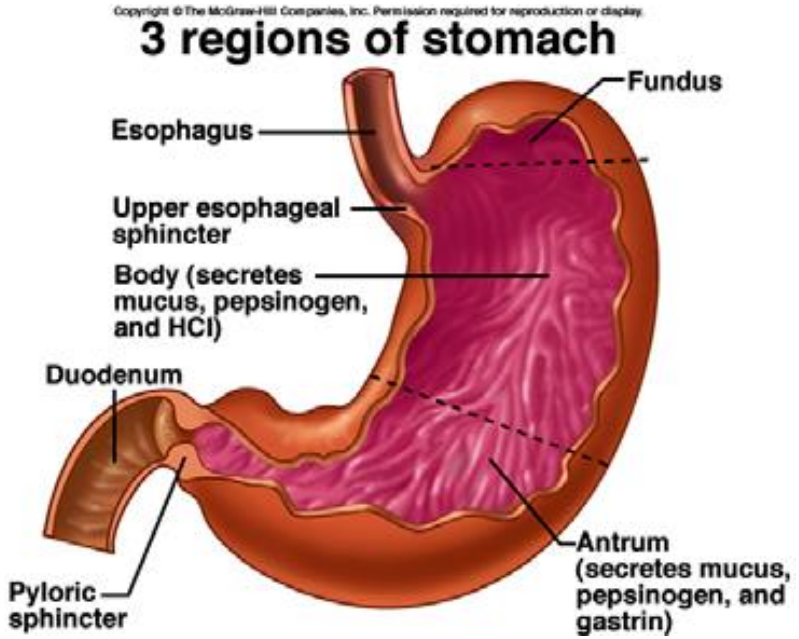
THE DIGESTION PROCESS: PART II

Digestion in the Small Intestine

- Chyme from stomach contains
  - Partially digested carbohydrates and proteins
  - Undigested fats
- 2-3 hours in small intestine (up to 6 if sluggish)
  - Most water absorbed
  - ~ All nutrients absorbed
- Small intestine, like stomach, has no role in ingestion or defecation

Requirements for Digestion and Absorption in the Small Intestine

- Slow delivery of acidic chyme
- Delivery of bile, enzymes, and bicarbonate ions from liver and pancreas
- Mixing



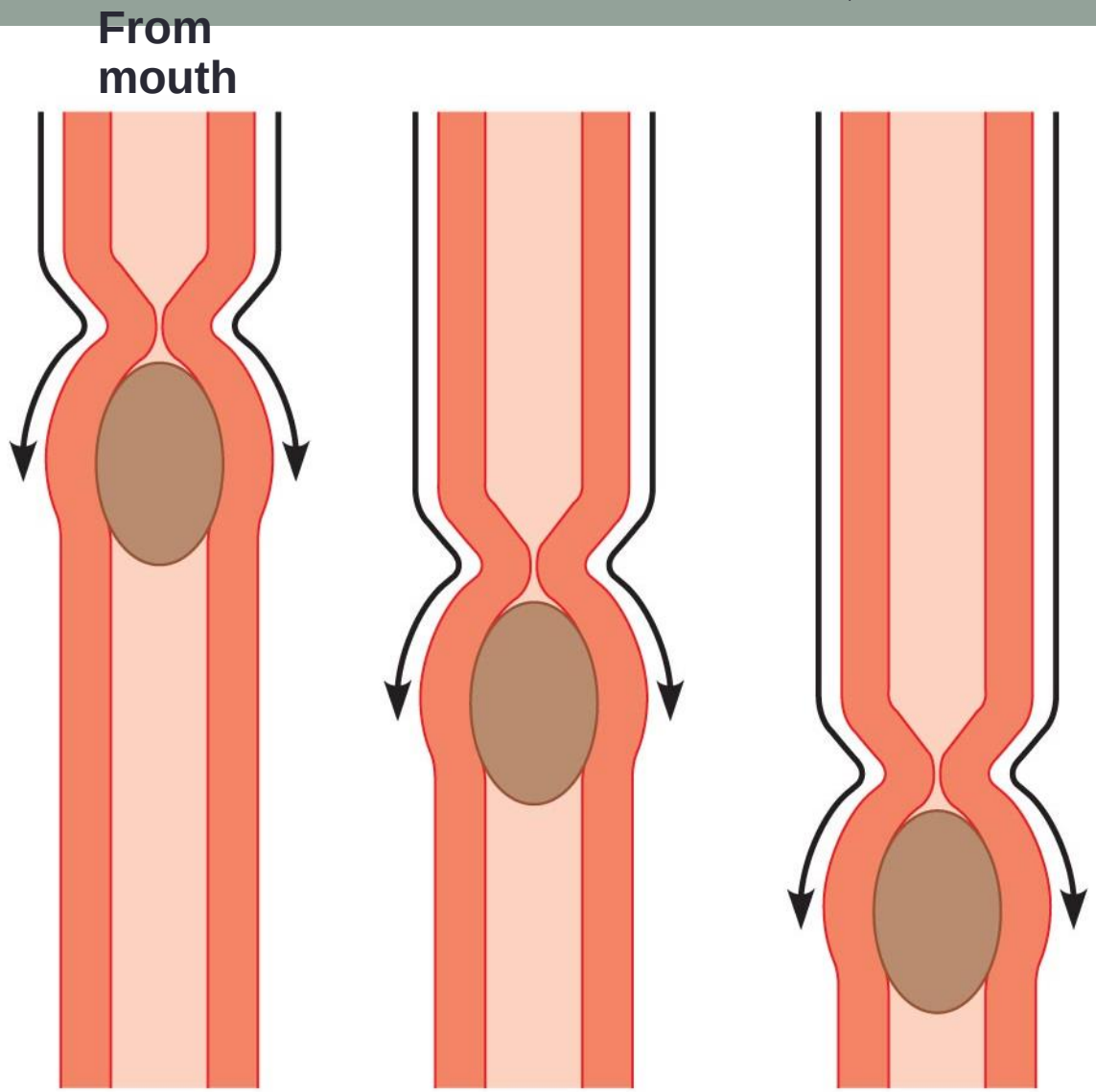
Motility of the Small Intestine

- **Segmentation**
  - Most common motion of small intestine
  - Initiated by intrinsic pacemaker cells (located in the stomach, intestines and colon and connected to smooth muscle)
  - Mixes/moves contents toward ileocecal valve
  - Intensity altered by long & short reflexes; hormones
    - Parasympathetic ↑ ; sympathetic ↓
  - Wanes in late intestinal phase
- Segmentation contractions moves chyme in both directions, allowing better mixing with the secretions of the intestines. Involves contractions of the circular muscles instead rhythmic contractions of the longitudinal muscles in the GI tract like peristalsis, Segmentation actually can slow progression of chyme through the system.

Motility of the Small Intestine

- **Peristalsis**
  - Initiated by rise in hormone *motilin* in late intestinal phase; every 90–120 minutes
  - Each wave starts after the previous wave
    - Migrating motor complex trigger peristaltic waves through the system
  - Food parts, bacteria, and debris moved to large intestine
  - From duodenum → ileum ~ 2 hours
  - This is a key fact for gut health of the small intestines

Figure 23.3a Peristalsis and segmentation.



(a) Peristalsis: Adjacent segments of alimentary tract organs alternately contract and relax, moving food along the tract distally.

Motility of the Small Intestine

- Local enteric neurons coordinate intestinal motility
- Neurons activate myenteric plexus (which provides motor stimulation of nerves)
  - Causes contraction of circular muscle proximally (at the point of attachment) and of longitudinal muscle distally (furthest from the point of attachment)
  - Forces chyme along the tract

Motility of the Small Intestine

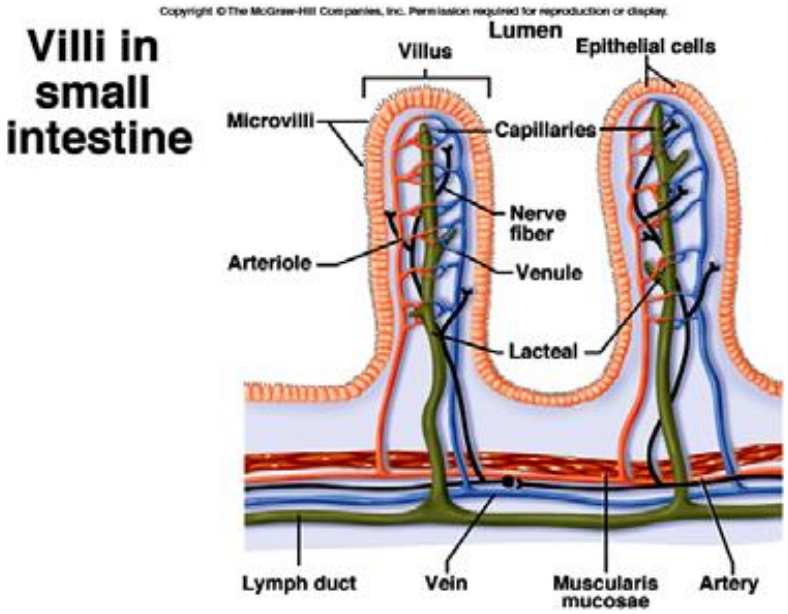
- **Ileocecal sphincter** relaxes, allowing the chyme into large intestine when:
  - **Gastroileal reflex** (stimulate by the presence of food and peristalsis) enhances the force of segmentation in ileum
  - Gastrin increases motility of ileum
- Ileocecal valve flaps close when chyme exerts backward pressure
  - Prevents regurgitation into ileum

Digestion

- Digestion
  - Catabolic; macromolecules → smallest constituent parts enough for absorption
- Enzymes
  - Intrinsic and accessory gland enzymes break down food
- Hydrolysis
  - Water is added to break bonds

Brush Border Enzymes

- Brush border (of the mucosa) refers to the membrane of **intestinal epithelial** cells that is folded to form **microvilli**;
- Serves to increase surface area.
- Digestive enzymes, called brush border enzymes, are located in the membranes of the **microvilli**.



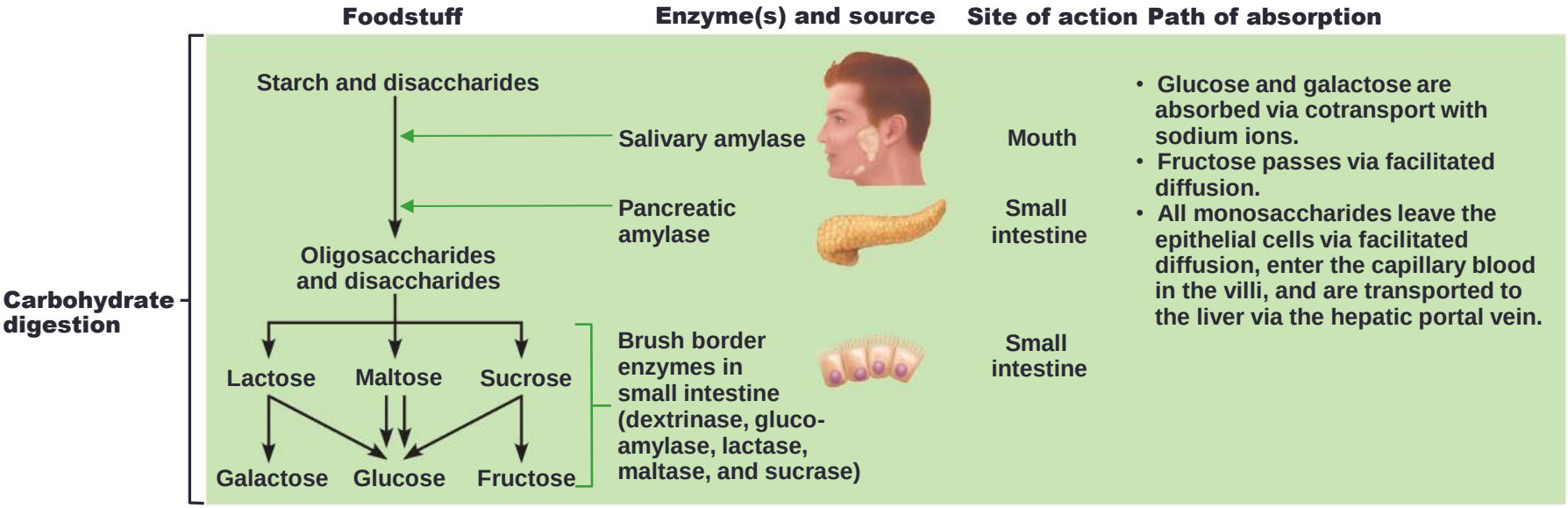
Digestion of Carbohydrates

- Only monosaccharides can be absorbed
- **Monosaccharides** absorbed as ingested
  - Glucose, fructose, galactose
- Digestive enzymes
  - Salivary amylase, pancreatic amylase, and brush border enzymes (dextrinase, glucoamylase, lactase, maltase, and sucrase)
  - Break down disaccharides sucrose, lactose, maltose; polysaccharides glycogen and starch

Digestion of Carbohydrates

- Starch digestion – Started by salivary enzymes
  - Starch and oligosaccharides coat salivary amylase (saliva) for continued use in the duodenum
  - Pancreatic amylase (small intestine) → breaks down any starch or oligosaccharides that escaped salivary amylase
  - Brush border enzymes (dextrinase, glucoamylase, lactase, maltase, sucrase) finish the process of turning oligosaccharides into monosaccharides

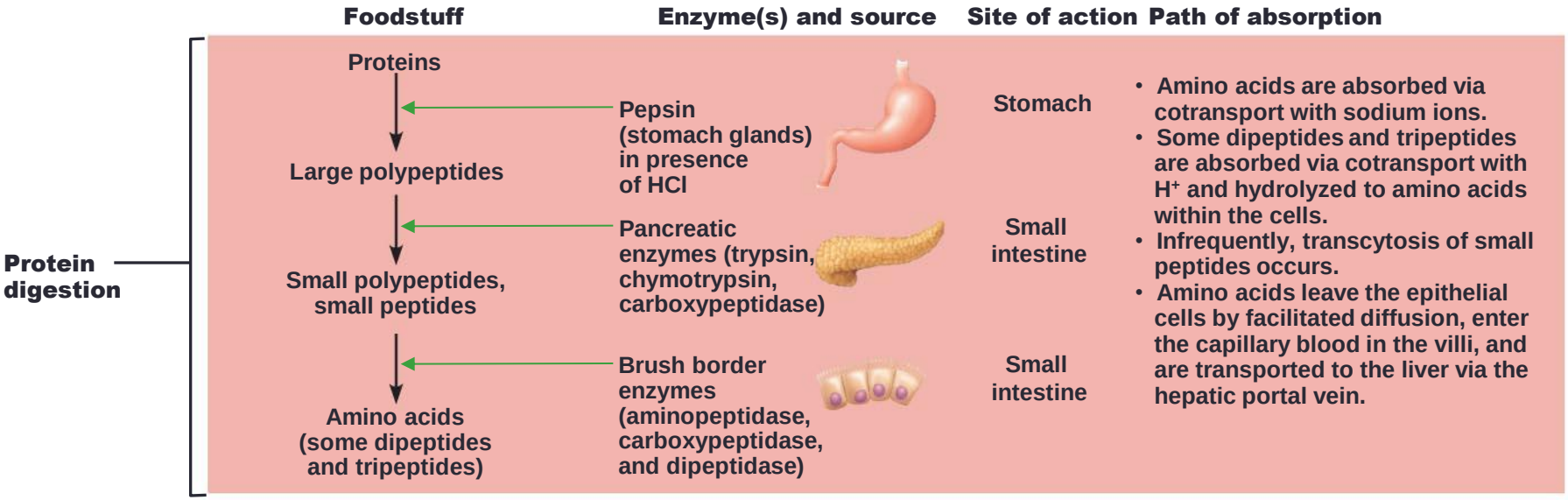
Figure 23.32 Flowchart of digestion and absorption of foodstuffs. (1 of 4)



Digestion of Proteins

- Source is dietary, digestive enzymes, mucosal cells; digested to single amino acids
- Begins with **pepsin** in stomach at pH 1.5 – 2.5
  - Inactive in high pH of duodenum
- Pancreatic proteases
  - Trypsin, chymotrypsin, and carboxypeptidase
- Brush border enzymes
  - Aminopeptidases, carboxypeptidases, and dipeptidases

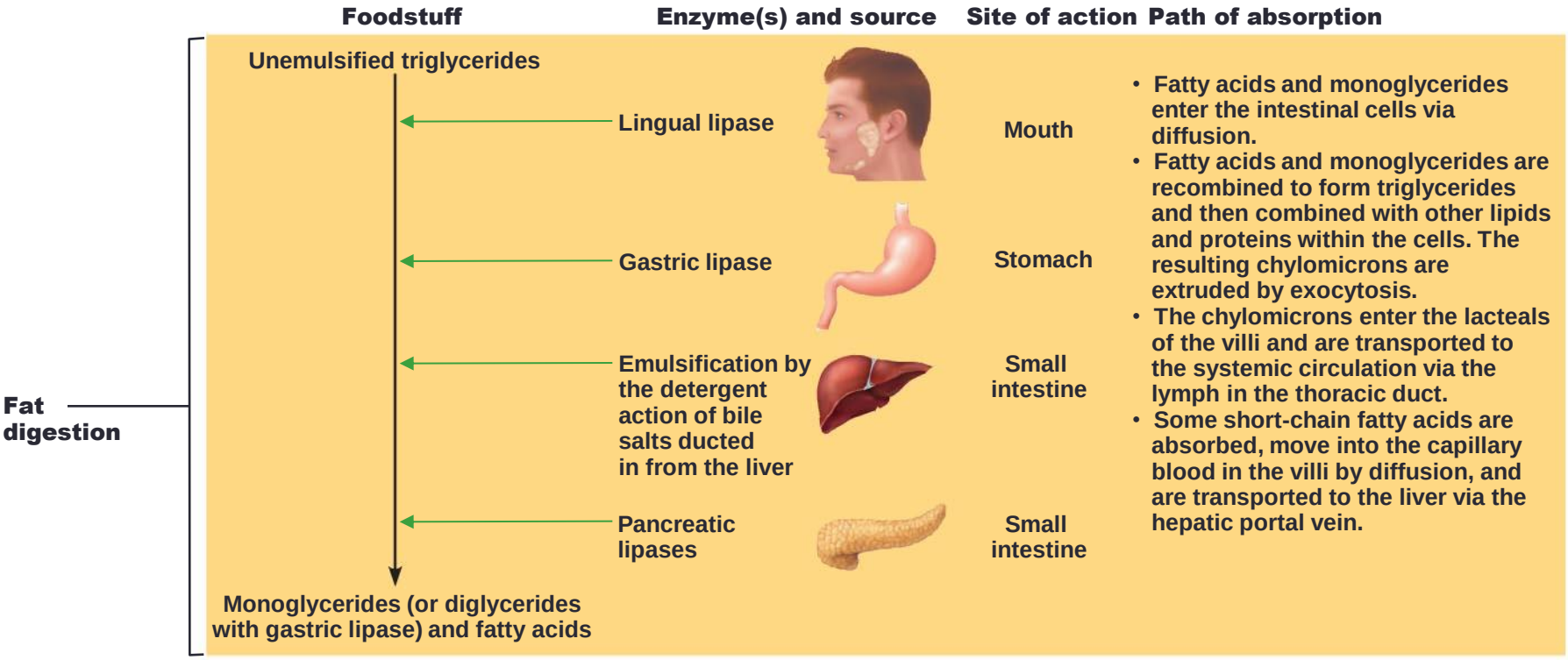
Figure 23.32 Flowchart of digestion and absorption of foodstuffs. (2 of 4)



Digestion of Lipids

- Pre-treatment—emulsification by bile salts
  - Does not break bonds
- Enzymes—pancreatic lipases
  - → Fatty acids and monoglycerides

Figure 23.32 Flowchart of digestion and absorption of foodstuffs. (3 of 4)

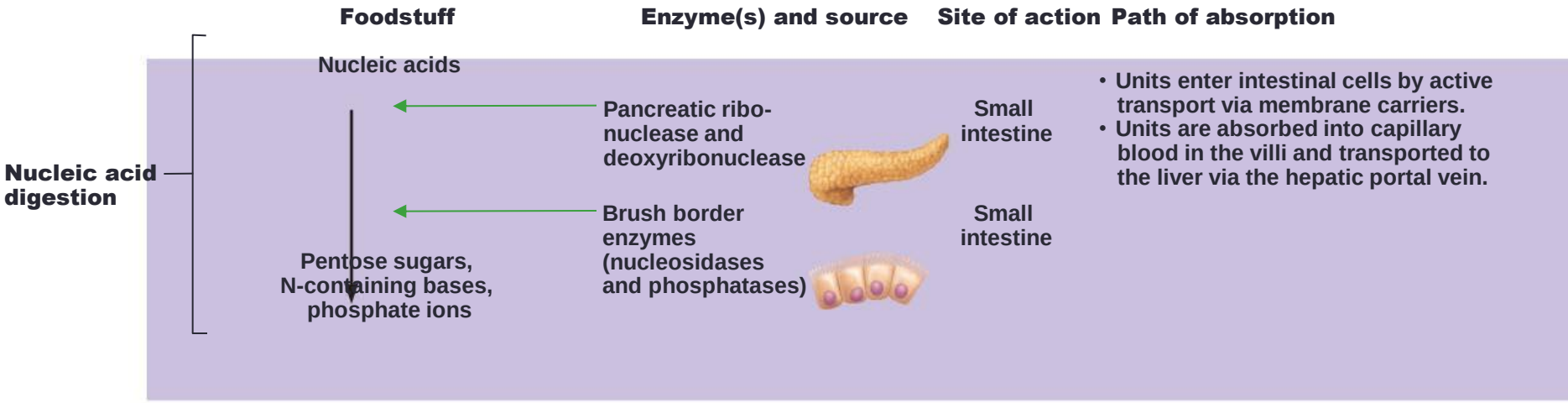


Digestion of Nucleic Acids

- Enzymes
  - Pancreatic ribonuclease and deoxyribonuclease → nucleotide monomers (building blocks of nucleic acids)
  - Help degrade RNA produces by the bacteria into smaller proponents
  - Brush border enzyme nucleosidases and phosphatases → free bases, pentose sugars, phosphate ions

Nucleic Acids: A complex organic substance present in living cells, especially DNA or RNA, whose molecules consist of many nucleotides linked in a long chain

Figure 23.32 Flowchart of digestion and absorption of foodstuffs. (4 of 4)



Absorption

- ~ All food; 80% electrolytes; most water absorbed in small intestine
  - Most prior to ileum
    - Ileum reclaims bile salts
- Most absorbed by active transport → blood
  - Exception – lipids
  - **Active transport** is the movement of molecules across a cell membrane in the direction against their concentration gradient, i.e. moving from an area of lower concentration to an area of higher concentration.

Absorption of Carbohydrates

- Glucose and galactose
  - Secondary active transport (cotransport - two substances are simultaneously transported) with Na^+ → epithelial cells
  - Move out of epithelial cells by facilitated diffusion → capillary beds in villi
- Fructose
  - Facilitated by diffusion to enter and exit cells

Absorption of Protein

- Amino acids transported by several types of carriers
  - Most coupled to active transport of Na^+
- Dipeptides and tripeptides actively absorbed by H^+- dependent cotransport; digested to amino acids within epithelial cells
- Enter capillary blood by diffusion

Homeostatic Imbalance

- Whole proteins not usually absorbed
- Can be taken up by endocytosis/exocytosis
  - Most common in newborns → food allergies
    - Usually disappear with mucosa maturation
  - Allows IgA antibodies in breast milk to reach infant's bloodstream → passive immunity

Endocytosis: Energy-using process by which cells absorb molecules (such as proteins) by engulfing them

Exocytosis: materials are *exported* out of the cell via secretory vesicles

Absorption of Lipids

- Absorption of monoglycerides and fatty acids
  - Cluster with bile salts and lecithin to form **micelles**
  - Released by micelles to diffuse into epithelial cells
  - Combined with lecithin, phospholipids, cholesterol, & coated with proteins to form **chylomicrons**
  - Enter **lacteals** (lymphatic capillary that absorbs dietary fats in the villi of the small intestine); transported to systemic circulation
  - Hydrolyzed to free fatty acids and glycerol in the capillary endothelium
    - Cells can use for energy or stored fat
- Absorption of short chain fatty acids
  - Diffuse into portal blood for distribution

Absorption of Nucleic Acids

- Absorption
  - Active transport across epithelium → bloodstream
  - Definition of Diffusion: Passive movement of molecules along a concentration gradient
  - Concentration gradient: The gradual difference in concentration of a dissolved substance in a solution between a region of high density and one of lower density.

Absorption of Vitamins

- In small intestine
  - Fat-soluble vitamins (A, D, E, and K) carried by micelles; diffuse into cells for absorption
  - Water-soluble vitamins (vitamin C and B vitamins) absorbed by diffusion or by passive or active transporters.
  - Vitamin B_{12} (large, charged molecule) binds with intrinsic factor, and is absorbed by endocytosis (the process by which a living cell takes up molecules bound to its surface)
- In large intestine: Vitamin K and B vitamins from bacterial metabolism are absorbed

Absorption of Electrolytes

- Most ions are actively along length of small intestine
- Iron and calcium are absorbed in duodenum
- Na^+ coupled with active absorption of glucose and amino acids
- Cl^- transported actively
- K^+ diffuses in response to osmotic gradients; lost if poor water absorption
- Usually the amount in intestine is the amount absorbed

Absorption of Electrolytes

- Iron and calcium absorption related to need
  - Ionic iron stored in mucosal cells with ferritin
  - When needed, transported in blood by transferrin
- Ca^{2+} absorption regulated by vitamin D and parathyroid hormone (PTH)
- Phytic acid and oxalic acid help regulate calcium and iron levels with aids of good bacteria to prevent to much or calcium or iron absorption

Absorption of Water

- The body use 9 litres of water, most from GI tract secretions, and it enters the small intestine
  - 95% absorbed in the small intestine by osmosis
  - Most of rest absorbed in large intestine
- This will include water uptake coupled with nutrient uptake

Summary of digestion and absorption

Nutrient	Digestion	Site of absorption	Mechanism of absorption
Carbohydrates	To monosaccahrides (glucose, galactose, fructose)	SI	•Na-dependent co-transport (glucose, galactose) •Facilitated Diffusion (fructose)
Proteins	To amino acids, dipeptides, tripeptides	SI	•Na-dependent co-transport (amino acids) •H+ dependent co-transport (di- and tripeptides)
Lipids	To fatty acids, monoglycerides, cholesterol	SI	•Micelles form with bile salts in intestinal lumen •Diffusion of fatty acids, mono glycerides, and cholesterol into cell •Reesterification in cell to TG and phospholipids •Chylomicrons form in cell (requires apoprotein) and are transferred to lymph
Fat-soluble vitamins		SI	•Micelles with bile salts
Water-soluble vitamins •Vit B12		Ileum of SI	•Na-dependent co-transport •IF-Vit B12 complex
Bile acids		Ileum of SI	Na-dependent co-transport ; recirculated to liver
Ca^{+}		SI	•Vit D-dependent Ca binding protein
Fe^{+}	Fe^{3+} is reduced to Fe^{2+}	SI	•Binds to apoferritin in cell •Circulates in blood bound to transferrin

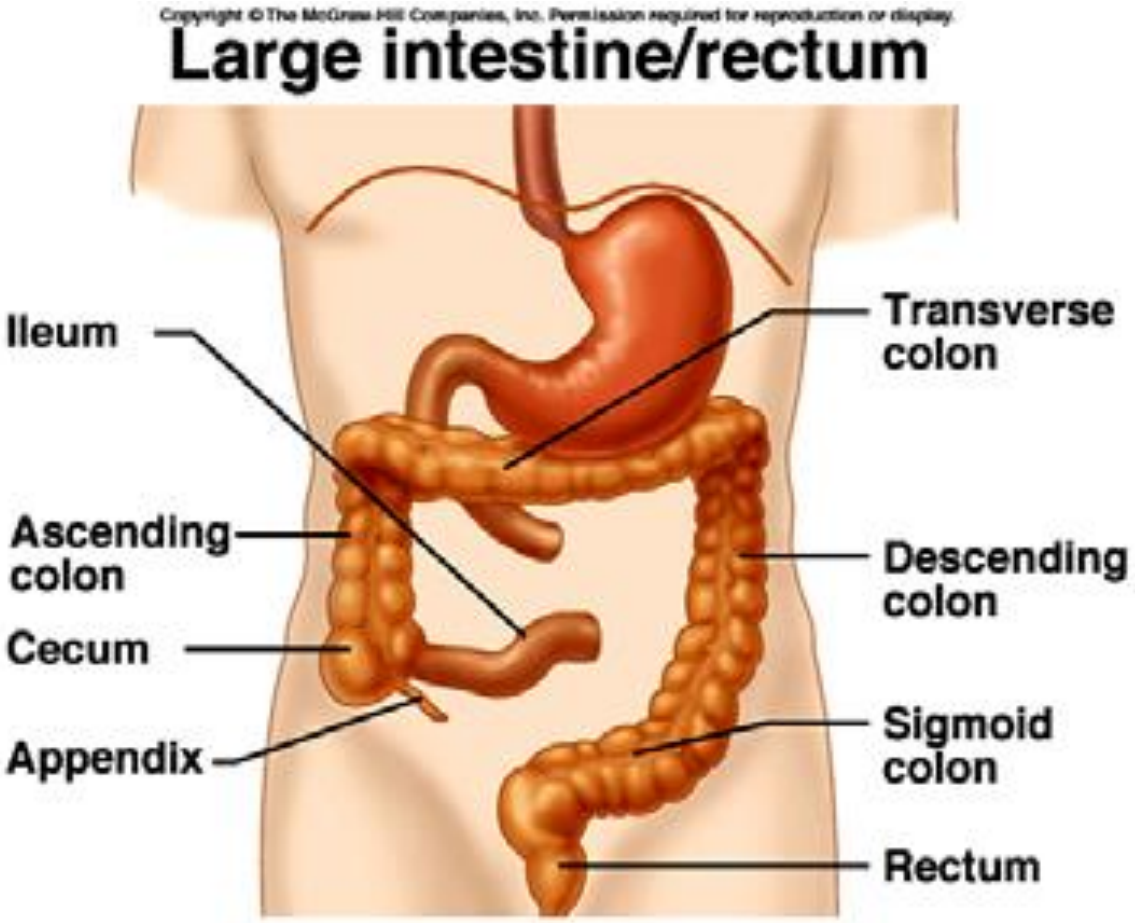
Malabsorption of Nutrients

- Causes
  - Anything that interferes with delivery of bile or pancreatic juice
  - Insufficient good bacteria
  - Damaged intestinal mucosa (e.g., bacterial infection; some antibiotics, NSAIDS, aspirin, Ibuprofen, coriticosteroids)

Malabsorption of Nutrients

- *Gluten-sensitive enteropathy* (*celiac disease*)
  - Immune reaction to gluten
  - Gluten causes immune cell damage to intestinal villi and brush border
  - Treated by eliminating gluten from diet (all grains but rice and corn)

GI motility: Large Intestinal Motility



GI motility: large intestinal motility

- Fecal material moves from the cecum to the colon, to the rectum, and then to the anal canal

- Haustra, or sac-like segments, appear after contractions of the large intestines – the gives the colon it's segmented appearance

GI motility: large intestinal motility

1. Cecum and proximal colon

   - When the proximal colon is distended with fecal material, ileocecal sphincter contracts to prevent reflux into the ileum.
   - Segmentation contractions in the proximal colon mix the contents
   - Mass movements occur 1-3x/day and cause the colonic content to move from the transverse colon→ sigmoid colon)

2. Distal colon

   - Because most colonic water absorption occurs in the proximal colon, fecal material in the distal colon becomes semisolid and moves slowly

GI motility: large intestinal motility

3. Rectum, anal canal, and defecation

- Sequence of events:
  1. Rectum fills with fecal material, contracts, and then internal anal sphincter relaxes. (rectosphincteric reflex)
  2. Once rectum is filled with 25% of its capacity→ there is an urge to defecate, however, defecation is prevented because the external anal sphincter is tonically contracted
  3. When it is convenient to defecate, the external anal sphincter is relaxed voluntarily. The smooth muscle of the rectum contracts, forcing the feces out.

GI motility: large intestinal motility

4. Gastrocolic reflex

- The presence of food in the stomach increases the motility of the colon and increases the frequency of mass movements
- It has a rapid parasympathetic component that is initiated when the stomach is stretched by food.