Digestion

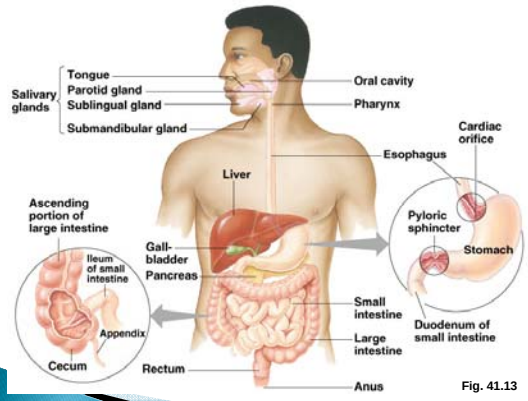


Fig. 41.13

Digestion

- Why we need it
- Why Enzymes
  - Rate needs to increase at body temperature
- Conditions
  - Amylase
  - Protease
  - Lipase

Digestive Enzyme Conditions

Enzyme	Substrate	Products	Optimum pH
Ptyalin (alpha Amylase)	Starch	Maltose	6.7–7
Pepsin	Protein	Smaller peptides	1.2–2
Pancreatic Lipase	Triglyceride	Monoglycerides and free fatty acids	5.5–6.5

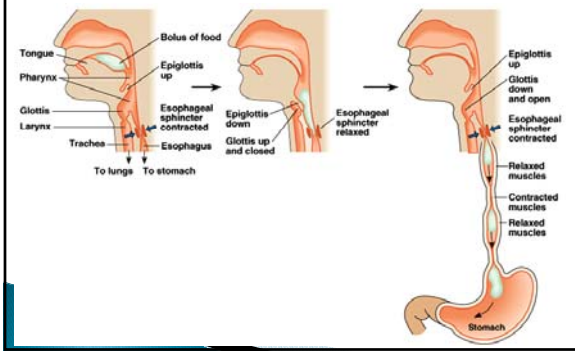
Stages of Digestion

- Chemical digestion of carbohydrates, a main source of chemical energy, begins in the oral cavity.
  - Saliva contains **salivary amylase**, an enzyme that hydrolyzes starch and glycogen into smaller polysaccharides and the disaccharide maltose.
- The tongue tastes food, manipulates it during chewing, and helps shape the food into a ball called a **bolus**.
  - During swallowing, the tongue pushes a bolus back into the oral cavity and into the pharynx.

Swallowing

- The **pharynx**, also called the throat, is a junction that opens to both the esophagus and the trachea (windpipe).
  - When we swallow, the top of the windpipe moves up such that its opening, the glottis, is blocked by a cartilaginous flap, the **epiglottis**.
  - This mechanism normally ensures that a bolus will be guided into the entrance of the esophagus and not directed down the windpipe.

Swallowing



Movement

- The **esophagus** conducts food from the pharynx down to the stomach by peristalsis.
  - The muscles at the very top of the esophagus are striated and therefore under voluntary control.
  - Involuntary waves of contraction by smooth muscles in the rest of the esophagus then takes over.

Stomach

- The **stomach** is located in the upper abdominal cavity, just below the diaphragm.
  - With accordionlike folds and a very elastic wall, the stomach can stretch to accommodate about 2 L of food and fluid, storing an entire meal.
  - The stomach also secretes a digestive fluid called **gastric juice** and mixes this secretion with the food by the churning action of the smooth muscles in the stomach wall.

Control of Gastric Juice Secretion

- stretch receptors → medulla oblongata → endocrine cells in the stomach → gastrin → circulatory system → stomach → secretes gastric juice

Gastric Juice

- Gastric juice is secreted by the epithelium lining numerous deep pits in the stomach wall.
  - gastric juice is about 2 – acidic enough to digest iron nails.
    - It kills most bacteria that are swallowed with food.
  - Also present in gastric juice is **pepsin**, an enzyme that begins the hydrolysis of proteins.

Gastric Pits

- Parietal cells, also in the pits, secrete hydrochloric acid which converts pepsinogen to the active pepsin only when both reach the lumen of the stomach, minimizing self-digestion.
  - Pepsin is secreted in an *inactive* form, called **pepsinogen** by specialized chief cells in gastric pits.
  - Also, in a positive-feedback system, activated pepsin can activate more pepsinogen molecules.

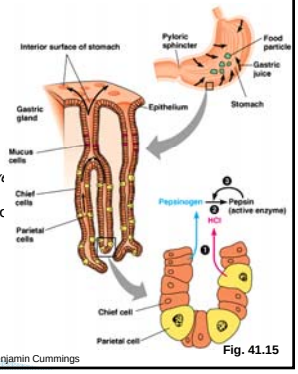


Fig. 41.15

Ulcers

- The stomach's second line of defense against self-digestion is a coating of mucus, secreted by epithelial cells, that protects the stomach lining.
  - Still, the epithelium is continually eroded, and the epithelium is completely replaced by mitosis every three days.
  - Gastric ulcers, lesions in the stomach lining, are caused by the acid-tolerant bacterium *Heliobacter pylori*. They remove the mucous and then the acid and bacteria irritate the lining
    - Ulcers are often treated with antibiotics.

- About every 20 seconds, the stomach contents are mixed by the churning action of smooth muscles.
  - As a result of mixing and enzyme action, what begins in the stomach as a recently swallowed meal becomes a nutrient-rich broth known as **acid chyme**.

Leaving the Stomach

- Most of the time the stomach is closed off at either end.
  - The opening from the esophagus to the stomach, the **cardiac orifice**, normally dilates only when a bolus driven by peristalsis arrives.
    - The occasional backflow of acid chyme from the stomach into the lower esophagus causes **heartburn**.
  - At the opening from the stomach to the small intestine is the **pyloric sphincter**, which helps regulate the passage of chyme into the intestine.
    - A squirt at a time, it takes about 2 to 6 hours after a meal for the stomach to empty.

Small Intestine

- With a length of over 6 m in humans, the **small intestine** is the longest section of the alimentary canal.
- Most of the enzymatic hydrolysis of food macromolecules and most of the absorption of nutrients into the blood occurs in the small intestine.

Small Intestine

- In the first 25 cm or so of the small intestine, the **duodenum**, acid chyme from the stomach mixes with digestive juices from the pancreas, liver, gall bladder, and gland cells of the intestinal wall.
  - The pancreas produces several hydrolytic enzymes and an alkaline solution rich in bicarbonate which buffers the acidity of the chyme from the stomach.

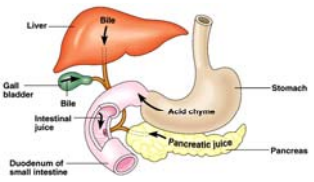


Fig. 41.16

Liver Additions (See Liver notes)

- The liver performs a wide variety of important functions in the body, including the production of **bile**.
  - Bile is stored in the gallbladder until needed.
  - It contains bile salts which act as detergents that aid in the digestion and absorption of fats.
  - Bile also contains pigments that are by-products of red blood cell destruction in the liver.
    - These bile pigments are eliminated from the body with the feces.

More Liver Functions

- *Liver function*
  All cells = hepatocytes – but do have some variation in function
- blood filter – kupffer cells – site of metastasis because of this
- blood storage – can release blood into circulation if needed
- hemopoiesis in fetus and newborn
- processing nutrients from gi tract
  Sugars – glycogenesis vs. glycogenolysis – control blood glucose Via hormones
  Lipids – take in and process to usable lipoproteins (ldl, vldl bad – hdl good)
- synthesis of plasma proteins – albumin, clotting factors, others
- drug metabolism and detoxification – some (barbiturates) cause ser to expand
- bilirubin metabolism and secretion – this from breakdown of rbcs
  Liver takes it up and conjugates it to protein – excretes in bile
  Jaundice = bilirubin in blood
- bile secretion – emulsifies fats – also excretes wastes

- Specific enzymes from the pancreas and the duodenal wall have specific roles in digesting macromolecules.

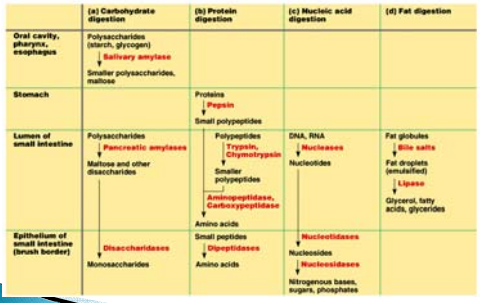


Fig. 41.17

Enzymes secreted in an inactive form

- Many of the protein-digesting enzymes, such as aminopeptidase, are secreted by the intestinal epithelium, but trypsin, chymotrypsin, and carboxypeptidase are secreted in inactive form by the pancreas.
  - Another intestinal enzyme, **enteropeptidase**, converts inactive trypsinogen into active trypsin.
  - Active trypsin then activates the other two.

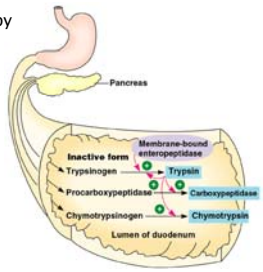


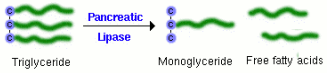
Fig. 41.18

Nucleases

- The digestion of nucleic acids involves a hydrolytic assault similar to that mounted on proteins.
  - A team of enzymes called **nucleases** hydrolyzes DNA and RNA into their component nucleotides.
  - Other hydrolytic enzymes then break nucleotides down further into nucleosides, nitrogenous bases, sugars, and phosphates.

Lipases

- Nearly all the fat in a meal reaches the small intestine undigested.
  - Normally fat molecules are insoluble in water, but bile salts, secreted by the gallbladder into the duodenum, coat tiny fats droplets and keep them from coalescing, a process known as **emulsification**.
  - The large surface area of these small droplets is exposed to **lipase**, an enzyme that hydrolyzes fat molecules into glycerol, fatty acids, and monoglycerides.



Small Intestine Continued

- Most digestion occurs in the duodenum.
- The other two sections of the small intestine, the **jejunum** and **ileum**, function mainly in the absorption of nutrients and water.
- To enter the body, nutrients in the lumen must pass the lining of the digestive tract.
  - The small intestine has a huge surface area – 300 m^2, roughly the size of a tennis court.

Surface Area

- The enormous surface of the small intestine is an adaptation that greatly increases the rate of nutrient absorption.
  - Large circular folds in the lining bear fingerlike projections called **villi**, and each epithelial cell of a villus has many microscopic appendages called **microvilli** that are exposed to the intestinal lumen.

Villi etc.

- Tight Junctions
- Pinocytosis
- Mitochondria
- Microvilli
- Lacteal

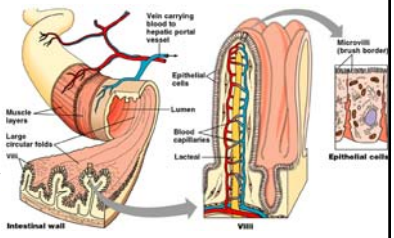


Fig. 41.19

Lacteal Function

- Penetrating the core of each villus is a net of microscopic blood vessels (capillaries) and a single vessel of the lymphatic system called a **lacteal**.
  - Nutrients are absorbed across the intestinal epithelium and then across the unicellular epithelium of capillaries or lacteals.
  - Only these two single layers of epithelial cells separate nutrients in the lumen of the intestine from the bloodstream.

Fat Movement

- Glycerol and fatty acids absorbed by epithelial cells are recombined into fats.
- The fats are mixed with cholesterol and coated with special proteins to form small globules called **chylomicrons**.
- These are moved in the lymphatic system
  - The capillaries and veins that drain nutrients away from the villi converge into the **hepatic portal vessel**, which leads directly to the liver.

All blood flows to the Liver

- Therefore, the liver – which has the metabolic versatility to interconvert various organic molecules – has first access to amino acids and sugars absorbed after a meal is digested.
- The liver modifies and regulates this varied mix before releasing materials back into the blood stream.
  - For example, the liver helps regulate the levels of glucose in the blood, ensuring that blood exiting the liver usually has a glucose concentration very close to 0.1%, regardless of carbohydrate content of the meal.

Other Hormones

- **enterogastrones**, are secreted by the walls of the duodenum.
  - The acidic pH of the chyme entering→hormone **secretin** which signals the pancreas to release bicarbonate to neutralize the chyme.
  - **Cholecystokinin** (**CCK**), secreted in response to the presence of amino acids or fatty acids, causes the gallbladder to contract and release bile into the small intestine and triggers the release of pancreatic enzymes.

Large Intestine

- The **large intestine**, or **colon**, is connected to the small intestine at a T-shaped junction where a sphincter controls the movement of materials.
  - One arm of the T is a pouch called the **cecum**.
    - The relatively small cecum of humans has a fingerlike extension, the **appendix**, that makes a minor contribution to body defense.
  - The main branch of the human colon is shaped like an upside-down U about 1.5 m long.

Colon

- A major function of the colon is to recover water that has entered the alimentary canal as the solvent to various digestive juices.
  - About 7 L of fluid are secreted into the lumen of the digestive tract of a person each day.
  - Over 90% of the water is reabsorbed, most in the the small intestine, the rest in the colon.

Intestinal organisms

- Living in the large intestine is a rich flora of mostly harmless bacteria.
  - One of the most common inhabitants of the human colon is *Escherichia coli*, a favorite research organism.
  - As a byproduct of their metabolism, many colon bacteria generate gases, including methane and hydrogen sulfide.
  - Some bacteria produce vitamins, including biotin, folic acid, vitamin K, and several B vitamins, which supplement our dietary intake of vitamins.

Feces

- Feces contain masses of bacteria and undigested materials including cellulose.
  - Although cellulose fibers have no caloric value to humans, their presence in the diet helps move food along the digestive tract.
  - The feces may also contain excess salts that are excreted into the lumen of the colon.
  - Egested: lignin, cellulose, bile pigments, bacteria and digestive cells.

Rectum

- The terminal portion of the colon is called the **rectum**, where feces are stored until they can be eliminated.
  - Between the rectum and the anus are two sphincters, one involuntary and one voluntary.
  - Once or more each day, strong contractions of the colon create an urge to defecate.