Physiology
Digestive System

I. Overview of Digestive System

A. Structures of Digestive System

1. alimentary canal (gastrointestinal [GI] tract)

a. digestion - break down molecules
b. absorption - move into circulatory system
c. mouth, pharynx, esophagus, stomach, small intestine, large intestine, anus

2. accessory digestive organs

a. function - assist in breakdown and absorption of foodstuffs
b. teeth, tongue, gallbladder, salivary glands, liver, pancreas

B. Primary Functions of Digestive System

1. ingestion - getting food into the GI tract (eating)

2. propulsion - moving food along the tract
a. swallowing and peristalsis (wave-like motion)

3. mechanical digestion - the physical grinding and churning of foodstuffs to breakdown and expose to enzymes and the surface of the GI tract

4. chemical digestion - breakdown of larger molecules into absorbable parts by enzymatic action

5. absorption - transport of digested molecules, vitamins, minerals, water, into blood

6. defecation - elimination of unused foodstuff (feces)

C. Control of Conditions in the GI Tract

1. mechanoreceptors and chemoreceptors respond to:

a. stretching of the lumen by foodstuffs
b. solute concentration and pH within the lumen
c. presence of digestible and digested molecules

2. actions initiated by these receptors:

a. activate/inhibit secretions into the lumen
b. activate/inhibit muscular "mixing" activity
c. activate/inhibit secretion of hormones
d. activate/inhibit local "nerve plexuses"

3. types of digestive reflex processes:

a. short reflex - controlled by "nerve plexus" within the GI tract (enteric plexus)
b. long reflex - those involving the CNS and extrinsic autonomic nerves

II. Digestive Processes Occurring in the Mouth, Pharynx, Esophagus

A. Composition of Saliva & Control of Salivation

1. major components of saliva:

a. water (97-99.5%)
b. electrolytes: Na^+, K^+, Cl^-, PO_4^-
c. mucin - protein that forms thick, slimy mucus
d. IgA antibodies - immune defense
e. lysozyme - antibacterial enzyme
f. salivary amylase - starts breakdown of carbo's

2. control of salivation:

ingestion of foodstuffs →
activate chemoreceptors and pressoreceptors →
salivatory nuclei (pons & medulla) →
PARASYMPATHETIC nerve activation →
Facial (VII) and Glassopharyngeal (IX) nerves →
secretion by salivary glands

SYMPATHETIC nerve activation →
decreased salivation

B. Mechanical Processes

1. mastication (chewing) - cheeks, tongue, and teeth involved in both voluntary and involuntary grinding, ripping, and tearing of foodstuffs

2. deglutition (swallowing) - moving "bolus" on its way

a. tongue compacts ground food into a "bolus"

b. buccal phase (voluntary)

tongue against hard palate
tongue contraction
bolus forced into oropharynx

c. pharyngeal-esophageal phase (involuntary)

- tongue blocks off mouth
- soft palate blocks off nasopharyx

- epiglottis blocks off trachea
→ peristaltic waves moves food to stomach

III. Regulation of Gastric Secretion, Motility, and Emptying

A. Regulation of Gastric Secretion ("Gastric Juice")

1. cephalic (reflex) phase

sight, aroma, taste, thought →
hypothalamus gustatory centers →
vagal nuclei of medulla →
vagus nerve (parasympathetic) →
increased gastric secretion

2. gastric phase

a. food reaches the stomach

neural mechanism	**hormonal mechanism**
distention & low acidity --->	digested proteins --->
vagal afferents to medulla --->	increase in pH --->
vagal efferents to stomach --->	gastrin released --->
parasympathetic ACh release --->	enzymes & HCl released
increased gastric secretion	

b. control of HCl secreting parietal cells

i. gastrin, histamine, & ACh increase the release of HCl from parietal cells
ii. H^+ comes from carbonic acid release

3. intestinal phase

excitatory phase	**inhibitory phase**
chyme enters the duodenum ->	inhibition of vagal nuclei
release of intestinal gastrin ->	inhibition of local reflexes
continued gastric secretion	activation of sympathetics
	release of inhibitory hormones:
	(secretin, cholecystokinin CCK, gastric inhibitory peptide GIP)

B. Gastric Motility and Emptying

1. receptive relaxation - trilayer of muscles in wall of the stomach relax to allow filling to occur
2. plasticity - smooth muscle tension specially regulated to prevent regurgitation of food
3. basic electrical rhythm - pacemaker cells of longitudinal muscle allow rhythmic contractions
4. emptying to duodenum - regulated by amount and type of chyme entering into the duodenum; faster with high carbo, slower with higher fats
5. vomiting (emesis) - irritants activate neurons which stimulate the "emetic center" of medulla

IV. Content of Bile and Bile Release into Small Intestine

A. Content of Bile (made in Liver, released by Gall Bladder)

1. bile salts, bile pigments, cholesterol, neutral fats, phospholipids, electrolytes
2. bile salts - derivatives of cholesterol (cholic acid, chenodeoxycholic acid)

    a. emulsify fats - separate fats into tiny droplets for digestion & absorption
    b. enterohepatic circulation - conservation of bile salts by re-processing

        i. reabsorbed in distal small intestine
        ii. to liver via hepatic portal blood
        iii. resecreted as bile from gall bladder

3. bile pigment (bilirubin) - waste product of heme from broken-down erythrocytes
    a. urobilinogen - breakdown product of bilirubin, causes darker coloration of feces

B. Regulation of Bile Release to Small Intestine

1. hepatocytes - cells of the liver that produce 0.5-1.0 liters of bile each day
2. parasympathetic - stimulates gall bladder release
3. cholecystokinin (CCK) - hormone released by cells of the mucosa of the duodenum

acidic, fatty chyme enters duodenum →
duodenal mucosa secretes CCK →

    a. gall bladder contracts to release bile
    b. pancreas secretes pancreatic juices
    c. hepatopancreatic sphincter opens

4. gallstones - crystallized formation of cholesterol and salts, causing obstruction of bile release

V. Composition of Pancreatic Juice and Regulation of Secretion

A. Composition of Pancreatic Juice

1. 1.2 - 1.5 liters per day
2. water and electrolytes (mainly bicarbonate ions)
3. enzymes - precursors and active digestive forms
   a. trypsinogen ------> trypsin
      enterokinase

   b. procarboxypeptidase --------> carboxypeptidase
      trypsin

      chymotrypsinogen --------> chymotrypsin
      trypsin

   c. amylase (carbohydrates), lipases (fats), nucleases (nucleic acids)

B. Regulation of Pancreatic Secretion

1. parasympathetic causes release during cephalic and gastric phases of gastric secretion

2. secretin - hormone that causes release of "bicarbonate-rich" pancreatic juices in response to the presence of HCl

3. cholecystokinin - hormone that causes release of "enzyme-rich" pancreatic juice in response to the presence of proteins and fats

VI. Digestive Processes of the Small Intestine

A. Optimal Conditions for Digestion & Absorption

1. pancreatic juice & bile - enzymes, emulsifying fats, and pH are essential for proper intestinal processes
2. small intestine is PRIMARY site for absorption of nutrients into the cardiovascular system

B. Movement in the Small Intestine

1. segmentation - longitudinal flow of chyme through the tube (duodenum -> ileum)

2. migrating mobility complex - activity that moves the chyme from the ileum to the cecum through the ileocecal valve

VII. Digestive Processes of the Large Intestine

A. Bacterial Flora

1. digest remaining carbohydrates
2. responsible for producing gas (flatus)
3. synthesize & complex B vitamins and vitamin K

B. Digestion and Absorption

1. reclaim most of the water
2. reclaim some of the electrolytes (Na^+ and Cl^-)

C. Motility of the Large Intestine

1. haustral contractions - slow acting segmental motion; moves chyme from one segment to next
2. mass movements - peristaltic waves that move food to the rectum during/after eating
    a. diverticula - herniation of the mucosa through the wall of the colon (sigmoid colon)

D. Defecation

1. defecation reflex when feces (stool) enters rectum, spinal cord reflex is triggered

    a. internal sphincter (involuntary)
    b. external sphincter (voluntary)

2. Valsalva's maneuver - contraction of diaphragm and abdominal muscles to increase pressure for defecation

3. diarrhea - too much water in the stool

4. constipation - insufficient water or fiber

VIII. Chemical Digestion

A. Enzymatic Hydrolysis ("water" "breaking")

1. hydrolysis - a water molecule is added between two "monomers" of a complex organic molecule in order break it down into its component parts

B. Carbohydrate Digestion

1. monosaccharides - "monomers" such as glucose, fructose, and galactose
2. disaccharides - sucrose (table sugar), lactose (milk sugar), and maltose (grain sugar)
3. polysaccharides - starch (grains), glycogen (muscle)
4. carbohydrate hydrolyzing enzymes
    a. salivary amylase - produces "oligosaccharides"
    b. pancreatic amylase - in small intestine
    c. intestinal enzymes - dextranase & glucoamylase (> 3 sugars), maltase, sucrase, and lactase
5. lactose intolerance - decreased ability to digest lactose in the diet (use "lactase" supplements)

C. Protein Digestion

1. amino acids - the "monomer" components of protein
2. stomach - pepsinogen --------> pepsin (low pH)
3. small intestine

a. enzymes that cleave throughout the protein

trypsinogen ----------> trypsin
chymotrypsinogen -----> chymotrypsin

b. carboxypeptidase (carboxyl end of protein)
c. aminopeptidase, dipeptidase (amino end)

D. Lipid (Fat) Digestion

1. lipid structure - glycerol + 3 triglycerides
2. lipases - enzymes that break down lipids
3. bile salts - "emulsify" fats in 1 micron "micelles"

E. Nucleic Acid Digestion

1. pancreatic nucleases - break down DNA and RNA

IX. Absorption of Nutrients

A. General Features

1. transepithelial transport - nutrients must pass across the epithelial lining of the small intestine

2. active transport - most nutrients must be transported across membrane using ATP of the cells

B. Carbohydrate Absorption

1. facilitated diffusion - glucose and galactose (coupled with active transport of Na^+)

a. "carrier molecule" has binding sites for both sugar and Na^+; relies on Na^+ gradient

C. Protein (Amino Acid) Absorption

1. facilitated diffusion - amino acids and small peptides (coupled with Na+ active transport)

a. "carrier molecule" has binding sites for both amino acid and Na+; relies on Na+ gradient

2. food allergies - absorption of proteins in infant gut causes early immune reaction

D. Lipid Absorption

1. micelles - tiny balls of fats that result from bile salt emulsification and "lecithin"

    a. contain cholesterol and fat-soluble vitamins
    b. diffuse through lipid bilayer of membrane
    c. chylomicrons - micelles combined with associated proteins within the cell; enter the lacteals of the lymphatic system

E. Nucleic Acid Absorption

1. pentoses, nitrogen bases, phosphates - absorbed by similar processes as sugars and amino acids

F. Vitamin Absorption

1. fat soluble - Vitamins A, D, E, K are absorbed by epithelial cells along with lipid micelles
    a. OLESTRA - will carry fat-soluble vitamins out in feces with it

2. water soluble - Vitamins B & C absorbed by diffusion

3. Vitamin B_{12} - large and electrically charged, must bind with "intrinsic factor" before being taken into the cell by endocytosis

G. Electrolyte Absorption

1. Fe and Ca - primarily absorbed in small intestine

    a. ferritin - sequesters Fe in intestinal cells
    b. transferrin - transfers Fe into circulation when need is present (menstruation)
    c. Vitamin D - facilitates Ca absorption

2. Na - exchanged for sugars and amino acids

3. Cl - absorbed into cells and exchanged for HCO_3^-

4. K - absorbed into cells due to osmotic gradients

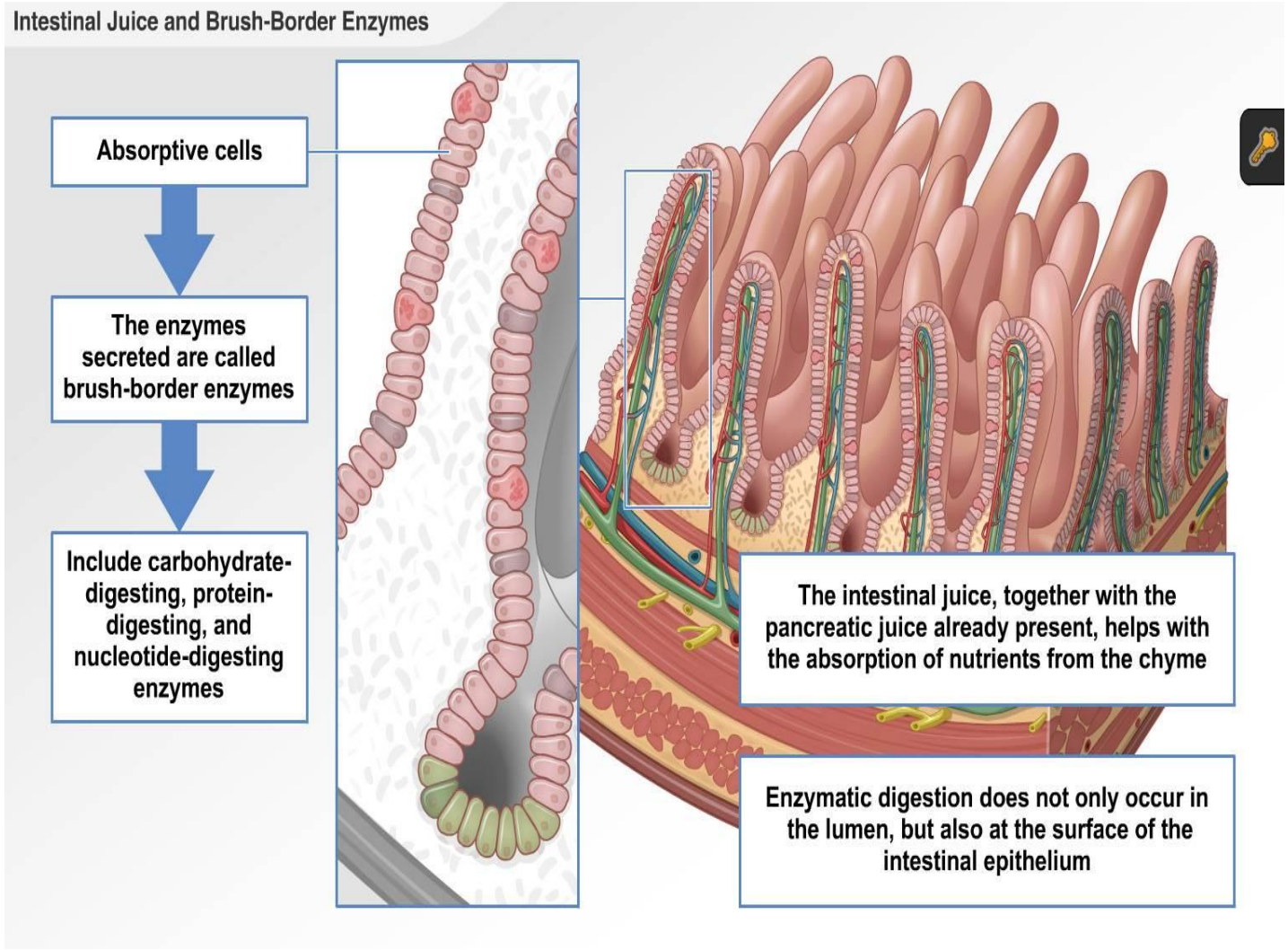
H. Water Absorption

1. small intestine - 95% of water absorbed by small intestine following transport of solutes
2. large intestine - absorbs remaining water before moving the chyme on to the rectum

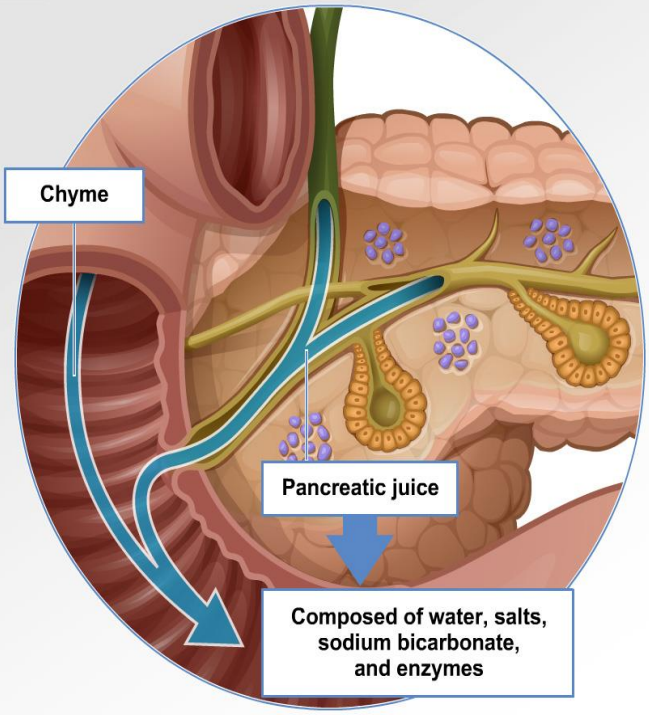
I. Malabsorption of Nutrients

1. impairment of bile or pancreatic juice release
2. infections of the intestinal mucosa
3. gluten enteropathy - "gluten" protein in grains damages the mucosa of the intestines

Intestinal Juice and Brush-Border Enzymes



The Pancreas



Sodium bicarbonate:

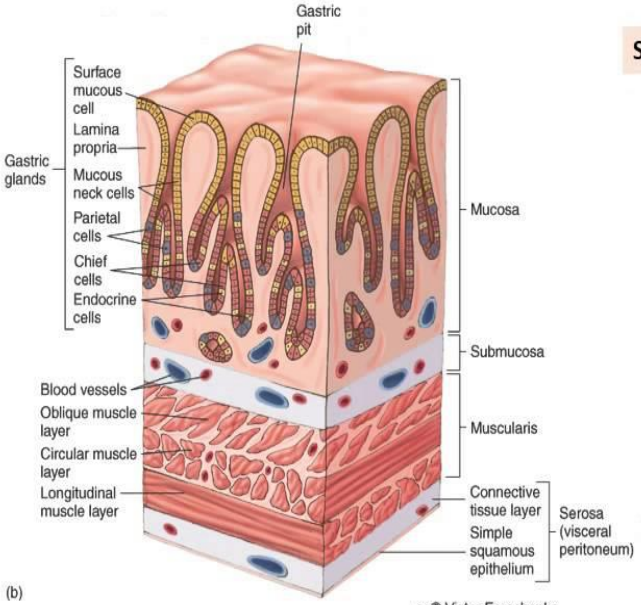
- Neutralize the acidic gastric juice entering the small intestine from the stomach
- Adjust the pH to allow the proper function of digestive enzymes

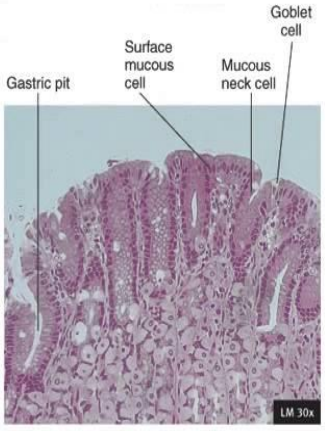
Pancreatic enzymes:

- Pancreatic amylase that digests sugars
- Trypsin and chymotrypsin that digest proteins
- Pancreatic lipase that digests fats
- Nucleases that digest RNA and DNA into their nucleic acid building blocks

Gastric Glands

See Figure 24.12, Table 24.3





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