THE DIGESTIVE SYSTEM
Topic 4: Secretion

Page 1: Title Page
- Digestive system secretion involves the production and release of juices and hormones by the GI tract and its accessory glands.

Page 2: Goals
- To list the secretions of the digestive tract
- To describe the function of each secretion
- To describe the control of secretion throughout the digestive tract.

Page 3: Large volumes of fluid move in and out of the GI tract
- For a typical daily consumption of food (800 g) and fluid (2.0 L):
  - About 1.5 L of saliva is secreted into the mouth.
  - About 2.0 L of gastric juice are produced
  - The pancreas delivers about 1.5 L of pancreatic juice to the duodenum
  - The liver/gallbladder delivers about 0.5 L of bile into the duodenum
  - The small intestine produces about 1.5 L of fluid
  - The total of all of the above secretions = about 9.0 L
- The small intestine absorbs about 8.5 L of fluids & most of the ingested food
- The large intestine absorbs about 0.35 L of fluid, some salts and vitamin K
- Although the GI tract contains about 9.0 L of fluid every day, only about 0.15 L is eliminated with the feces
- Of the approximately 800 g of food ingested in a typical daily diet, only about 50 g (< 10%) of undigested food are eliminated as feces

Page 4: Salivary glands secrete saliva
- The extrinsic salivary glands include the paired parotid, submandibular and sublingual glands
• Parotid glands produce serous fluid containing enzymes, electrolytes, and limited mucin
• Submandibular and sublingual glands produce a more viscous fluid than parotid glands
• Saliva functions include:
  o Protection (esp. antibacterial lysozyme and IgA antibodies)
  o Taste (dissolved food chemicals)
  o Lubrication (mucus)
  o Digestion (esp. starch via amylase)

**Page 5: Nerves control salivation**
• The control of salivation is almost exclusively via the autonomic nervous system
• Both parasympathetic and sympathetic innervation stimulate salivation
• Both the facial nerve (CN VII) and glossopharyngeal nerve (CN IX) carry parasympathetic nerve fibers to the salivary glands
• Parasympathetic stimulation causes mostly watery, enzyme-rich secretion of the salivary glands
• The thought, sight, and/or smell of food stimulate the salivatory nuclei in the medulla to increase parasympathetic innervation to the salivary glands
• Acidic substances and the pressure of chewing also cause an increase in parasympathetic innervation to the salivary glands
• Nausea and intestinal irritation also stimulate salivation
• Fear, fatigue, sleep, and dehydration inhibit salivation
• Sympathetic stimulation of the salivary glands causes them to produce small amounts of viscous (mucus) saliva
• *LABEL THE NERVE FIBERS BELOW INDICATING WHICH ARE SYMPATHETIC AND WHICH ARE PARASYMPATHETIC*
Page 6: The esophagus secretes mucus
- The only secretion of the esophagus is mucus

Page 7: Gastric secretions are produced regionally
- The gastric mucosa produces exocrine, endocrine, and paracrine secretions*
- Exocrine secretions, collectively called gastric juice, include mucus, pepsinogen, HCl, and intrinsic factor; they are released into the stomach lumen as follows:
  - Mucus – throughout the stomach
  - Pepsinogen – throughout the stomach
  - HCl – fundus and body
  - Intrinsc factor (IF) – fundus and body

*Play the animation on page 7 of the Secretion topic to help reinforce this regional distribution of chemical secretions in the stomach.
- Enteroendocrine cells in the pylorus release gastrin into the bloodstream; it returns to the stomach to exert its effects

- Paracrine cells in the fundus and body of the stomach release histamine into the lamina propria interstitium

**Page 8: Specialized cells produce each gastric secretion**
- The stomach mucosa is invaginated to form deep wells called gastric pits; gastric glands are located within the pits
• Gastric glands produce mucus and pepsinogen throughout the stomach
• Gastric glands in the body and fundus produce HCl and intrinsic factor and other cells in the gastric pits of these regions produce histamine
• Two types of mucus are produced in the stomach
  o Thick, alkaline mucus in the luminal mucosa
  o Thin, watery mucus from the mucus neck cells of the gastric pits
• Parietal cells in the gastric glands produce HCl and IF
• Chief cells, a.k.a. zymogenic cells (a zymogen is an inactive proteolytic enzyme) in the gastric glands produce pepsinogen
• Some cells in the gastric glands of the pylorus secrete gastrin while other secrete mucus and pepsinogen

Page 9: The stomach produces many secretions (The interactive animations on page 9 are really great here; play them again to help “digest” this material)
• Mucus protects the stomach from self-digestion (a.k.a. auto-digestion) by neutralizing stomach acid and inhibiting pepsin (a proteolytic or protein-digesting enzyme)
• Mucus + tight junctions between cells in the gastric mucosa are collectively known as the gastric mucosal barrier
• Only aspirin and alcohol are absorbed across the stomach’s mucosal epithelium
• When aspirin and/or alcohol pass through the stomach’s mucosal barrier, they destroy cells, thus leaving the stomach’s wall susceptible to peptic ulcer development
• HCl, secreted by parietal cells, lowers the luminal pH to between 1.5-2 (remember that because pH is on a logarithmic scale, each point change on the scale represents a 10-fold change in pH; in the stomach, for example, a pH of 2 is about 100,000 times more acidic than the pH of near 7 in the mouth)
• The highly acidic gastric environment is lethal to most bacteria and other microorganisms
• HCl function includes:
  o breaking down plant cell walls (mostly cellulose) and connective tissue
  o denaturing proteins
  o converting pepsinogen to pepsin (optimal pH near 2.0)
• Pepsin, a proteolytic enzyme, begins the chemical digestion of proteins in the stomach
• Parietal cells also secrete intrinsic factor (IF), which is required by the intestine to absorb vitamin B$_{12}$

• Vitamin B$_{12}$ is needed for maturation of RBCs – without it, pernicious anemia may develop
• Peptides in the stomach trigger the release of gastrin from G-cells into the bloodstream
• Gastrin stimulates HCl secretion by parietal cells and histamine secretion by paracrine cells
• Histamine acts synergistically with gastrin to stimulate HCl release from parietal cells
Page 10: Nerves and hormones control gastric secretion*

- The thought, sight, and/or smell of food triggers an increase in gastric juice secretion from chief and parietal cells via the vagus nerves (a long neural reflex)

- Indirectly, long neural reflexes cause increased gastric juice secretion by stimulating an increased production of gastrin from the G-cells
- Gastrin, in turn, stimulates the production of histamine from paracrine cells
- Histamine acts together with gastrin to stimulate increased release of HCl
- The gastric phase of digestion begins when the stomach contains peptides and is distended
- Both neural reflexes and the hormone gastrin mediate increased gastric juice secretion during the gastric phase
- The intestinal phase of digestion begins when the meal enters the duodenum
- Both neural reflexes and hormones (CCK & secretin) mediate the response of the stomach during the intestinal phase
- Lipids in the duodenum cause the release of CCK, which slows gastric emptying
- Acid in the duodenum causes the release of secretin
- The sympathetic nerves inhibit digestive activities while the parasympathetic nerves stimulate them

*Filling in this table on page 10 should help to reinforce these concepts.
Page 11: The pancreas secretes enzymes and bicarbonate into the small intestine

- Most chemical digestion and absorption occur in the small intestine
- The secretions that initiate chemical digestion in the small intestine come from the exocrine (acinar) pancreas

- Bile, produced by the liver and stored in/released from the gall bladder, emulsifies fats to increase their surface area for subsequent chemical digestion by pancreatic lipases
- The exocrine pancreas produces two types of pancreatic juice:
  - enzyme-rich pancreatic juice (stimulated by CCK)
  - bicarbonate-rich pancreatic juice (stimulated by secretin)
- Exocrine pancreas secretions are delivered through the hepatopancreatic sphincter (a.k.a. sphincter of Oddi) into the duodenum via the pancreatic duct
- Exocrine pancreatic secretions include the following enzymes:
  - Proteases (a.k.a. proteolytic enzymes)
  - Amylase
  - Lipase
- Pancreatic proteases (in zymogenic or inactive form) include trypsinogen, chymotrypsinogen, procarboxypeptidase
- Enterokinase in the intestinal cell membranes, converts (activates) trypsinogen into trypsin
- Once produced, trypsin activates more trypsinogen in a positive feedback mechanism
- Duct cells secrete bicarbonate into the duodenum to neutralize acid from the stomach; this produces an optimal pH environment for pancreatic digestive enzymes to function in
- The endocrine pancreas secretes two antagonistic hormones:
  - Insulin – regulates the absorptive state
  - Glucagon – regulates the post-absorptive state
The liver secretes bile and bicarbonate into the small intestine

- The main digestive function of the liver is to produce bile
- Bile backs up into the gallbladder for storage/concentration when the hepatopancreatic sphincter (of Oddi) is closed
- The two components of bile are:
  - Organic compounds (esp. bile salts) to emulsify fats
  - Bicarbonate solution
- Bile emulsifies fat to increase surface area for subsequent digestion with pancreatic lipase
- The organic compounds of bile include
  - Bile salts
  - Lecithin
  - Cholesterol
  - Bilirubin
- Cholesterol and bilirubin are eliminated in the feces
- Bile salts are recycled; they stimulate the secretion of bile from the liver (via the enterohepatic circulation – play the interactive animation here to visualize this circulation)
- When stimulated by secretin (“nature’s antacid”), bile duct cells secrete a bicarbonate solution that is identical to pancreatic bicarbonate; this protective function of the liver neutralizes acidic chyme in the duodenum
The small intestine secretes fluid, mucus, and hormones

- The small intestine secretes watery mucus and hormones
- Mucus, secreted by abundant epithelial goblet cells, protects the intestinal mucosa from auto-digestion by proteases and acid
- Intestinal glands or crypts (of Lieberkuhn) secrete water and electrolytes to combine with mucus to form intestinal juice
- Intestinal epithelial cells contain brush border enzymes in their microvilli cell membranes; these enzymes complete the chemical digestion of foodstuffs
Page 14: Nerves and hormones control secretions entering the small intestine*
- Fat in the duodenum causes it to release of CCK, which triggers contraction of the gall bladder and release of bile into the duodenum
- Acid in the duodenum causes it to release of secretin, which causes the release of bicarbonate into the duodenum from the pancreas and liver
- Distention of the small intestine and/or acidic/hypertonic chyme trigger a neural reflex that increases intestinal juice secretion
- Sympathetic stimulation decreases intestinal digestive activity while parasympathetic stimulation increases it

* Complete the interactive table here for reinforcement

Page 15: The large intestine secretes mucus and bicarbonate
- Alkaline mucus containing bicarbonate and potassium ions is secreted by the large intestine for protection from bacterial acid
- Mucus lubricates feces and protects the large intestine wall from mechanical damage
- Both long and short reflexes, triggered by mechanical stimulation and acid, increase secretion of alkaline mucus from the large intestine
Study Questions on Secretion: Digestive System:

1. (Page 3.) List the general secretions of the digestive tract from mouth to anus.
2. (Page 3.) Where do the majority of ingested materials get absorbed?
3. (Page 3.) Approximately what percentage of ingested solids is eliminated as feces? Liquids?
4. (Page 4.) List the three pair of salivary glands and briefly describe their secretions.
5. (Page 5.) Which cranial nerves send parasympathetic innervation to the salivary glands?
6. (Page 5.) Describe the difference in saliva composition and volume as stimulated by the parasympathetic versus the sympathetic nervous systems.
7. (Page 7.) List the exocrine secretions of the stomach and briefly describe the functions of each.
8. (Page 7.) Which hormone do stomach cells release?
9. (Page 8, 9.) List the cells found in the gastric glands, the secretion(s) produced by each cell type, and briefly describe the function of each secretion.
10. (Page 10.) Discuss the relationship between long reflexes, gastrin, histamine, and HCl production during the cephalic phase of digestion.
11. (Page 10.) Describe the roles of CCK and secretion during the intestinal phase of secretion.
12. (Page 10.) Why are aspirin and alcohol problematic in the gastric environment?
13. (Page 11.) What is the source and role of bile in the digestive process?
14. (Page 11.) What are the two types of pancreatic juice? What are the roles of each? What is the stimulus for the secretion of each type?
15. (Page 11.) Discuss the activation and function of the pancreatic proteases.
16. (Page 11.) What are the two endocrine secretions of the pancreas and when do they function?
17. (Page 11, 12.) Discuss the cooperative effort of bile and pancreatic lipase in the digestion of dietary lipids.
18. (Page 12.) List the chemical constituents of bile.
19. (Page 12.) What is the relationship between the liver and the gall bladder regarding bile?
20. (Page 13.) List the chemical secretions of the small intestine and briefly describe the function of each.
21. (Page 13.) What are brush border enzymes?
22. (Page 14.) Compare and contrast the chemical and mechanical stimuli for secretions that function in the small intestine.
23. (Page 15.) List the secretions of the large intestine and briefly describe the function of each.