The Digestive System

PowerPoint® Lecture Presentations prepared by
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The digestive system consists of:

- The digestive tract
- Accessory organs of digestion

**Digestive tract**

- Mouth
- Pharynx
- Esophagus
- Stomach
- Small intestine
- Large intestine
Introduction

• **Accessory Organs of the Digestive Tract**
  - Teeth
  - Tongue
  - Salivary glands
  - Pancreas
  - Liver
  - Gallbladder
Figure 25.1 Components of the Digestive System

- **Oral Cavity, Teeth, Tongue**
  - Mechanical processing, moistening, mixing with salivary secretions

- **Liver**
  - Secretion of bile (important for lipid digestion), storage of nutrients, many other vital functions

- **Gallbladder**
  - Storage and concentration of bile

- **Pancreas**
  - Exocrine cells secrete buffers and digestive enzymes; endocrine cells secrete hormones

- **Large Intestine**
  - Dehydration and compaction of indigestible materials in preparation for elimination

- **Salivary Glands**
  - Secretion of lubricating fluid containing enzymes that break down carbohydrates

- **Pharynx**
  - Muscular propulsion of materials into the esophagus

- **Esophagus**
  - Transport of materials to the stomach

- **Stomach**
  - Chemical breakdown of materials via acid and enzymes; mechanical processing through muscular contractions

- **Small Intestine**
  - Enzymatic digestion and absorption of water, organic substrates, vitamins, and ions
Introduction

• Functions of the Digestive System
  • Ingestion
  • Mechanical processing
  • Digestion
  • Secretion
  • Absorption
  • Excretion
  • Compaction
Introduction

• Functions of the Digestive System (details)
  • **Ingestion**
    • Bringing food and liquids into the mouth
  • **Mechanical processing**
    • Chewing and swallowing food
  • **Digestion**
    • Chemical breakdown of food into nutrient form
  • **Secretion**
    • Secretion of products by the lining of the digestive tract
    • Secretion of products by the accessory organs of digestion
Introduction

• Functions of the Digestive System (continued)
  • **Absorption**
    • The movement of nutrients from the small intestine to the bloodstream
  • **Excretion**
    • The removal of waste products from the digestive tract
  • **Compaction**
    • Progressive dehydration of organic wastes
An Overview of the Digestive System

• The Components of the Digestive System
  • **Mouth**
    • Begins the process of mechanical digestion
  • **Esophagus**
    • Passage tube for food to enter the stomach
  • **Stomach**
    • Enzymatic breakdown of food
  • **Small intestine**
    • Enzymatic breakdown of food
    • Absorption of nutrients into the bloodstream
An Overview of the Digestive System

• The Components of the Digestive System (continued)
  • Salivary glands
    • Produce an enzyme to begin digesting food
  • Pancreas
    • Produces numerous enzymes that enter into the small intestine to digest food
  • Liver
    • Produces bile for the emulsification of fat in the small intestine
  • Gallbladder
    • Stores bile
An Overview of the Digestive System

• The Components of the Digestive System (continued)
  • **Large intestine**
    • Removes solid waste
    • Reabsorbs water into the bloodstream to prevent dehydration
    • Houses bacteria that produce vitamin K for blood clotting processes
Figure 25.1 Components of the Digestive System

- **Oral Cavity, Teeth, Tongue**: Mechanical processing, moistening, mixing with salivary secretions
- **Liver**: Secretion of bile (important for lipid digestion), storage of nutrients, many other vital functions
- **Gallbladder**: Storage and concentration of bile
- **Pancreas**: Exocrine cells secrete buffers and digestive enzymes; endocrine cells secrete hormones
- **Large Intestine**: Dehydration and compaction of indigestible materials in preparation for elimination
- **Salivary Glands**: Secretion of lubricating fluid containing enzymes that break down carbohydrates
- **Pharynx**: Muscular propulsion of materials into the esophagus
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- **Small Intestine**: Enzymatic digestion and absorption of water, organic substrates, vitamins, and ions

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An Overview of the Digestive System

- Histological Organization of the Digestive Tract
  - There are four major layers of the digestive tract
    - The mucosa
    - The submucosa
    - The muscularis externa
    - The serosa
Figure 25.2a Histological Structure of the Digestive Tract

Three-dimensional view of the histological organization of the general digestive tube

- **Mesenteric artery and vein**
- **Mesentery**
- **Plica**
- **Mucosa**
- **Submucosa**
- **Muscularis externa**
- **Serosa (visceral peritoneum)**

**Three-dimensional view of the histological organization of the general digestive tube**
An Overview of the Digestive System

- **The Mucosa**
  - The inner lining of the digestive tract
  - The mucosa of the small intestine makes up folds called **plicae**
    - Plicae increase the surface area for increased absorption

- **The Submucosa**
  - Surrounds the muscularis mucosae
  - Large blood vessels and lymphatics are in this layer

- **The Muscularis Externa**
  - Surrounds the submucosa
  - Dominated by smooth muscle fibers

- **The Serosa**
  - Covers the muscularis externa
  - Outermost layer of the digestive system
An Overview of the Digestive System

• Movement of digestive materials through the digestive tract
  • The muscularis externa propels material through the digestive tract
    • This is called peristalsis
  • Material is churned and fragmented and at the same time is propelled through the digestive tract
    • This is called segmentation
Peristalsis propels materials along the length of the digestive tract by coordinated contractions of the circular and longitudinal layers.
Segmentation movements primarily involve the circular muscle layers. These activities churn and mix the contents of the digestive tract, but do not produce net movement in a particular direction.
An Overview of the Digestive System

• Mesenteries
  • These are fused double sheets of peritoneal membrane
  • Stabilize the position of organs
  • Stabilize the position of blood vessels
  • Provide the attachment of blood vessels going to and from the small intestine
  • The mesentery between the stomach and the liver is the lesser omentum
  • The mesentery that extends from the stomach and covers the rest of the abdominal organs on the anterior surface is the greater omentum
The organization of mesenteries in the adult. This is a simplified view; the length of the small intestine has been greatly reduced.
The Oral Cavity

- Structures within the Oral Cavity
  - Tongue
  - Uvula
  - Palatoglossal arches
  - Salivary glands
  - Teeth
The Oral Cavity

- **Tongue**
  - Has numerous functions
    - Manipulation of food
    - Sensory analysis
    - Secretion of enzymes to aid in fat digestion
    - Movement for the formulation of words
• Tongue (continued)
  • Can be divided into different areas
    • **Body**: anterior portion of the tongue
    • **Root**: posterior portion of the tongue
    • **Dorsum**: superior portion of the tongue
    • The dorsum contains the **papillae**
    • Papillae contain the **taste buds**
The Oral Cavity

• Tongue (continued)
  • Small glands embedded in the tongue release *lingual lipase*
    • Begins digestion of fat
  • The inferior portion of the tongue is attached to the floor of the mouth via the *lingual frenulum*
The oral cavity as seen in sagittal section

- Hard palate
- Soft palate
- Nasal cavity
- Palatoglossal arch
- Opening of parotid duct
- Upper lip
- Cheek
- Dorsum of tongue
- Lower lip
- Gingiva
- Vestibule
- Body of tongue
- Root of tongue
- Pharyngeal tonsil
- Entrance to auditory tube
- Nasopharynx
- Uvula
- Palatine tonsil
- Fauces
- Palatopharyngeal arch
- Oropharynx
- Lingual tonsil
- Epiglottis
- Hyoid bone
- Laryngopharynx

The oral cavity as seen in sagittal section
Figure 25.5b  The Oral Cavity

- Frenulum of upper lip
- Hard palate
- Soft palate
- Fauces
- Palatoglossal arch
- Palatopharyngeal arch
- Palatine tonsil
- Lingual frenulum
- Gingiva
- Vestibule
- Frenulum of lower lip
- Openings of submandibular ducts

b An anterior view of the oral cavity as seen through the open mouth
The Oral Cavity

• Salivary Glands
  • There are three pairs of salivary glands
    • Parotid
    • Sublingual
    • Submandibular
  • All three glands produce salivary amylase, which partially digests carbohydrates
Lateral view showing the relative positions of the salivary glands and ducts on the left side of the head. Much of the left half of the body and the left ramus of the mandible have been removed. For the positions of the ducts inside the oral cavity, see Figure 25.5.
The Oral Cavity

• The Teeth
  • Types of teeth
    • Four incisors per jaw
    • Two cuspids per jaw
    • Four bicuspids per jaw
    • Four to six molars per jaw
The normal orientation of adult teeth. The normal range of ages at eruption for each tooth is shown in parentheses.
The Oral Cavity

• Teeth Anatomy
  • **Crown**
    • Made of enamel
    • Consists of dentine
    • Consists of pulp (highly vascularized)
  • **Neck**
    • Area of gingiva
  • **Root**
    • Consists of root canal
    • Consists of artery, vein, and nerve
Figure 25.7a Teeth

Diagrammatic section through a typical adult tooth

- Enamel
- Dentine
- Pulp cavity
- Gingiva
- Gingival sulcus
- Cement
- Periodontal ligament
- Root canal
- Bone of alveolus
- Apical foramen
- Branches of alveolar vessels and nerves
The Pharynx

• The Pharynx
  • Serves as a common passageway for food, liquid, and air
The Pharynx

- The Swallowing Process (three phases)
  - Buccal phase
    - The tongue pushes the food to the oropharynx area
  - Pharyngeal phase
    - The epiglottis closes over the glottis and swallowing begins
  - Esophageal phase
    - Upper esophageal sphincter opens and the bolus begins moving down the esophagus
Figure 25.8 The Swallowing Process

1. Buccal Phase
   - Hard palate
   - Tongue
   - Epiglottis
   - Bolus
   - Esophagus
   - Trachea

2. Pharyngeal Phase
   - Bolus
   - Soft palate
   - Epiglottis
   - Hard palate

3. Esophageal Phase
   - Peristalsis
   - Esophagus
   - Diaphragm
   - Stomach
   - Thoracic cavity
The Esophagus

- The bolus moves down the esophagus toward the stomach via peristaltic action.
- The esophagus passes through the diaphragm by passing through the esophageal hiatus.
- The esophagus has an upper esophageal sphincter and a lower esophageal sphincter.
The Esophagus

• Histology of the Esophageal Wall
  • The esophageal wall is made of:
    • Mucosa lining
    • Submucosa
    • Smooth muscle layer (muscularis mucosae)
    • Muscularis externa
    • The esophagus does not have a serosa layer
Figure 25.9a Histology of the Esophagus

Low-power view of a section through the esophagus

Muscularis mucosae
Mucosa
Submucosa
Muscularis externa
Adventitia

The esophagus

a Low-power view of a section through the esophagus
The Stomach

• The stomach consists of:
  • Lesser curvature
  • Greater curvature
  • Fundus
  • Body
  • Pylorus
Surface anatomy of the stomach showing blood vessels and relation to liver and intestines
The Stomach

• The stomach also consists of:
  • Gastric rugae
  • Circular muscles
  • Longitudinal muscles
  • Oblique muscles
Figure 25.11a Gross Anatomy of the Stomach

- Esophagus
- Fundus
- Cardia
- Longitudinal muscle layer
- Circular muscle layer
- Lesser curvature (medial surface)
- Greater curvature (lateral surface)
- Left gastroepiploic vessels
- Body
- Oblique muscle layer overlying mucosa
- Rugae
- Pyloric canal
- Pylorus
- Pyloric antrum

External and internal anatomy of the stomach
The Stomach

• Histology of the Stomach
  • Structures within the lining of the stomach
    • **Mucous surface cells**: produce copious amounts of mucus to protect the lining of the stomach
    • **Gastric pits**: produce cells to continuously replace lost stomach cells
    • **Mucous neck cells**: produce mucus to lubricate the food entering the stomach
The Stomach

• Histology of the Stomach
  • Structures within the lining of the stomach (continued)
    • **Parietal cells**: secrete intrinsic factor and hydrochloric acid
    • **Intrinsic factor** facilitates the absorption of vitamin $B_{12}$ from the small intestine into the bloodstream, which is used during erythropoiesis
    • **Hydrochloric acid** kills microorganisms and activates pepsinogen
The Stomach

• Histology of the Stomach
  • Structures within the lining of the stomach (continued)
    • **Chief cells**: secrete **pepsinogen**, which is converted to **pepsin** via the action of hydrochloric acid
    • **Enteroendocrine cells**: these are cells of the stomach that produce hormones. The G cells produce the hormone **gastrin**. Gastrin causes the parietal and chief cells to release their products
Figure 25.13ab Histology of the Stomach Wall

Diagrammatic view of the stomach and mucosa

- Esophagus
- Fundus
- Greater curvature
- Greater omentum
- Pylorus
- Rugae
- Body
- Cardia
- Lesser curvature
- Lesser omentum
- Diaphragm

Colorized SEM of the gastric mucosa

- Mucous epithelial cells
- Entrances to gastric pits

**a** Diagrammatic view of the stomach and mucosa

**b** Colorized SEM of the gastric mucosa
Diagrammatic view of the organization of the stomach wall. This corresponds to a sectional view through the area indicated by the box in part (b).
Figure 25.13cd Histology of the Stomach Wall

Diagrammatic view of the organization of the stomach wall. This corresponds to a sectional view through the area indicated by the box in part (b).

Micrograph of the gastric mucosa and a diagrammatic view of a gastric gland.

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The Stomach

• Regulation of the Stomach
  • Food enters the stomach and the stomach stretches
  • Stretching causes the G cells to release gastrin
  • Gastrin causes the parietal and chief cells to release their products
The Small Intestine

- Features of the small intestine
  - Approximately 20 feet in length
  - Approximately 1 to 2 inches in diameter
  - Consists of:
    - **Duodenum**: 10 inches long; receives digestive enzymes from the pancreas, bile from the liver and gallbladder
    - **Jejunum**: 8 feet long; most of the digestion and absorption occurs in the jejunum
    - **Ileum**: 12 feet long
Figure 25.14 Regions of the Small Intestine

- Duodenum
- Transverse colon
- Jejunum
- Ascending colon
- Descending colon
- Cecum
- Ileum
- Sigmoid colon
- Rectum
The Small Intestine

- Histology of the Small Intestine
  - The lining consists of:
    - **Plicae**
    - Each plica consists of numerous *microvilli* (villi)
    - Within each villus are capillaries
    - Villi will absorb the digested nutrients from the lumen of the small intestine into the capillaries
Figure 25.15a Histology of the Intestinal Wall

Characteristic features of the intestinal lining

- Plica circulares
- Villi
The Small Intestine

- Histology of the Small Intestine
  - Intestinal crypts
    - Appear at the base of the villi
    - New epithelial cells are formed in this area
    - Contain enteroendocrine cells that produce intestinal hormones, including cholecystokinin and secretin
Figure 25.15b Histology of the Intestinal Wall

The organization of villi and the intestinal crypts

Mucosa

Muscularis mucosae

Muscularis externa

Submucosa

Villi

Intestinal crypt

Lymphoid nodule

Lacteal

Submucosal artery and vein

Lymphatic vessel

Submucosal plexus

Circular layer of smooth muscle

Myenteric plexus

Longitudinal layer of smooth muscle

b The organization of villi and the intestinal crypts
The Small Intestine

- Histology of the Small Intestine
  - Each villus also consists of **lacteals**
  - Lacteals absorb material that cannot be absorbed by the capillaries
  - Examples would be large lipid complexes
Figure 25.15bc  Histology of the Intestinal Wall

The organization of villi and the intestinal crypts

Diagrammatic view of a single villus showing the capillary and lymphatic supply

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The Small Intestine

• Hormone Activity of the Small Intestine
  • Upon vagal stimulation, the enteroendocrine cells of the small intestine release:
    • **Secretin**: causes the liver to begin making bile; causes the pancreas to release buffers into the duodenum
    • **Cholecystokinin**: causes the pancreas to release digestive enzymes into the duodenum; causes the gallbladder to contract thus releasing stored bile into the duodenum
The Large Intestine

- Features of the Large Intestine
  - Approximately 5 feet in length
  - Approximately 3 inches in diameter
  - Consists of the following regions
    - Cecum
    - Ascending colon
    - Transverse colon
    - Descending colon
    - Sigmoid colon
    - Rectum
Figure 25.17a The Large Intestine

- **Gross anatomy and regions of the large intestine**
  - Rectum
  - Sigmoid colon
  - Sigmoid flexure
  - Taenia coli
  - Rectal artery
  - Sigmoid arteries and veins
  - Left colic artery
  - Inferior mesenteric artery
  - Inferior mesenteric vein
  - Descending colon
  - Left colic vein
  - Superior mesenteric vein
  - Left colic (splenic) flexure
  - Greater omentum (cut)
  - Descending colon
  - Left colic vein
  - Inferior mesenteric artery
  - Left colic artery
  - Haustra
  - Ascending colon
  - Right colic artery and vein
  - Middle colic artery and vein
  - Right colic (hepatic) flexure
  - Transverse colon
  - Inferior vena cava
  - Hepatic portal vein
  - Aorta
  - Splenic vein
  - Superior mesenteric artery
  - Inferior mesenteric vein
  - Intestinal arteries and veins
  - Ileum
  - Ileocecal valve
  - Cecum
  - Appendix
  - Omental appendices
  - Ileum
  - Rectal artery
  - Sigmoid arteries and veins
  - Taenia coli
  - Sigmoid flexure
  - Sigmoid colon
  - Rectum
The Large Intestine

• The Cecum
  • The ileum of the small intestine connects to the medial surface of the cecum
  • An **ileocecal valve** regulates the movement of material from the ileum to the cecum
  • The **vermiform appendix** attaches to the cecum
    • Appendix is about 9 cm in length
The Large Intestine

• The Colon
  • The regions of the colon are:
    • Ascending colon
    • Transverse colon
    • Descending colon
    • Sigmoid colon
  • Waste material goes “up” the ascending colon, around the hepatic flexure, “across” the transverse colon, around the splenic flexure, “down” the descending colon, around the sigmoid flexure, then to the sigmoid colon
The Large Intestine

• Other Features of the Large Intestine
  • The wall of the colon has pouches that allow for expansion called **haustra**
  • Longitudinal muscles called **taeniae coli** aid in the process of peristalsis
Figure 25.17a The Large Intestine

Gross anatomy and regions of the large intestine

- Rectum
- Sigmoid colon
- Sigmoid flexure
- Taenia coli
- Rectal artery
- Sigmoid arteries and veins
- Left colic artery
- Haustra
- Inferior mesenteric artery
- Left colic vein
- Descending colon
- Middle colic artery and vein
- Right colic artery and vein
- Ascending colon
- Right colic (hepatic) flexure
- Omental appendices
- Ileocecal valve
- Cecum
- Appendix
- Ileum
- Rectal artery
- Sigmoid arteries and veins
- Taenia coli
- Sigmoid flexure
- Sigmoid colon
- Rectum
The Large Intestine

- Histology of the Large Intestine
  - The walls lack villi
  - Has numerous goblet cells
  - Has very distinctive intestinal crypts
  - Produces lots of mucus to lubricate undigested material
  - Contains large lymphoid nodules
The Large Intestine

• The Rectum
  • Temporarily stores waste matter
  • The last portion of the rectum is the anal canal
  • The anal canal consists of anal columns
  • The anal canal ends at the anus
Figure 25.17c The Large Intestine

Rectum

Anal canal

Anal columns

Internal anal sphincter

External anal sphincter

Anus

Detailed anatomy of the rectum and anus

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Accessory Glandular Digestive Organs

• The accessory organs of digestion are:
  • Liver
  • Gallbladder
  • Pancreas
Accessory Glandular Digestive Organs

• The Liver
  • The largest visceral organ of the body
  • The liver is involved in:
    • Metabolic regulation
    • Hematological regulation
    • Bile production
Accessory Glandular Digestive Organs

• Metabolic Regulation
  • All blood leaving the digestive tract enters the liver through the hepatic portal system
  • Hepatocytes will adjust the circulating metabolites before the blood enters into systemic circulation
Accessory Glandular Digestive Organs

• Hematological Regulation
  • The liver is the largest blood reservoir of the body
  • As blood passes through the liver:
    • Phagocytic cells remove old or damaged erythrocytes
    • Liver cells synthesize plasma proteins for blood clotting
Accessory Glandular Digestive Organs

• Bile Production
  • Bile is made by liver cells
  • Bile is stored in the gallbladder
  • Bile is secreted into the duodenum when it is needed
  • Bile \textit{emulsifies} fat (from the diet) in the small intestine
    • This emulsification process makes it easier for lipase to do the actual digestion of fat
Figure 25.20a Anatomy of the Liver

Inferior view of a horizontal section through the upper abdomen showing the position of the liver relative to other visceral organs.

- Right lobe of liver
- Caudate lobe of liver
- Inferior vena cava
- Pleural cavity
- Cut edge of diaphragm
- Porta hepatis
- Falciform ligament
- Left lobe of liver
- Stomach
- Lesser omentum
- Aorta
- Spleen
- Sternum

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Accessory Glandular Digestive Organs

• Histology of the Liver
  • The liver is divided into numerous sections called **lobules**
  • Each lobule is separated by the **interlobular septum**
  • The center of each lobule consists of a vein from the **hepatic portal system**
  • The hepatocytes are arranged in such a manner forming cellular lines extending from the central vein outward
Accessory Glandular Digestive Organs

• Histology of the Liver
  • Spaces are created between the lines of **hepatocytes**; these spaces are called **sinusoids**
  • Sinusoids consist of:
    • Capillaries: leading to the central vein
    • **Kupffer cells**: phagocytic cells of the liver
• Histology of the Liver (continued)
  • Each lobule of the liver has a hexagonal shape
  • At each of the six corners is:
    • Branch of the hepatic portal vein
    • Branch of the bile duct
    • Branch of the hepatic artery proper
    • The above three branches form the hepatic triad
Figure 25.21a Liver Histology

Diagrammatic view of lobular organization

Interlobular septum  Bile duct  Branch of hepatic portal vein  Portal area  Bile ductules

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Figure 25.21b Liver Histology

- Central vein
- Kupffer cells
- Sinusoid
- Bile canaliculi
- Branch of hepatic portal vein
- Bile duct
- Branch of hepatic artery proper
- Hepatocytes

Magnified view showing the portal area and central vein
Accessory Glandular Digestive Organs

• Bile Secretion and Transport
  • **Hepatocytes** produce bile
  • Bile enters the bile **canaliculi**
  • Bile travels to the **bile ducts**
  • Bile then collects in the **left and right hepatic ducts**
  • Bile travels through the **common hepatic duct**
  • Bile can travel through the **common bile duct** to the duodenum or travel through the **cyst duct** into the gallbladder for storage
Figure 25.22ac  The Gallbladder and Associated Bile Ducts

A view of the inferior surface of the liver showing the position of the gallbladder and ducts that transport bile from the liver to the gallbladder and duodenum.

A portion of the lesser omentum has been cut away to make it easier to see the relationships among the common bile duct, the hepatic duct, and the cystic duct.
Accessory Glandular Digestive Organs

• The Pancreas
  • The pancreas is posterior to the stomach
    • **Pancreatic duct**: delivers secretions from the pancreas to the duodenum (through the hepatopancreatic sphincter)
Gross anatomy of the pancreas. The head of the pancreas is tucked into a curve of the duodenum that begins at the pylorus of the stomach.
Accessory Glandular Digestive Organs

• Histology of the Pancreas
  • Consists of lobules
  • Within each lobule are acinar cells and pancreatic islets
    • **Acinar cells** produce digestive enzymes; enzymes travel through the pancreatic duct to the small intestine
    • **Pancreatic islets** produce hormones; hormones enter into the bloodstream to travel to target organs
Figure 25.23c The Pancreas

Histology of the pancreas showing exocrine and endocrine cells

Pancreatic acini (exocrine)

Pancreatic islet (endocrine)

Duct

Pancreas

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Accessory Glandular Digestive Organs

• Pancreatic Enzymes
  • **Lipases**: digest lipids
  • **Carbohydrases**: digest carbohydrates
  • **Nucleases**: digest nucleic acids
  • **Proteininases**: digest protein

• Pancreatic hormones
  • **Insulin**
  • **Glucagon**
  • **Somatostatin**
Accessory Glandular Digestive Organs

• The Regulation of Pancreatic Secretion
  • Cholecystokinin from the small intestine will cause the pancreas to release its digestive enzymes
  • Secretin from the small intestine will cause the pancreas to release buffers
  • When food leaves the stomach and enters the duodenum, the chyme is mixed with acid in the stomach. Therefore, acidic chyme is entering the duodenum. Buffers are used to maintain a normal small intestine pH of about 7 or 8
Aging and the Digestive System

- Stem cell reproduction declines
  - Tissue repair decreases – the tissues become more fragile
- Smooth muscle tone decreases
  - Motility decreases – constipation increases
- Cumulative damage becomes apparent
  - Gradual loss of teeth
  - Accumulation of toxins over time
- Cancer rate increases
  - Colon cancer
  - Pharyngeal cancer