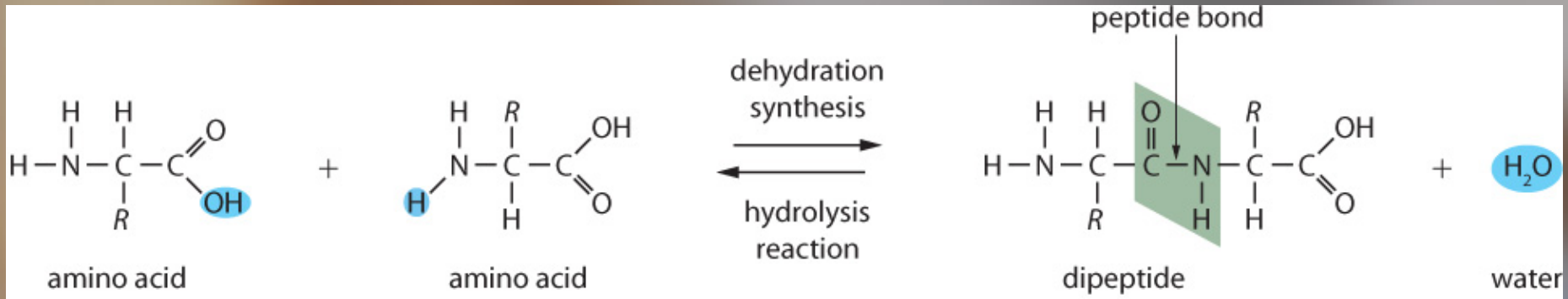


Figure 6.7 In dehydration synthesis, two amino acids bond to form a two-subunit molecule called a dipeptide. Hydrolysis breaks the peptide bond that links the amino acids. The *R* groups are shown here only as "*R*," because they do not take part in the reactions that make or break peptide bonds.

Examples of Proteins in your Body

- Biological catalysts-all enzymes are proteins
- Cell transport gates-part of the bilayer
- Antibodies - y shaped proteins that function in immune response
- Hormones - insulin, growth hormone
- Energy source - body uses protein when lipid and carbs are lacking
- Transport molecule - hemoglobin transports oxygen in blood

Protein Shapes

- As you can see, proteins can have many shapes
- The shape of a protein molecule is critical to its function

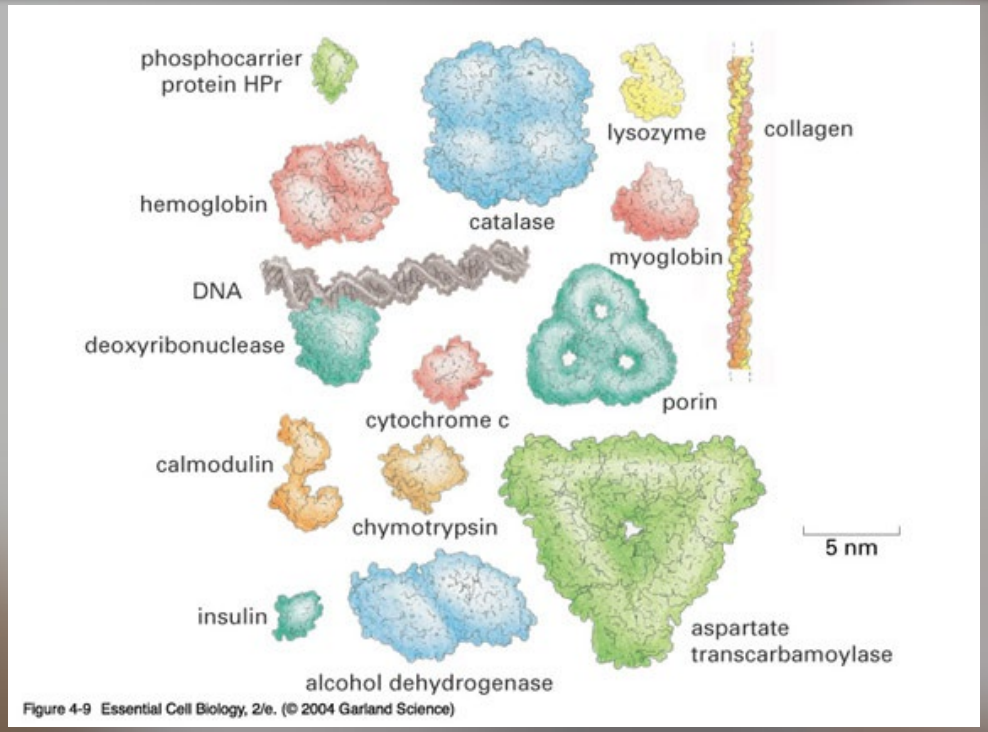


Figure 4-9 Essential Cell Biology, 2/e. (© 2004 Garland Science)

- Loss of the 3D structure of a protein is called denaturation
- [salt], temperature, pH can change the shape or denature proteins

Coagulation

- Proteins clump together into a solid like substance due to heat, acids, salts etc.
- Blood clots to prevent further bleeding
- Cooking an egg
- Permanent and irreversible (can't uncook your egg)

Enzymes

- Enzymes are biological catalysts
- They increase reaction rates by reducing the amount of energy is required to start a reaction

How an Enzyme Works:

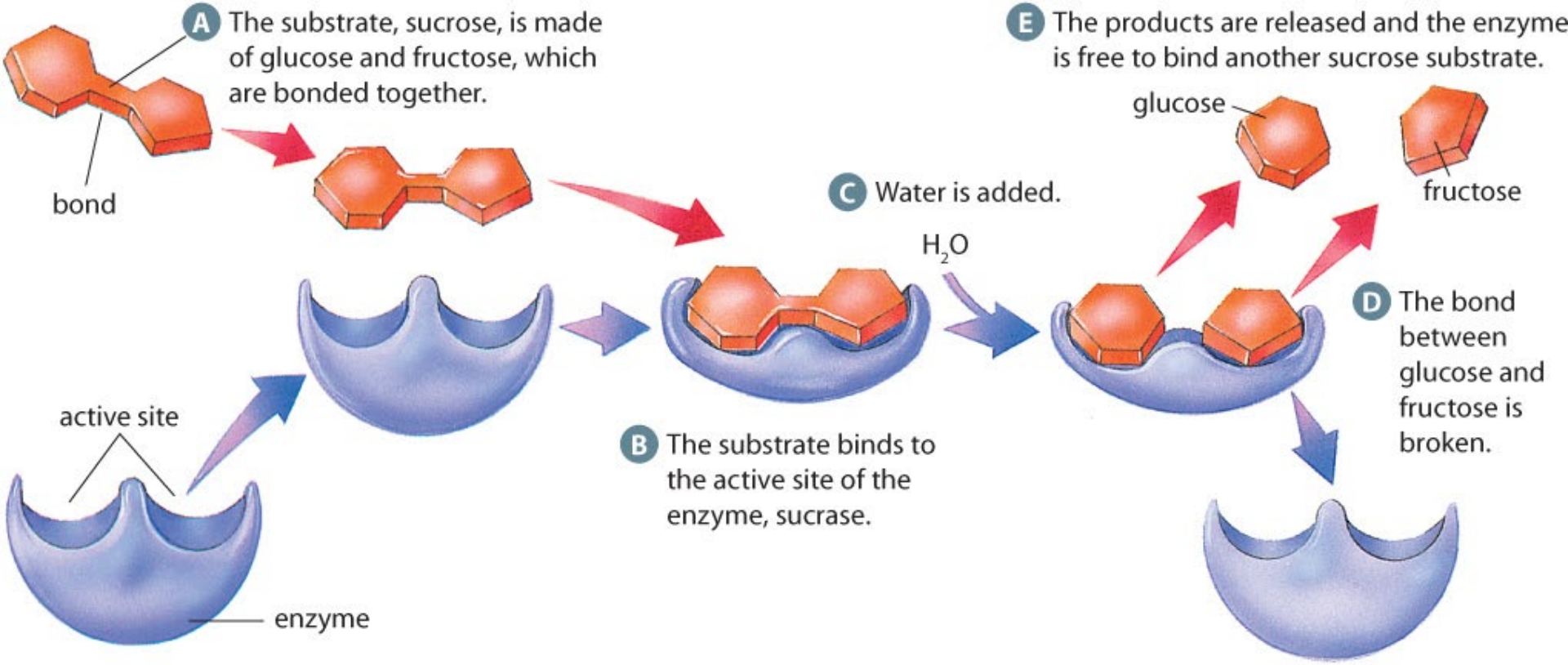


Figure 6.10 In this enzymatic reaction, the disaccharide sucrose is hydrolyzed to form its component simpler sugars, glucose and fructose.

Factors That Affect Enzymes

1. Temperature
2. pH
3. Competitive Inhibitors (fit into active sites)
4. Non-competitive Inhibitors (fit into other sites & change the shape of the enzyme)

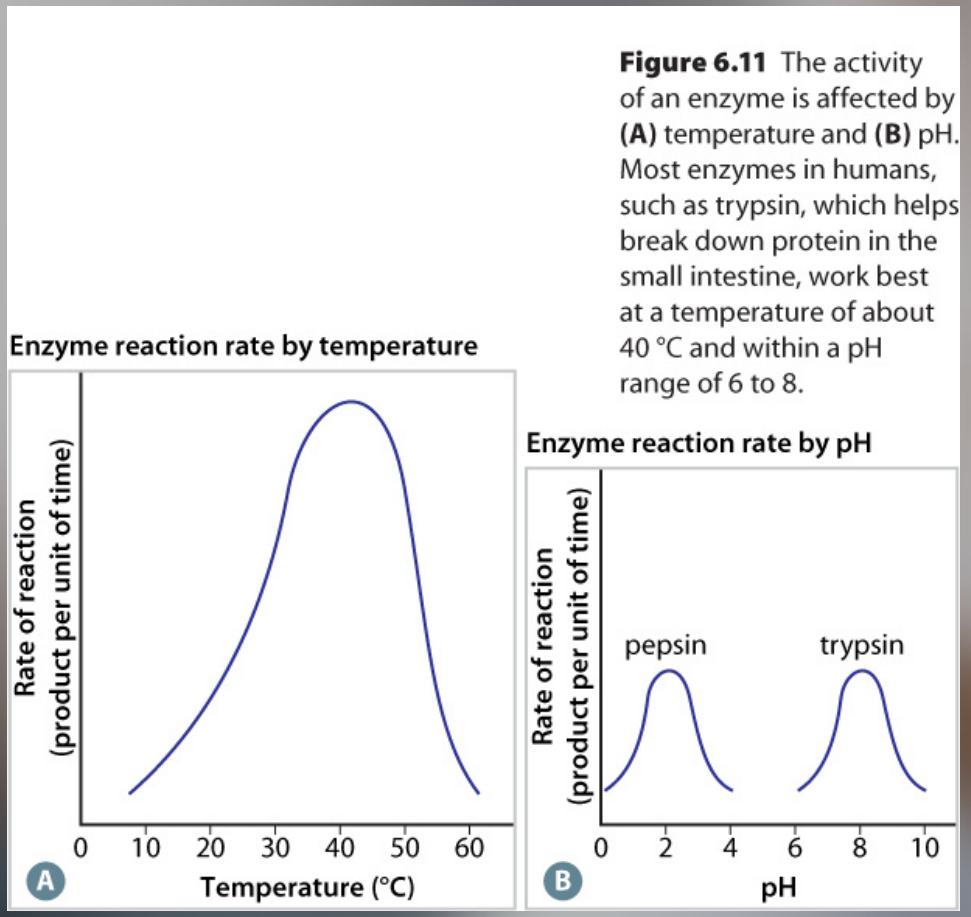


Figure 6.11 The activity of an enzyme is affected by **(A)** temperature and **(B)** pH. Most enzymes in humans, such as trypsin, which helps break down protein in the small intestine, work best at a temperature of about 40 °C and within a pH range of 6 to 8.

Nucleic Acids

- These compounds make up DNA and RNA
- They contain phosphate, a sugar, and a nitrogen base

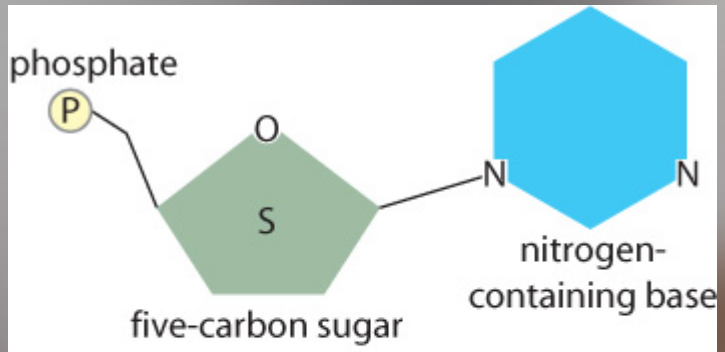


Figure 6.9 This model shows a generalized nucleotide. All nucleotides consist of a five-carbon simple sugar (ribose in RNA and deoxyribose in DNA), a nitrogen-containing base, and a phosphate group.

Testing for Macromolecules

- There are experimental tests we can perform to indicate whether or not a food sample contains different macromolecules
- These tests are:
  - Benedict's Test – for reducing (simple) sugars
  - Biuret Test – for proteins
  - Sudan IV Test – for lipids

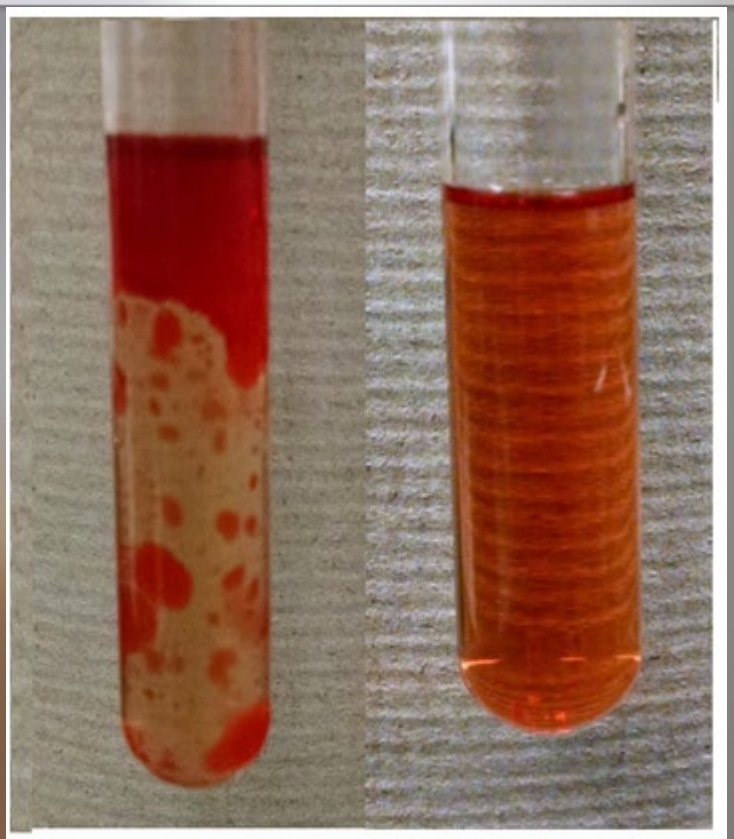
left to right: fructose glucose sucrose

Benedict's Test. Benedict's test was performed on three carbohydrates, depicted from left to right: fructose, glucose, and sucrose. The solution containing sucrose remains blue because sucrose is a nonreducing sugar (not a monosaccharide)

Biuret Test


30 mL
Biuret Reagent
Protein Test Solution
UN1824
For Laboratory Use Only.
Keep Out of Reach of Children.
Corrosive Storage Code White
50
40
30
20
10
50
40
30
20
10

Sudan IV test for lipids



positive result	negative result
- 2 layers - top layer is orange-red	- one layer - color is evenly distributed

Vitamins and Minerals

- Both vitamins and minerals are key components of chemical reactions in the body
- Vitamins are organic compounds that often help enzymes function
- Minerals are inorganic compounds that make up essential components of hemoglobin, hormones, enzymes and vitamins

Deficiency

- Night blindness: vitamin A deficiency
- Scurvy: Vitamin C deficiency (Vit C: helps maintain connective tissue)
- Rickets: Vitamin D deficiency (Vit D: helps with calcium and phosphorus absorption=healthy bones)
  - Government puts it in milk

Because we live in Canada

Water soluble vitamins: B and C

Lipid Soluble: A, D, E, K

6.2 – The Digestive System

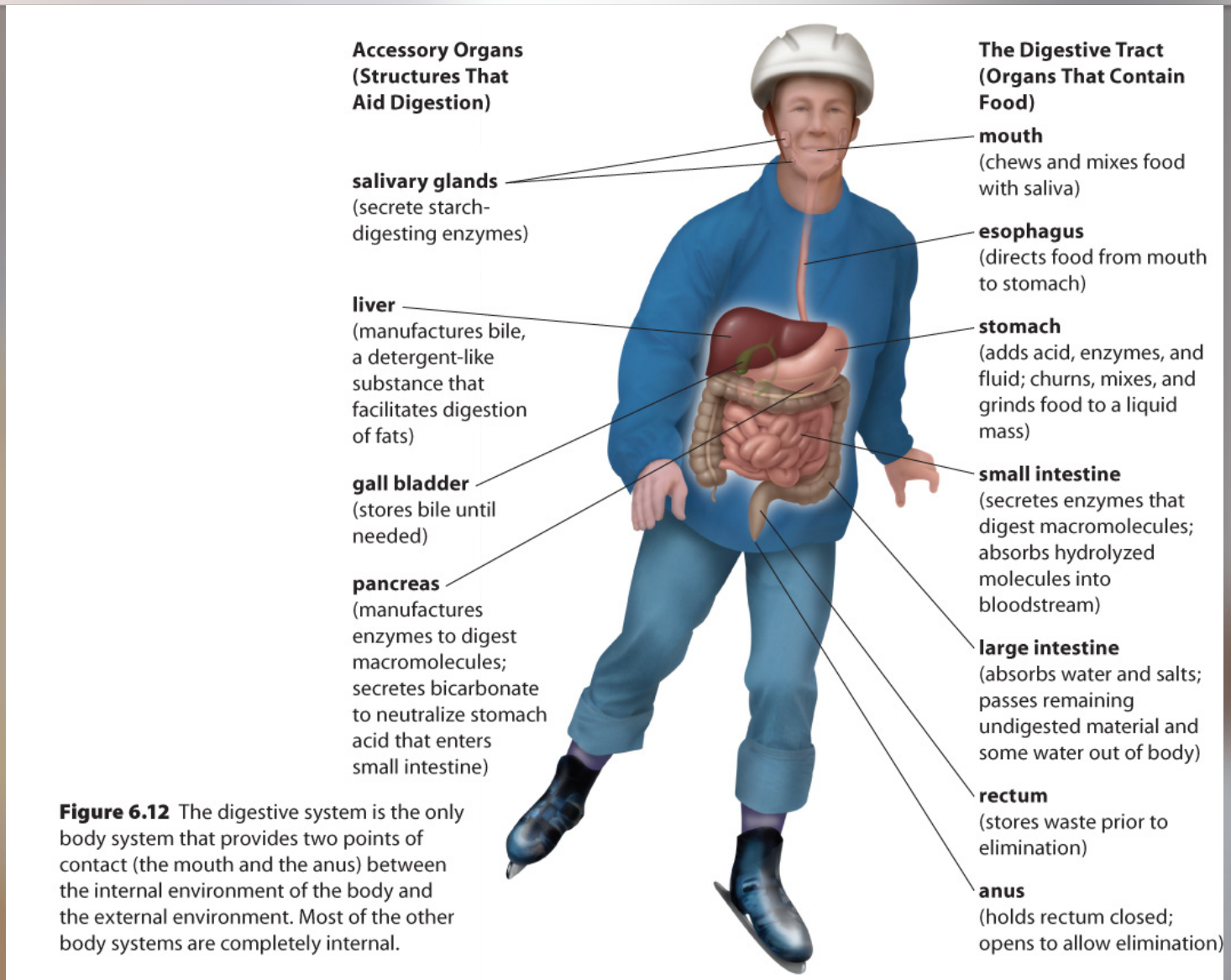


Figure 6.12 The digestive system is the only body system that provides two points of contact (the mouth and the anus) between the internal environment of the body and the external environment. Most of the other body systems are completely internal.

Importance of Digestion

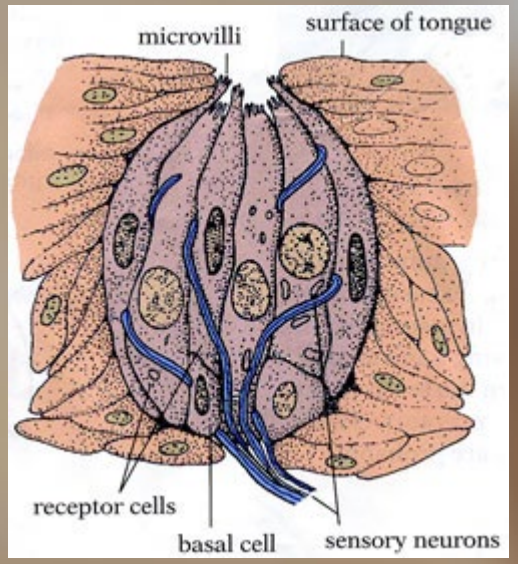
- We need to obtain our nutrients from the foods we eat
- However, the food that we eat contain the nutrients in forms that we may not be able to use directly
- Therefore, our digestive system breaks down the food into units that our cells can use

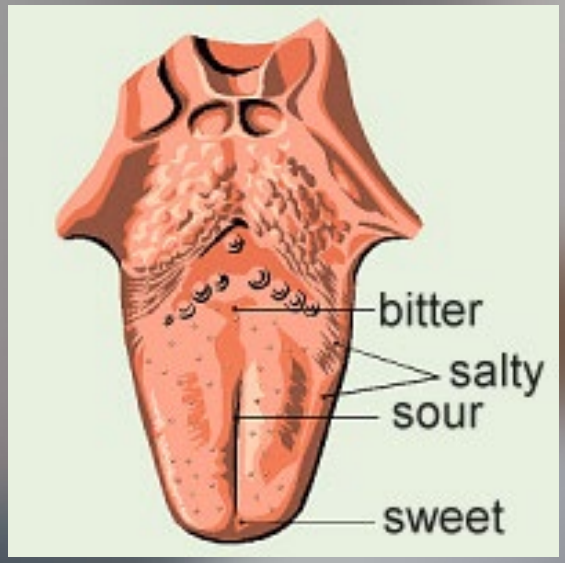
The Mouth

- Physical digestion begins in the mouth where food is formed into a "bolus"
- Amylase enzymes that begin the digestion of starches are secreted from the salivary glands

Taste

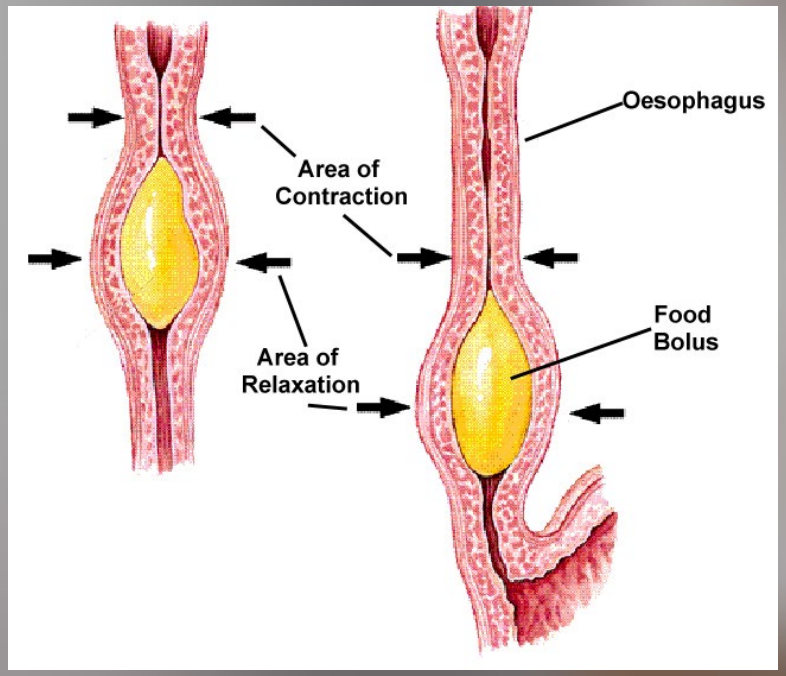
- Our tongue is covered with taste buds
- These chemical receptors identify the taste of specific chemicals in our food





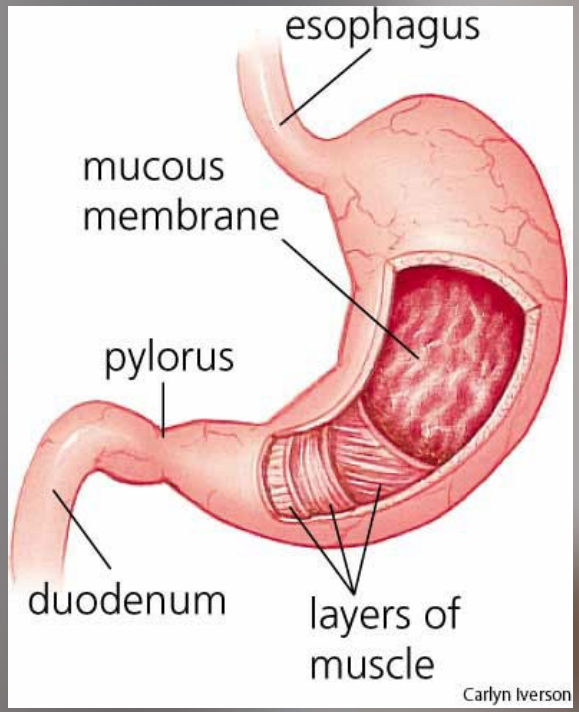
The Esophagus

- The tongue pushes the bolus of food into the esophagus
- The smooth muscle in the esophagus creates waves of muscle contractions (known as peristalsis) that push the food towards the stomach

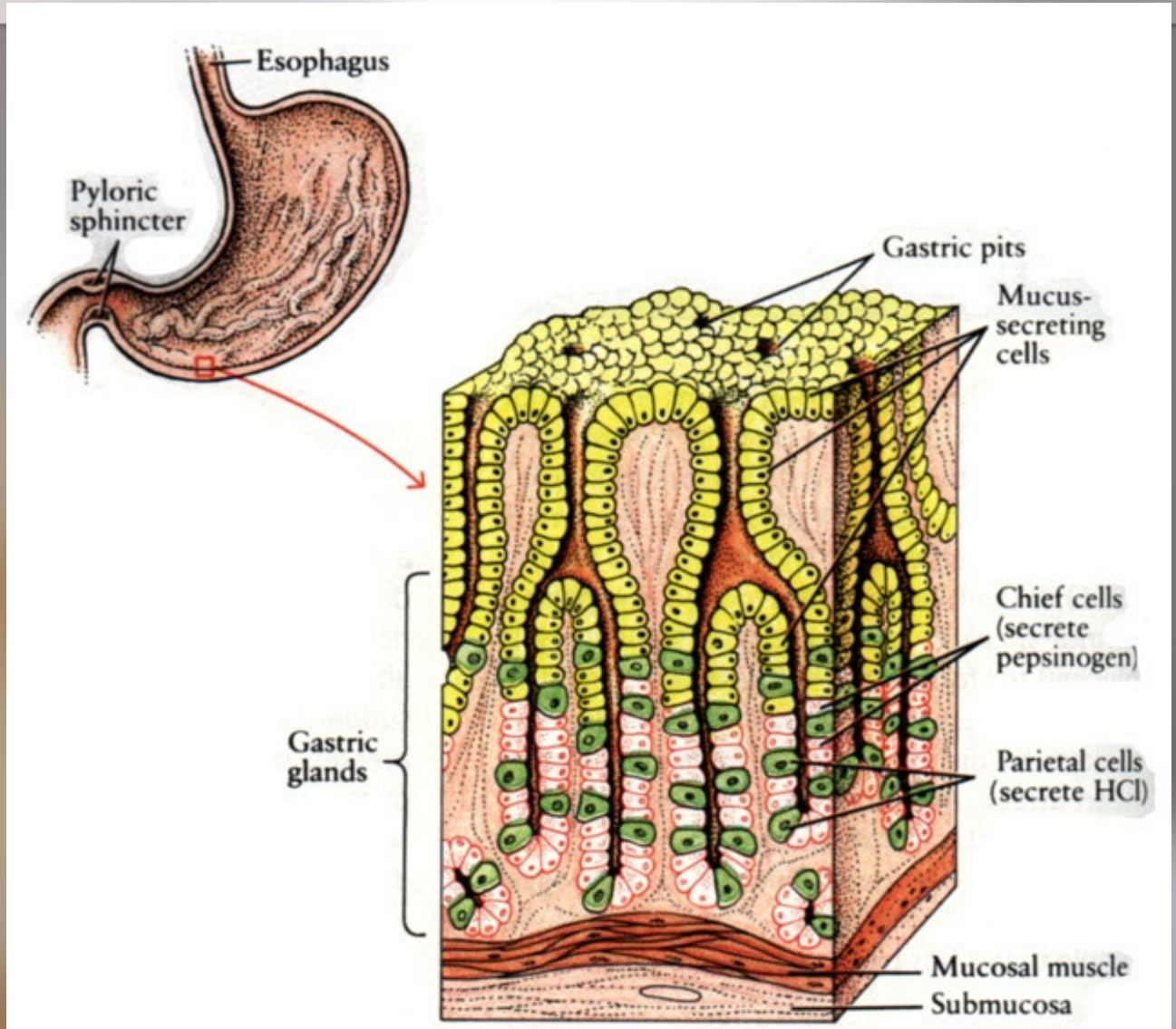


The Stomach

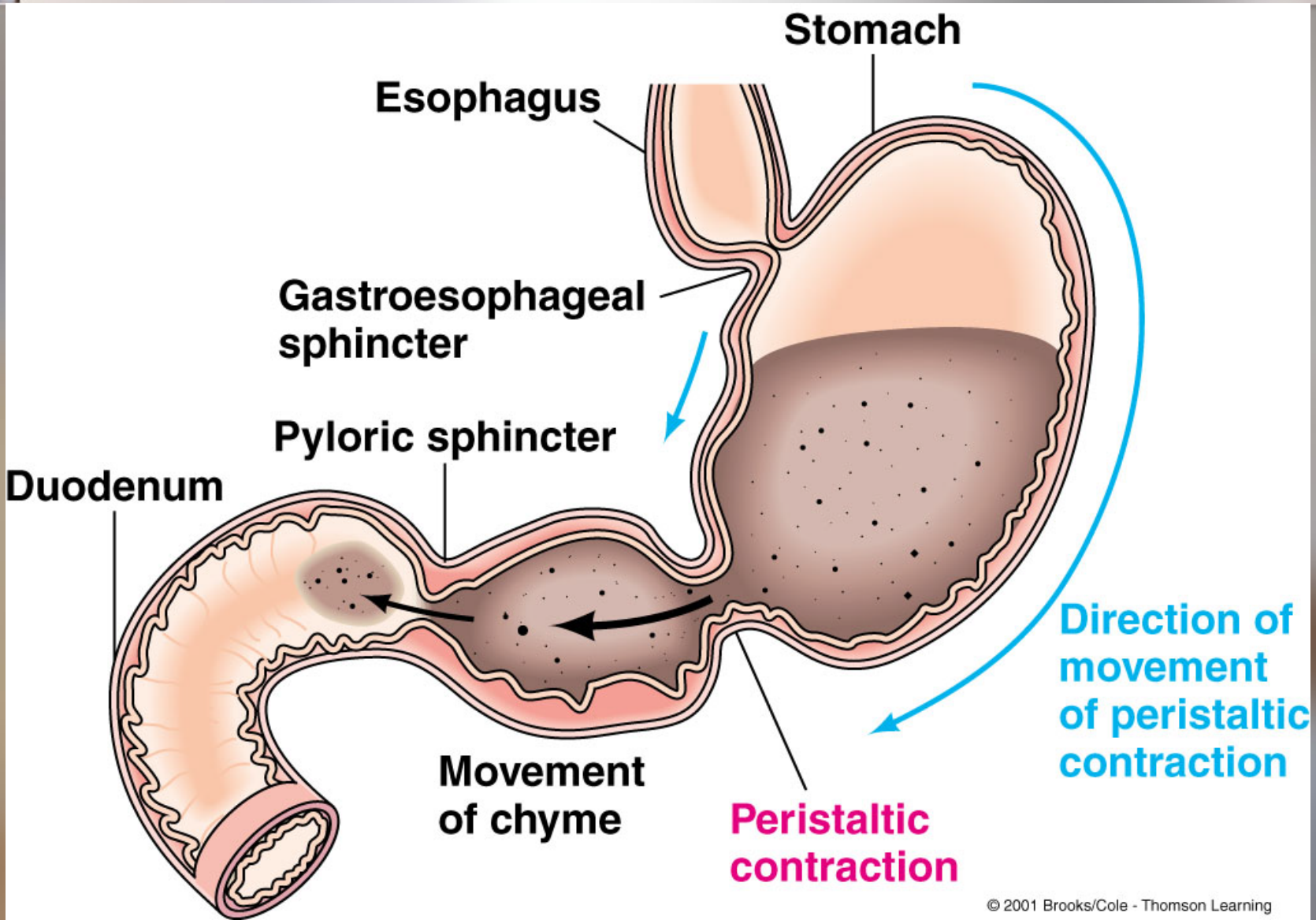
- The stomach both serves as a food storage site and the site of initial protein digestion
- The stomach can hold about 1.5 L of food and contains about 500 mL of corrosive gastric juices
- Mucous secreted from cells lining the stomach protect the stomach wall from being digested by its contents



Stomach (Con't)

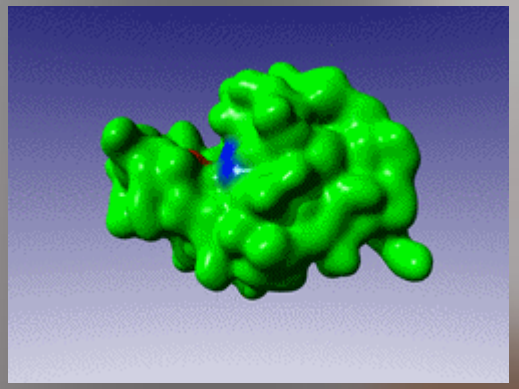


Stomach (Con't)



Protein Digestion

- Proteins and polypeptides are very large molecules
- An enzyme known as pepsin is produced by peptic cells in the stomach
- This enzyme works along with the hydrochloric acid in the stomach to break down the polypeptides into smaller units



Stomach (Con't)

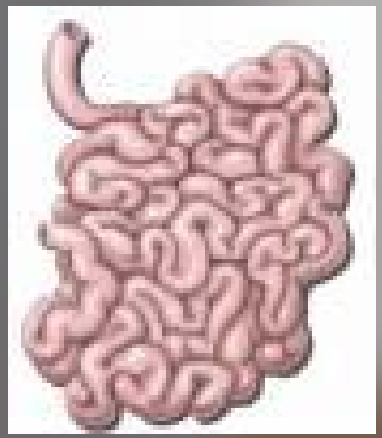
- Another enzyme, rennin, is used to slow the movement of milk through the digestive system
- If the mucous lining of the stomach breaks down, an ulcer is formed
- This is dangerous because beneath the stomach lining there are many capillaries

Absorption in the Stomach

- Because very little of the thick liquid called *chyme* that is produced in the stomach is absorbed there
- The stomach absorbs small amounts of salts, water, anti-inflammatory medicines such as Aspirin, and alcohol

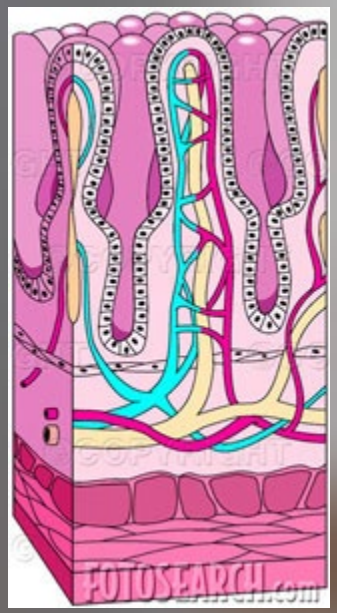
The Small Intestine

- The first 30 cm of the small intestine is known as the duodenum
- The presence of acids from the stomach here cause a release of bicarbonate ions from the pancreas
- These bicarbonate ions neutralize the acid (pH of the fluids goes from 2.5 to 9.0)



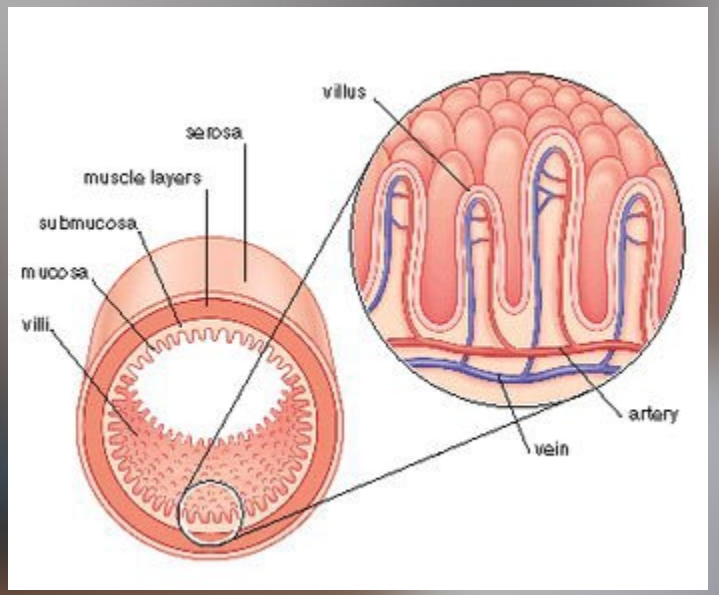
Small Intestine

- The stomach absorbs some water, vitamins and alcohol
- Most absorption takes place in the 2nd part of the small intestine (jejunum)
- The interior of the small intestine is lined with villi, which are small finger-like projections



Small Intestine

- The villi increase the surface area of absorption
- The cell membranes of the lining of the small intestine also have folds, known as microvilli



Small Intestine

- The villi contains capillaries that absorb carbohydrates and amino acids
- The larger lipid molecules are absobed by the lymph vessels

Digestion & Absorption of Macromolecules

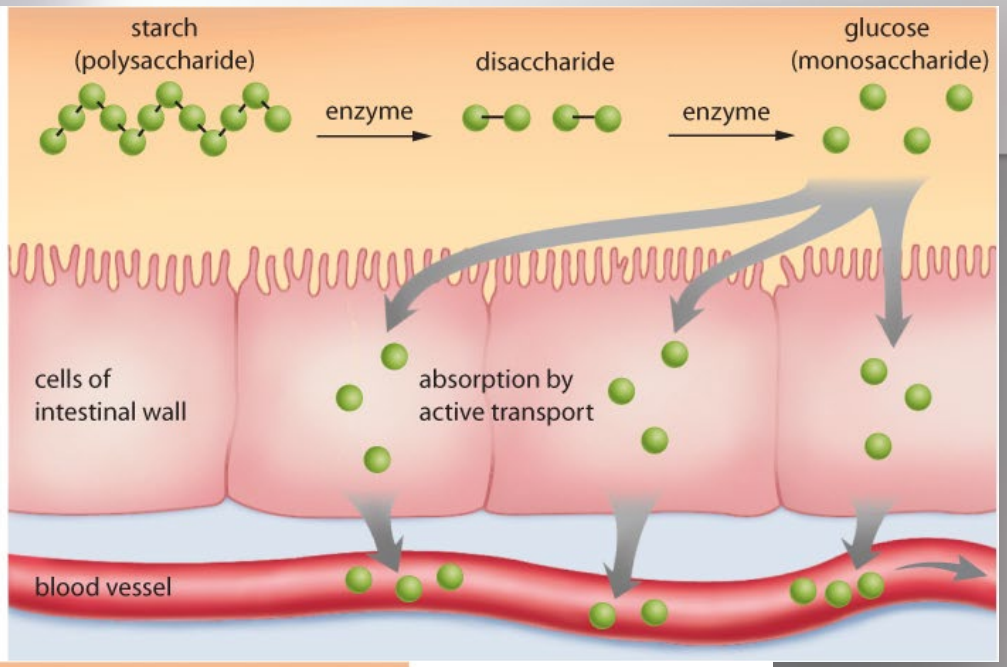


Figure 6.22 The monosaccharide glucose is actively transported into cells of the intestinal wall in order to move into the bloodstream.

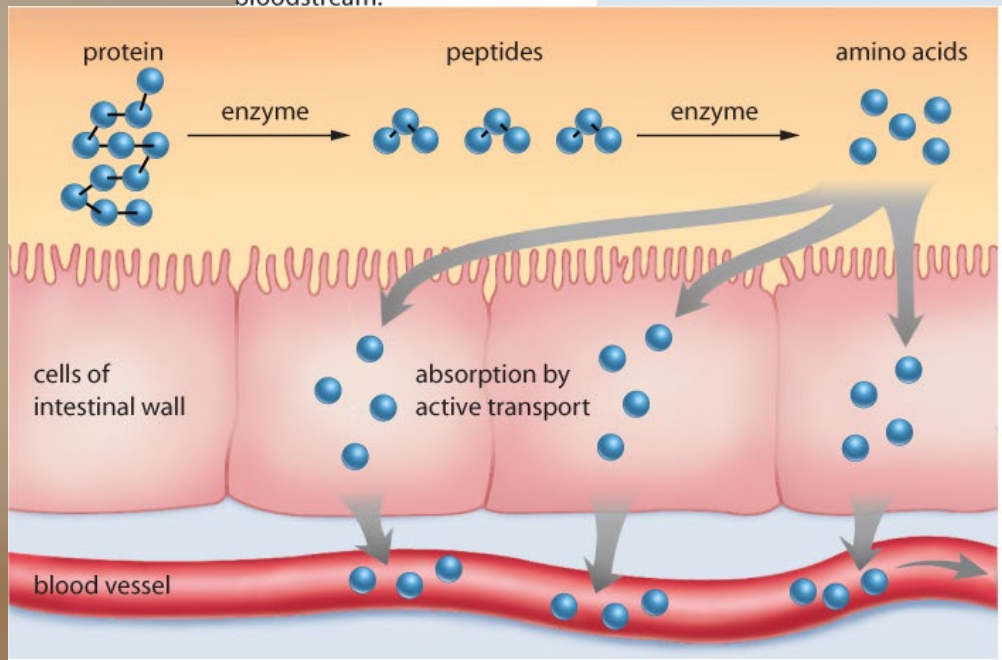
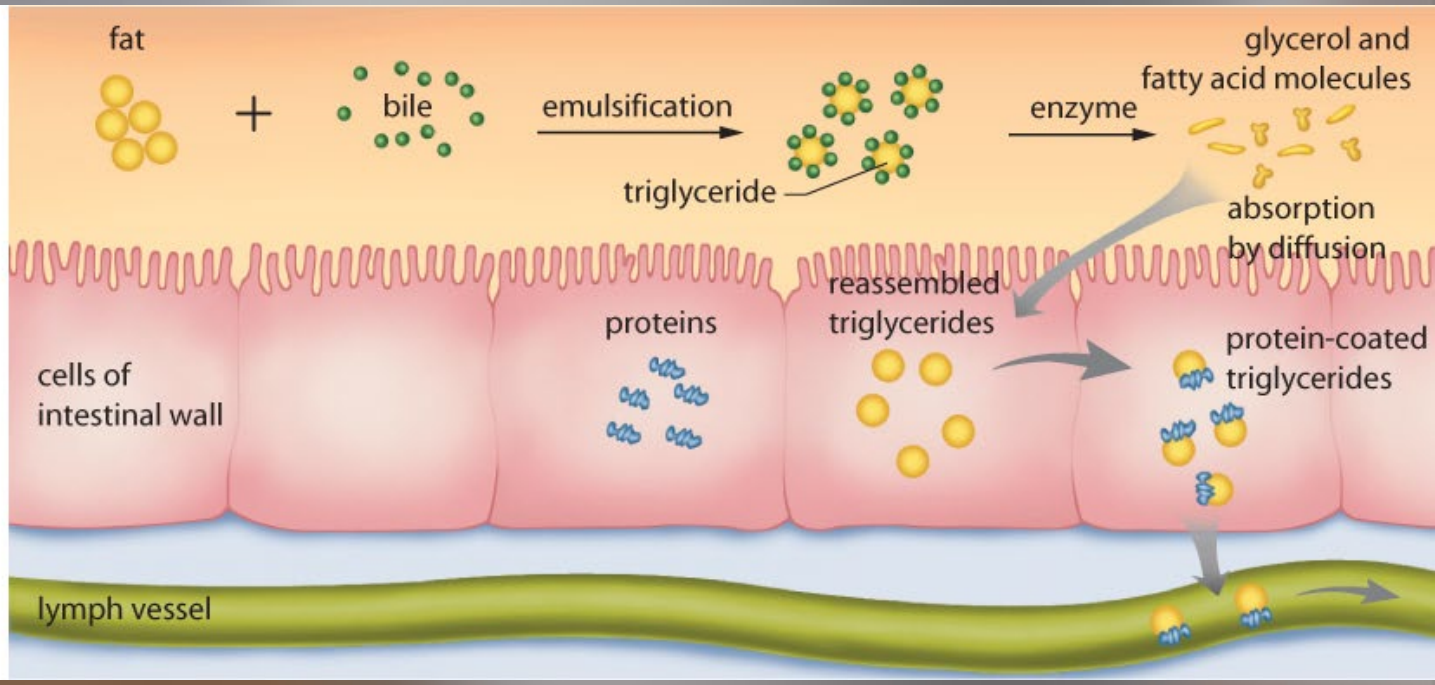


Figure 6.23 Amino acids are actively transported into the cells of the intestinal wall in order to move into the bloodstream.

Figure 6.24
Glycerol and fatty acid molecules diffuse into the cells of the intestinal wall where they are resynthesized into fats, coated with proteins, and move into lymph vessels for eventual transport into the bloodstream.



Small Intestine

- The 3rd part of the small intestine is called the ileum
- The Ileum functions to finish any remaining digestion or absorption left over from the duodenum and the jejunum

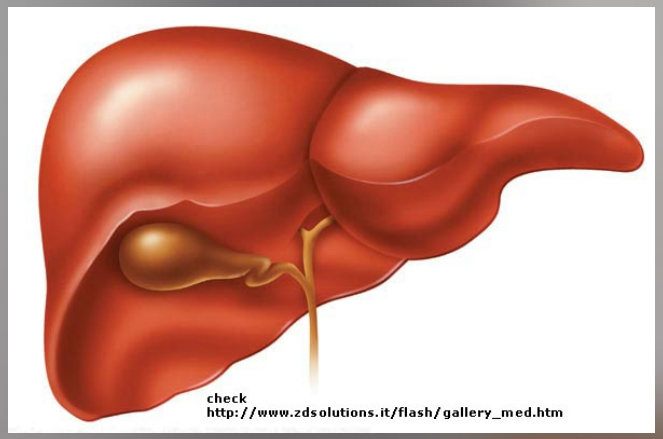
The Pancreas

- The pancreas also produces enzymes for digestion
- Trypsin and chymotrypsin act on partially digested proteins, breaking them down to shorter chains
- Other peptidases are also produced by the pancreas and small intestine
- Enzymes that break down nucleic acids are also produced by the pancreas and small intestine

- The breakdown of carbohydrates is due to amylase (which breaks down starch), maltase (breaks down maltose) and lactase (which breaks down milk sugar)
- Lipase enzymes break down lipids into their fatty acids and glycerol

The Liver and Gallbladder

- The liver produces bile salts, which emulsify the fat (cause it to form tiny globules)
- These tiny globules of fat have a large surface area to volume ratio, and the lipase enzymes work on them more effectively
- Occasionally, a gallstone will form, which is crystallized bile salt



- This gallstone prevents the bile salts from aiding in fat digestion and causes pain
- The pigments in bile are what give feces their characteristic brown color
- The liver also stores glycogen and vitamins

Regulation of Small Intestine Processes

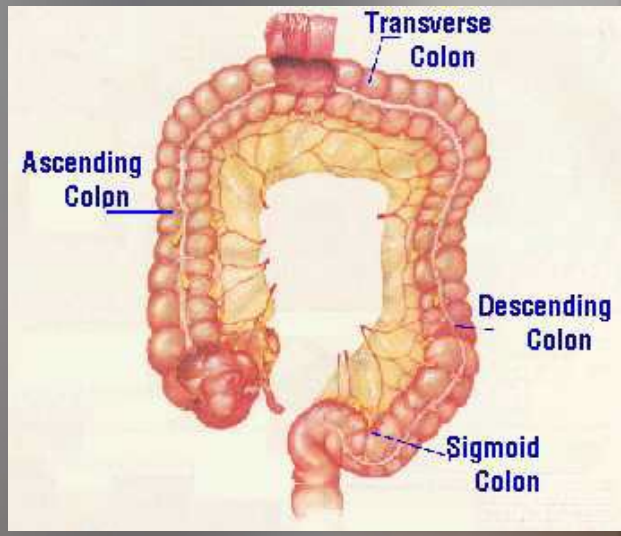
- The small intestine is regulated by the nervous and endocrine systems
- In the stomach, proteins in the food stimulate the production of gastrin, which stimulates hydrochloric acid production
- The movement of chyme into the duodenum inhibits muscular contrations in the stomach, preventing more chyme from entering the small intestine

- A hormone known as secretin stimulates the pancreas to produce bicarbonate
- CCK and GIP are both released when high-fat foods enter the duodenum
- Secretin, CCK and GIP reduce motility in the stomach, preventing more food from entering the small intestine
- CCK also increases the release of bile from the gall bladder

Hormone Animation

The Colon

- By the time food reaches the large intestine, it is completely digested
- The colon stores wastes long enough to absorb water
- As well, bacteria that synthesize vitamins B & K are found here
- The buildup of waste in the colon triggers nerve impulses that initiate a bowel movement

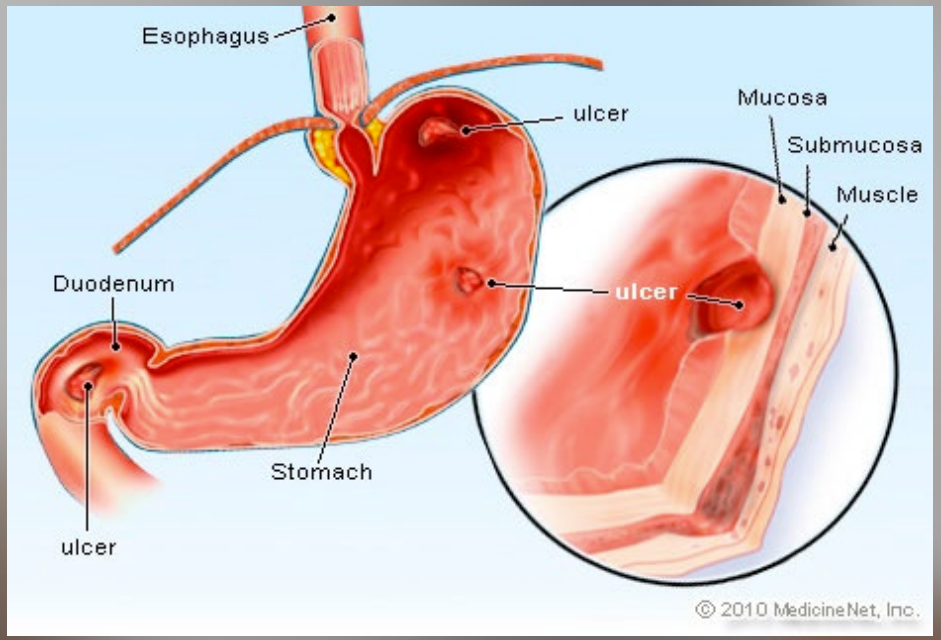


6.3 – Health and the Digestive System

- Many disorders of the digestive system will affect the health of the whole body
- These disorders may be physiological in nature, or they may also be psychological

Ulcers

- Ulcers are holes in the wall of the stomach and intestine
- These are often caused by a breakdown of the mucus lining the GI tract
- This is often caused by bacterial infections



Inflammatory Bowel Disease

- This is a general class of disorders that result in an inflammation of the GI tract
- Some types of these diseases may cause ulcers to appear, and the presence of blood in the stool
- In some cases, surgery may be required to remove diseased portions of the digestive tract

Accessory Organ Disorders

- Hepatitis: Inflammation of the liver
- Cirrhosis: A chronic liver disease where healthy liver tissue is replaced by fat and scar tissue
- Gallstones: Crystals of cholesterol and minerals build up in the gall bladder or duct, preventing the flow of bile

Psychological Disorders

- Anorexia nervosa
- Bulimia
- Obesity

The End