

# Biology 204: Introduction to Physiology

## The Digestive System II

### I. Pancreatic and biliary secretions

#### A. Exocrine pancreas

1. Anatomy (see Fig. 16-18)
  - a) Acini
  - b) Ducts
  - c) Pancreatic duct
  - d) Common bile duct
2. Duct cells secrete 1–2 L per day of an aqueous solution of  $\text{NaHCO}_3$ .
  - a) This neutralizes the chyme, and in fact makes it alkaline.
  - b) The process is the reverse of acid secretion in the stomach.
  - c) Quantitatively,  $\text{HCO}_3^-$  secretion in the pancreas about equals HCl secretion in the stomach, so blood pH is not seriously perturbed.
3. Acinar cells secrete zymogens (inactive precursors of enzymes) and active enzymes
  - a) Pancreatic amylase
  - b) Proteinase precursors
    - (1) Trypsinogen (activated by enterokinase in the gut)
    - (2) Chymotrypsinogen (activated by trypsin)
    - (3) Procarboxypeptidase (activated by trypsin)

- c) Pancreatic nucleases
    - (1) Ribonuclease (RNase)
    - (2) Deoxyribonuclease (DNase)
  - d) Pancreatic lipase: hydrolyses triglycerides
4. Regulation of pancreatic secretion
- a) Acid in the duodenum triggers the release of secretin, which stimulates the duct cells to secrete  $\text{NaHCO}_3$ .
  - b) Fat and protein in the duodenum triggers the release of cholecystokinin, which stimulates the acinar cells to secrete enzymes.
  - c) Both secretin and cholecystokinin have trophic effects on the pancreas.

**B. *Liver and the biliary system***

1. Physiological functions of the liver
- a) Metabolic processing of nutrients
  - b) Degradation and detoxification of hormones, body wastes, pharmacological agents, etc.
  - c) Synthesis of all plasma proteins except immunoglobulins
  - d) Storage of glycogen, fats, iron, copper, vitamins
  - e) Activation of vitamin D
  - f) Removal of worn-out red blood cells and bacteria, thanks to the action of macrophages
  - g) Secretion of bile, containing bile salts, cholesterol, and bilirubin
2. Anatomy (see Figs. 16-20 and 16-22; no overhead)
- a) Hepatic artery

- b) Portal vein
  - c) Hepatic vein
  - d) Bile duct
  - e) Gallbladder
  - f) Common bile duct
  - g) Sphincter of Oddi
3. Histology: the hexagonal lobule (see Fig. 16-21)
- a) Branches of hepatic artery
  - b) Branches of portal vein
  - c) Central vein
  - d) Sinusoids
  - e) Kupffer cells
  - f) Branches of the bile duct
  - g) Bile canaliculi
  - h) Hepatocytes
4. Composition of bile
- a) 250 mL to 1 L per day of alkaline fluid containing
    - b) Bile salts
      - (1) Derivatives of cholesterol
      - (2) Act as detergents
      - (3) Are reabsorbed in the ileum and recirculate back to the liver through the portal vein.
    - c) Cholesterol

- (1) Sometimes precipitates out to form gallstones
- (2) Is also recycled
- (3) Intestinal cholesterol binding resins can lower blood cholesterol
- d) Lecithin
- e) Bilirubin
  - (1) Sometimes precipitates out to form gallstones
  - (2) Breakdown product of heme
  - (3) Neurotoxic
  - (4) Jaundice
- 5. Regulation of bile secretion
  - a) Positive feedback: recirculated bile stimulates bile secretion
  - b) Secretin stimulates bile secretion
  - c) Some minor stimulation by vagus nerve
  - d) Cholecystokinin stimulates contraction of the gallbladder and relaxation of the sphincter of Oddi.
- 6. Liver pathology
  - a) Hepatitis: inflammation of liver
    - (1) Viral
    - (2) Toxic
  - b) Cirrhosis: hepatocytes permanently replaced by connective tissue

## II. Small intestine: site of most digestion and absorption

### A. Anatomy

1. 6.3-m (21-ft) tube, 2.5 cm (1 in) in diameter
2. First 20 cm (8 in): **duodenum**
3. Second 2.5 m (8 ft): **jejunum**
4. Third 3.6 m (12 ft): **ileum**

**B. Small intestine motility**

1. Segmentation contractions mix chyme; they are **not** peristaltic (see Fig. 16-25)
2. Frequency of segmentation contractions decreases with length, however, so chyme is propelled forward slowly
3. Motility originates in myogenic activity of the intestine itself
4. Motility enhanced by
  - a) Distention
  - b) Gastrin
  - c) Parasympathetic activity
5. Motility inhibited by
  - a) Sympathetic activity
6. Transit time: 3–5 hr
7. After most absorption is complete, segmentation contractions are replaced by weak migrating (peristaltic) contractions
8. Reflux of bacteria from large intestine into the small intestine is prevented by
  - a) Ileocecal valve
  - b) Ileocecal sphincter (relaxed by gastrin)

**C. Small intestine secretion: 1.5 L succus entericus contains no digestive enzymes!**

**D. Small intestine digestion**

1. Lumenal digestion by pancreatic enzymes
2. Other enzymatic activities are in (on?) the intestinal wall itself
  - a) Enterokinase activates trypsin
  - b) Amino peptidase further hydrolyses oligopeptides to amino acids
  - c) Disaccharidases
    - (1) Maltase
    - (2) Sucrase
    - (3) Lactase
      - (a) Lactose intolerance

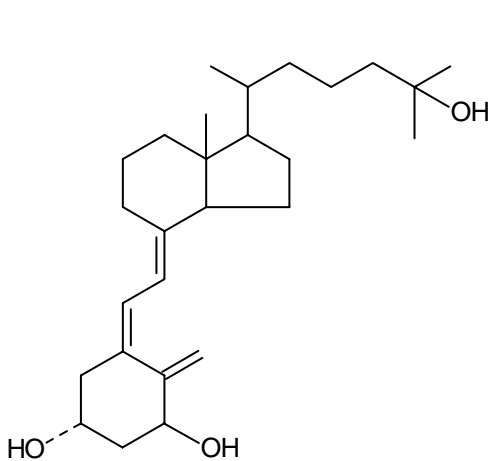
**E. Small intestinal absorption**

1. About 50% excess capacity: the usual tennis court
2. Anatomy maximizes surface-to-volume relationship (see Fig. 16-27)
  - a) Folds, not usually called rugae, oddly enough
  - b) Villi and crypts of Lieberkühn
    - (1) Central lacteal
  - c) Microvilli form the intestinal brush border
  - d) Tight junctions
  - e) Rapid cellular turnover: "100 million intestinal cells shed per minute!"
    - (1) "The entire trip from crypt to tip averages about 3 days, so entire epithelial lining...is replaced every 3 days."
3. Gluten enteropathy associated with loss of villi and microvilli

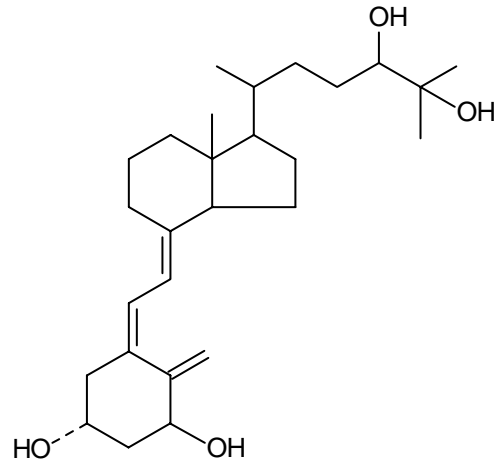
4. NaCl absorption
  - a) Passive diffusion of  $\text{Na}^+$  between epithelial cells
  - b) Cotransport of  $\text{Na}^+$  into epithelial cells with disaccharides and amino acids on luminal surface
  - c) Active transport of  $\text{Na}^+$  out of cell at basolateral surface
  - d)  $\text{Cl}^-$  follows passively through channels
5. Water absorption: follows  $\text{Na}^+$  movement
6. Carbohydrate absorption (see Fig. 16-30)
  - a) Cotransport of  $\text{Na}^+$  into epithelial cells with disaccharides at luminal surface; disaccharides split as they enter the cell
  - b) Absorption of a strictly limited repertoire of disaccharides is indirectly dependent upon the basolateral  $\text{Na}^+-\text{K}^+$  ATPase
7. Amino acid absorption (see Fig. 16-31)
  - a) Cotransport of  $\text{Na}^+$  into epithelial cells with amino acids on luminal surface
  - b) Absorption of amino acids is indirectly dependent upon the basolateral  $\text{Na}^+-\text{K}^+$  ATPase
  - c) Transport of oligopeptides into epithelial cells by aminopeptidases; oligopeptides split as they enter the cell
  - d) Facilitated diffusion of amino acids into interstitial fluid at basolateral surface
8. Triglyceride absorption (see Fig. 16-32)
  - a) Passive diffusion of monoglycerides and fatty acids into epithelial cells
  - b) Resynthesized into triglycerides in the cell
  - c) Packaged with apolipoprotein

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- d) Lipoprotein extruded from the cell by exocytosis into the interstitial fluid as chylomicrons
  - e) Chylomicrons taken up by central lacteals
  - f) Eventually find their way to the closed circulatory system via the thoracic duct
9. Bile salts and vitamin B<sub>12</sub> absorbed by the terminal ileum
10. Nucleic acids?!?!
11. Iron
- a) Actively transported from the lumen into the epithelial cells
  - b) Stored as ferritin in the intestinal epithelium; lost in three days by cell sloughing if not mobilized
  - c) Carried by transferrin in blood
  - d) Iron deficiency is a worldwide problem, particularly in women<sup>1</sup>
12. Calcium absorption: regulated by sunshine vitamin D



1,25-Dihydroxycholecalciferol



1,24,25-Trihydroxycholecalciferol

13. Most absorbed nutrients immediately pass through the liver for processing via the hepatic portal circulation

<sup>1</sup> SCRIMSHAW, N.S. Iron deficiency. *Sci.Am.* **265**(4): 46–52, October 1991.

14. Under normal circumstances, intestinal absorption keeps pace with gastrointestinal secretion (see Table 16-7)

**Table 16-7. Daily inputs and outputs of gastrointestinal system.**

Source	Type	Volume or Mass
Ingested	Food eaten	1,250 g
	Fluid drunk	1,250 mL
Secreted	Saliva	1,500 mL
	Gastric juice	2,000 mL
	Pancreatic juice	1,500 mL
	Bile	500 mL
	Intestinal juice	<u>1,500 mL</u>
<b>Total input</b>		<b>9,500 mL</b>
Absorbed	Small intestine	9,000 mL
	Large intestine	350 mL
Feces		<u>150 g</u>
<b>Total output</b>		<b>9,500 mL</b>

15. Biochemical balance among the stomach, pancreas, and small intestine is usually maintained (see Fig. 16-34).
- a) There should be no net gain or loss of  $\text{Na}^+$ ,  $\text{Cl}^-$ ,  $\text{H}^+$ ,  $\text{HCO}_3^-$ , or water.
  - b) Diarrhea is characterized by excessive volume of liquid feces
    - (1) Increased motility caused by local irritation
    - (2) Osmotic imbalances, e.g. lactose intolerance
    - (3) Bacterial toxins, e.g. cholera

### III. Large intestine: primarily a drying and storage organ

#### A. Anatomy (see Fig. 16-35)

1. Three longitudinal bands of muscle called taenia coli divide lumen into haustra

#### B. Large intestine motility

1. Haustral contractions: slow, irregular segmenting contractions
2. Gastrocolic reflex mediated by gastrin
3. Marked increase in motility after meals results in mass movement
4. Defecation reflex
  - a) Internal anal sphincter relaxes
  - b) External (voluntary) anal sphincter must relax also

**C. *Large intestine secretion and absorption***

1. Secretion: alkaline mucus lubricates, and neutralizes bacterial fermentation products
2. Absorption: water and salt

**D. *Composition of the feces; flatus***

1. Feces: 100 mL water plus 50 g bacteria and undigested food
2. Flatus: swallowed air plus gas from bacterial fermentations
  - a) H<sub>2</sub>
  - b) CO<sub>2</sub>
  - c) CH<sub>4</sub>
  - d) H<sub>2</sub>S
3. Borborygmi = gurgles