# Physiology of Digestive System

By

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3rd Year/ Lecture 5

# Proteins

- Amino acids absorbed by the small intestine come from three sources
  - Dietary proteins
  - Digestive enzymes digested by each other
  - Sloughed epithelial cells digested by enzymes
- Endogenous amino acids from last two sources total about 30 g/day
- Exogenous amino acids from our diet total about 44 to 60 g/day

# Proteins

- Proteases (peptidases)—enzymes that digest proteins
  - Begin their work in the stomach in optimum pH of 1.5 to 3.5
  - Pepsin hydrolyzes any peptide bond between tyrosine and phenylalanine
    - Pepsin digests 10% to 15% of dietary protein into shorter peptides and some free amino acids

# Proteins

- Continue to digest proteins in the small intestine
  - Pepsin inactivated when it passes into the duodenum and mixes with the alkaline pancreatic juice (pH 8)
  - Pancreatic enzymes trypsin and chymotrypsin take over the process
  - Hydrolyzing polypeptides into even shorter oligopeptides

# Proteins

Cont.

- Oligopeptides taken apart one amino acid at a time by three more enzymes
  - Carboxypeptidase—removes amino acids from
    - COOH end of the chain
  - Aminopeptidase: removes them from the $-NH_2$ end
  - Dipeptidase—split dipeptides in the middle and release two free amino acids
- Carboxypeptidase is a pancreatic secretion
- Aminopeptidase and dipeptidase are brush border enzymes

# Protein Digestion and Absorption



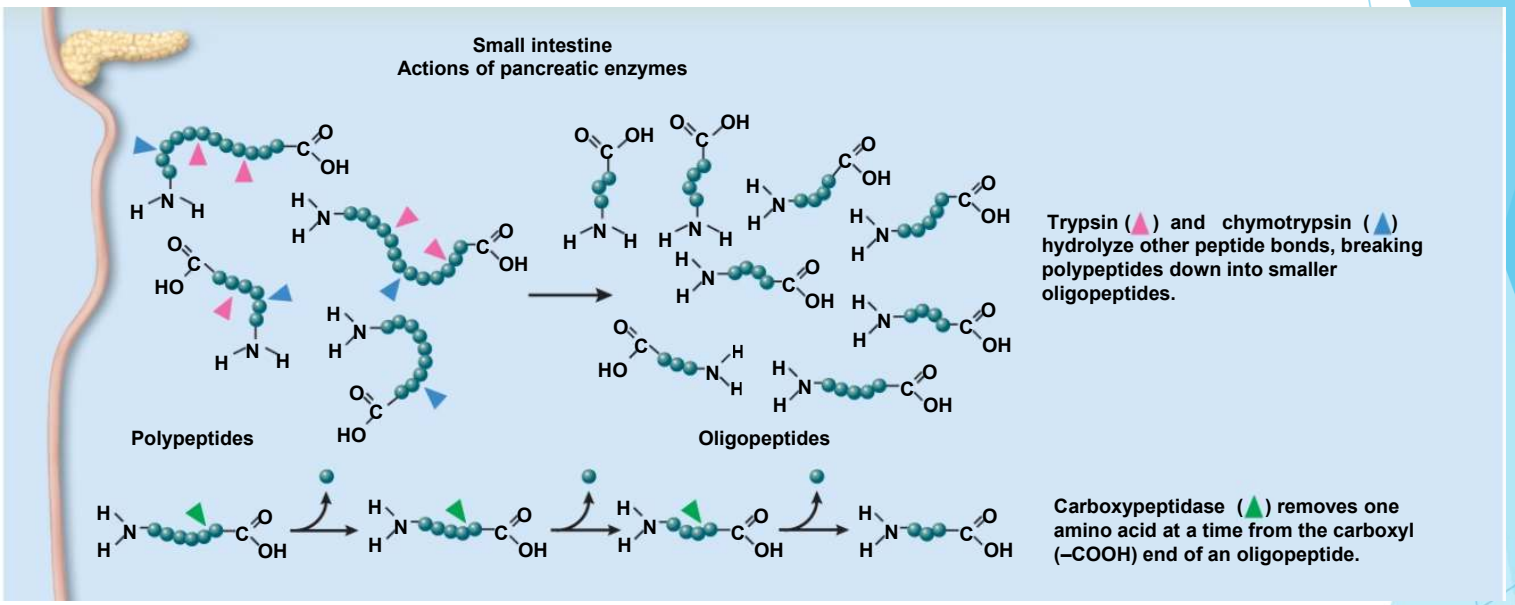


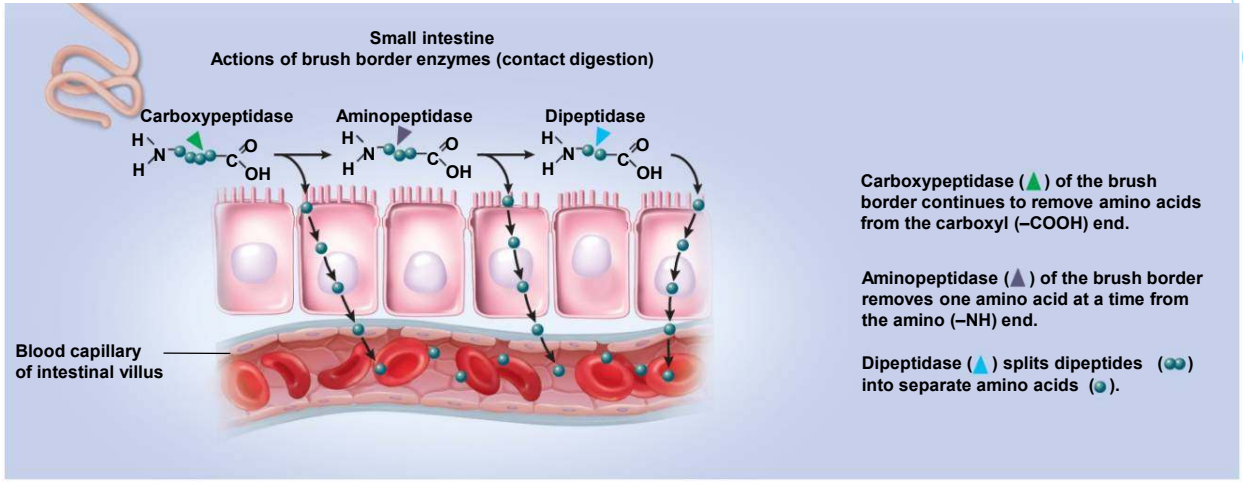

Figure 25.29

- Pancreatic enzymes take over protein digestion in small intestine by hydrolyzing polypeptides into shorter oligopeptides

# Protein Digestion and Absorption

Figure 25.29






- Brush border enzymes finish task, producing free amino acids that are absorbed into intestinal epithelial cells
  - Sodium-dependent amino acid cotransporters move amino acids into epithelial cells
  - Facilitated diffusion moves amino acids out into bloodstream
- Infants absorb proteins by pinocytosis (maternal IgA) and release into the blood by exocytosis

# Lipids

- Hydrophobic quality of lipids makes their digestion and absorption more complicated than carbohydrates and proteins
- Lipases—fat-digesting enzymes
  - Lingual lipase secreted by the intrinsic salivary glands of the tongue
    - Active in mouth, but more active in stomach along with gastric lipase
    - 10% to 15% of lipids digested before reaching duodenum

# Lipids

Cont.

- Pancreatic lipase: in the small intestine; digests most of the fats
- Fat enters duodenum as large globules exposed to lipase only at their surface
- Globules broken up into smaller emulsification droplets by certain components of bile
  - Lecithin and bile acids

# Lipids

Cont.

- Agitation by segmentation breaks up the fats into droplets as small as 1 μm in diameter
- The coating of lecithin and bile acids keeps it broken up, exposing far more of its surface to enzymatic action
- There is enough pancreatic lipase in the small intestine after a meal to digest the average daily fat intake in as little as 1 to 2 min.

# Lipids

Cont.

- Lipase acts on triglycerides
  - Removes the first and third fatty acids from glycerol backbone
  - Leaves the middle one
  - The product of lipase action are two free fatty acids (FFAs) and a monoglyceride

# Fat Digestion and Absorption



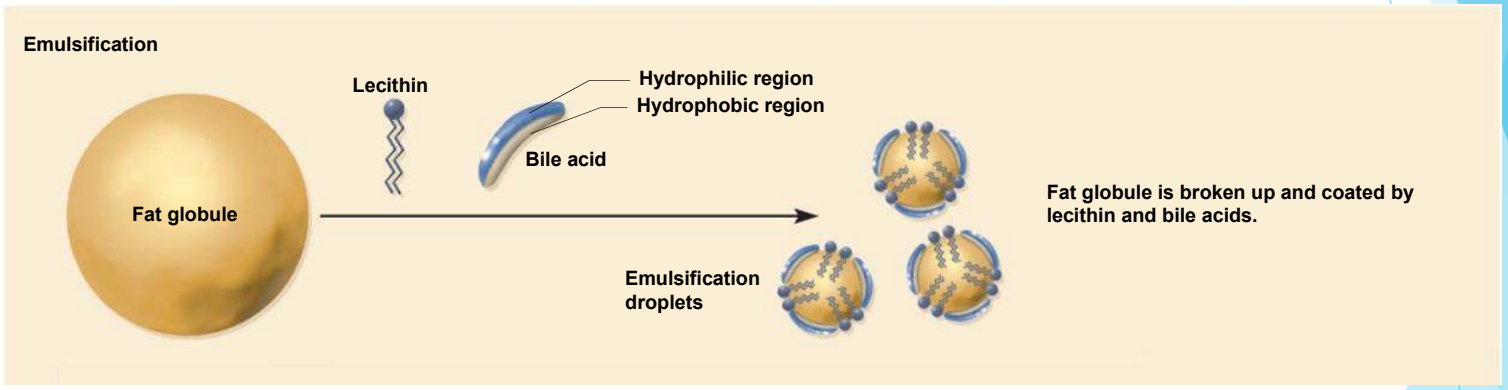



Figure 25.30

# Lipids

- Absorption of free fatty acids, monoglycerides, and other lipids depends on minute droplets in the bile called micelles, from the liver
  - Micelles pass down the bile duct into the duodenum
    - Where they absorb fat-soluble vitamins, more cholesterol, and the FFAs and monoglycerides produced by fat digestion
  - They transport lipids to the surface of the intestinal absorptive cells
  - Lipids leave the micelles and diffuse through the plasma membrane into the cells
  - Micelles are reused, picking up another cargo of lipid, transporting them to the absorptive cells

# Fat Digestion and Absorption



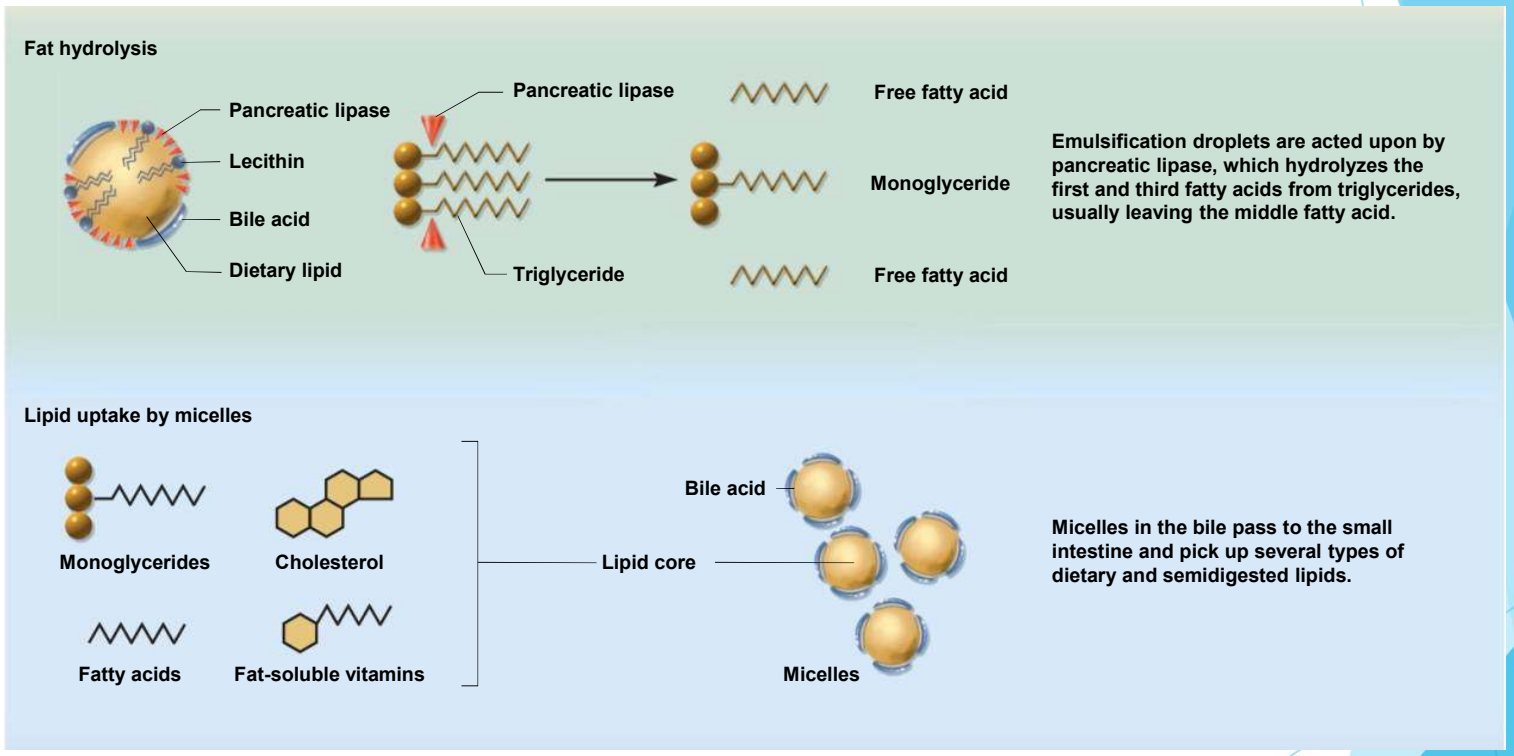



Figure 25.30

# Lipids

- Within the intestinal cell, free fatty acids and monoglycerides are transported to the smooth ER
- Resynthesized into triglycerides
- Golgi complex coats these with phospholipids and protein to form chylomicrons
  - Packaged into secretory vesicles that migrate to basal surface of cell
  - Release their contents into core of villus
  - Taken up by more porous lacteal into lymph
  - White, fatty intestinal lymph (chyle) flows into larger and larger lymphatic vessels until they reenter the bloodstream



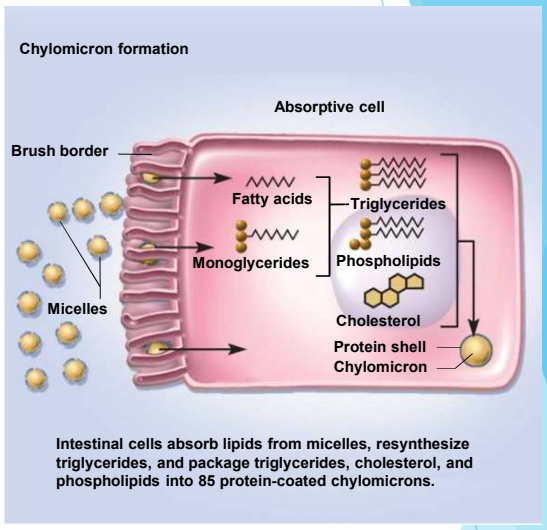



Figure 25.30

# Chylomicrons and the Lymphatics



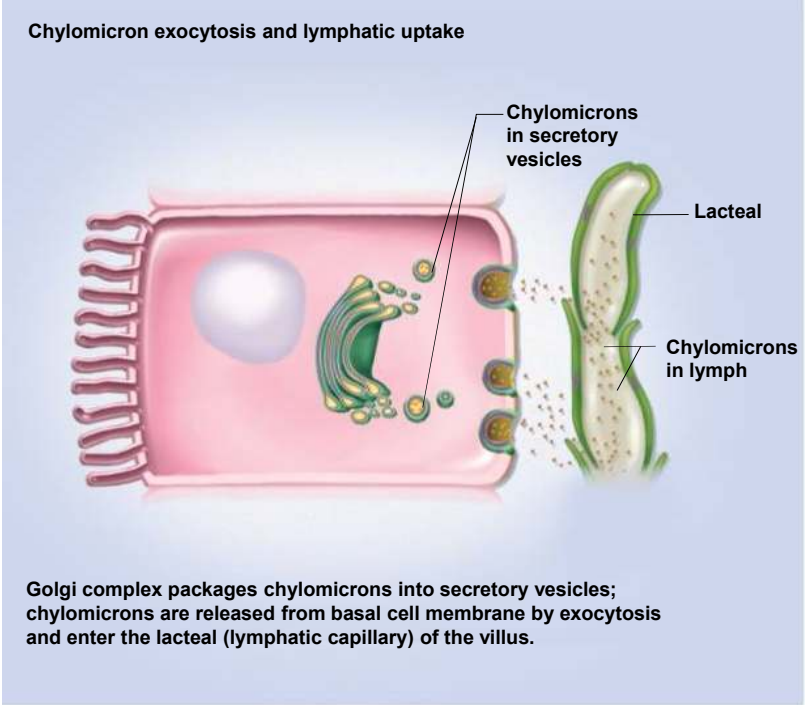



Figure 25.30

Chylomicrons are released into the lymphatic system in the lacteals of the villi. They enter the bloodstream when lymphatic fluid enters the subclavian vein via the thoracic duct.

# Nucleic Acids

- Nucleic acid
  - Nucleases (deoxyribonuclease and ribonuclease) hydrolyze DNA and RNA to nucleotides
  - Nucleosidases and phosphatases of brush border split them into phosphate ions, ribose or deoxyribose sugar, and nitrogenous bases

# Vitamins

- Vitamins
  - Absorbed unchanged
  - Fat-soluble vitamins: A, D, E, and K absorbed with other lipids
    - If they are ingested without fat-containing food, they are not absorbed at all, but are passed in the feces and wasted
  - Water-soluble vitamins, B complex and C, absorbed by simple diffusion and $B_{12}$ if bound to intrinsic factor from the stomach

# Minerals

- Minerals (electrolytes)
  - Absorbed all along small intestine
  - $Na^+$ cotransported with sugars and amino acids
  - $Cl^-$ exchanged for bicarbonate reversing chloride-bicarbonate exchange that occurs in the stomach

# Minerals

Cont.

- Iron and calcium absorbed as needed
  - Iron absorption is stimulated by liver hormone hepcidin
  - Absorptive cells bind ferrous ions ($Fe^{2+}$) and internalize by active transport
  - Unable to absorb ferric ions ($Fe^{3+}$) but stomach acid reduces ferric ions to absorbable ferrous ions
  - Transferrin (extracellular protein) transports iron in blood to bone marrow, muscle, and liver

# Minerals

- Calcium is absorbed throughout the intestine by different mechanisms
  - Active transport in the duodenum
    - Enters through calcium channels in apical cell membrane
    - Binds to calbindin protein so concentration gradient will continue to favor calcium influx
    - Actively transported out of base of cell into bloodstream by calcium-ATPase and $Na^{+}$-$Ca^{2+}$ antiport
  - Diffusion between epithelial cells in jejunum and ileum

# Minerals

- Parathyroid hormone—secreted in response to a drop in blood calcium levels
  - Stimulates kidney to synthesize vitamin D from precursors made by epidermis and liver
  - Vitamin D affects the absorptive cells of the duodenum in three ways
    - Increases number of calcium channels in apical membrane
    - Increases the amount of calbindin in the cytoplasm
    - Increases the number of calcium-ATPase pumps at basal membrane
  - Parathyroid hormone increases the level of calcium in the blood

# Water

- Digestive system is one of several systems involved in water balance
- Digestive tract receives about 9 L of water/day
  - 0.7 L in food, 1.6 L in drink, 6.7 L in gastrointestinal secretions
  - 8 L is absorbed by small intestine and 0.8 L by large intestine
  - 0.2 L voided in daily fecal output

# Water

- Water is absorbed by osmosis following the absorption of salts and organic nutrients
- Diarrhea—occurs when large intestine absorbs too little water
  - Feces pass through too quickly if intestine is irritated
  - Feces contain high concentrations of a solute (lactose)
- Constipation—occurs when fecal movement is slow, too much water gets reabsorbed, and feces become hardened

# The Large Intestine

# Gross Anatomy

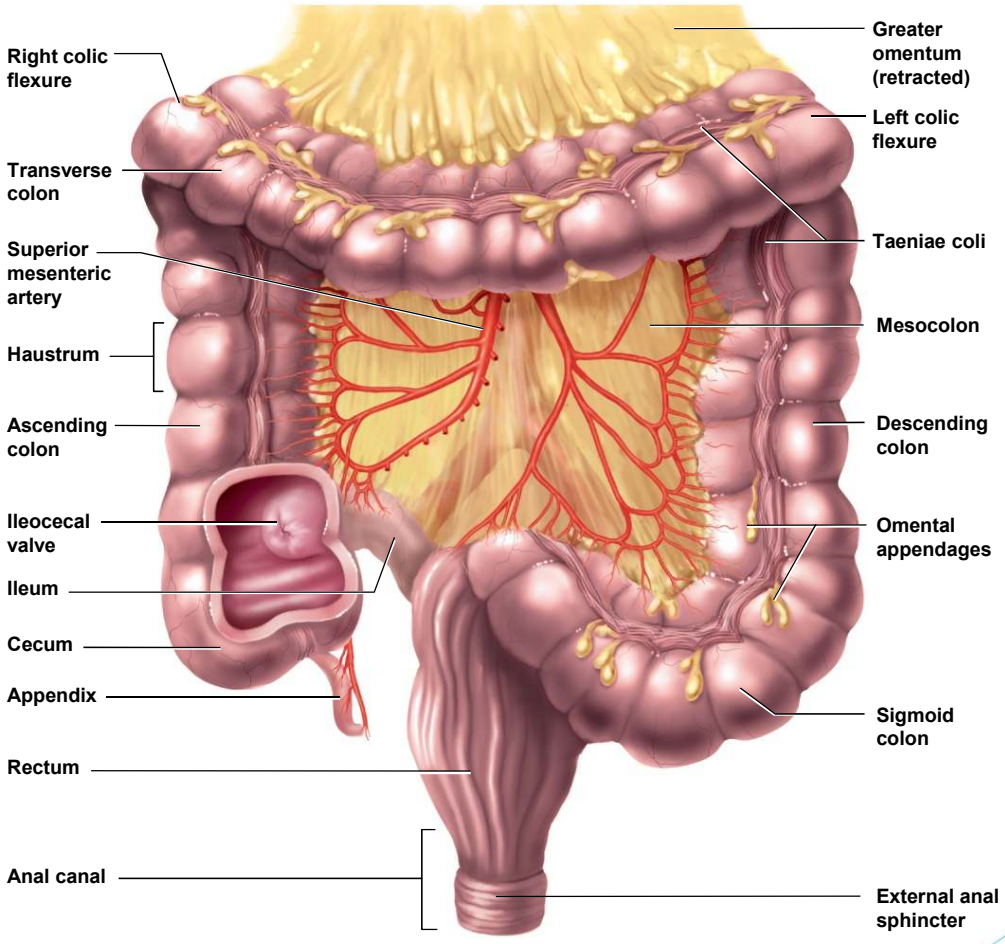
- Large intestine receives about 500 mL of indigestible residue per day
  - Reduces it to about 150 mL of feces by absorbing water and salts
  - Eliminates feces by defecation

# Gross Anatomy

- Large intestine
  - Measures 1.5 m (5 ft) long and 6.5 cm (2.5 in.) in diameter in cadaver
  - Begins as cecum inferior to ileocecal valve
  - Appendix attached to lower end of cecum
    - Densely populated with lymphocytes and is a significant source of immune cells
  - Ascending colon, right colic (hepatic) flexure, transverse colon, left colic (splenic) flexure, and descending colon frame the small intestine
  - Sigmoid colon is S-shaped portion leading down into pelvis

# The Large Intestine






(a) Gross anatomy

Figure 25.31a

# Microscopic Anatomy

- Mucosa—simple columnar epithelium through entire large intestine
  - Anal canal has nonkeratinized stratified squamous epithelium in its lower half
    - Provides abrasion resistance
- No circular folds or villi to increase surface area in large intestine
- Intestinal crypts—glands sunken into lamina propria

# Microscopic Anatomy

- Have a greater density of mucus-secreting goblet cells
- Lamina propria and submucosal layers have large amount of lymphatic tissue
  - Provide protection from the bacteria that densely populate the large intestine

# Bacterial Flora and Intestinal Gas

- Bacterial flora populate large intestine
  - About 800 species of bacteria
  - Digest cellulose and other undigested carbohydrates
    - Body absorbs resulting sugars
  - Help in synthesis of vitamins B and K
- Flatus—intestinal gas
  - Average person produces 500 mL per day (flatus) from 7 to 10 L of gas present but reabsorbed
  - Most is swallowed air, but hydrogen sulfide, indole, and skatole produce odor
    - Hydrogen gas may explode during electrical cauterization used in surgery

# Absorption and Motility

- Large intestine takes about 12 to 24 hours to reduce the residue of a meal to feces
  - Does not chemically change the residue
  - Reabsorbs water and electrolytes
- Feces consist of 75% water and 25% solids, of which 30% is bacteria, 30% undigested fiber, 10% to 20% fat, small amount of mucus, and sloughed epithelial cells

# Absorption and Motility

- Haustral contractions occur every 30 minutes
  - This kind of colonic motility is a form of segmentation
  - Distension of a haustrum stimulates it to contract
- Mass movements occur one to three times a day
  - Triggered by gastrocolic and duodenocolic reflexes
    - Filling of the stomach and duodenum stimulates motility of the colon
    - Moves residue for several centimeters with each contraction

# Defecation

- Stretching of rectum stimulates defecation reflexes
  - Accounts for urge to defecate that is often felt soon after a meal
  - Intrinsic defecation reflex works entirely within the myenteric plexus
    - Stretch signals travel through the plexus to the muscularis, causing it to contract and the internal sphincter to relax
      - Relatively weak contractions

# Defecation

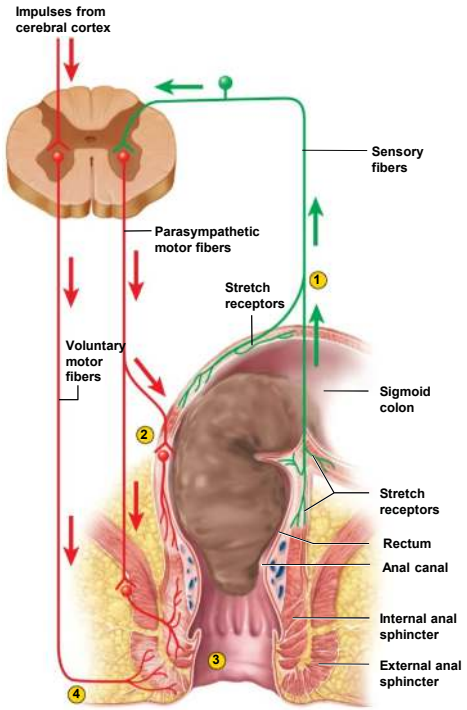
Cont.

- Parasympathetic defecation reflex involves spinal cord
  - Stretching of rectum sends sensory signals to spinal cord
  - Pelvic nerves return signals, intensifying peristalsis and relaxing the internal anal sphincter
  - Defecation occurs only if external anal sphincter is voluntarily relaxed

- Abdominal contractions (Valsalva maneuver) increase abdominal pressure as levator ani lifts anal canal upward
  - Feces will fall away

# Neural Control of Defecation






1. Feces stretch the rectum and stimulate stretch receptors, which transmit signals to the spinal cord.
2. A spinal reflex stimulates contraction of the rectum.
3. The spinal reflex also relaxes the internal anal sphincter.
4. Impulses from the brain prevent untimely defecation by keeping the external anal sphincter contracted. Defecation occurs only if this sphincter also relaxes.

1. Filling of the rectum
2. Reflex contraction of rectum and relaxation of internal anal sphincter
3. Voluntary relaxation of external sphincter

Figure 25.32