

Nutrition Physiology-2

Digestion and Absorption of Food

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Small Intestine

- Small Intestine
 - Majority of the digestive process
 - Duodenum
 - Jejunum
 - Ileum

Small Intestine

- **Villi:** Fingerlike projections those cover circular folds
- **Microvilli:** Small projections of epithelial cells that cover villi (Brush border)
- **Goblet cells:** between epithelial cells, secrete mucus

Small Intestine

- Villus
 - Lacteal: lymphatic vessel
 - Capillary network
- Most of the absorbed fat enters to lacteal, reaches the general circulation by thoracic duct

Small Intestine

- Most of the chyme is fully digested and absorbed in the first quarter of small intestine
 - Duodenum + part of the jejunum

Accessory organs

- Central pancreatic duct delivers exocrine secretions of pancreas into the duodenum
- Liver secretes bile into small ducts that join to form the common hepatic duct
- Gallbladder, storage of secreted bile
 - During the meal, walls contract
 - Bile flows down the common bile duct
 - Injected through the sphincter of Oddi into the duodenum

Pancreas

- Exocrine portion
 - HCO₃ and digestive enzymes
 - Enzymes secreted from acini lobules (acinar cells)
 - HCO₃ secreted by epithelial cells lining the pancreatic ducts
 - HCO₃ neutralizes the high acidity of chyme

Pancreas

- Enzymes secreted by pancreas;
 - Digest fat, polysaccharides, proteins, nucleic acids
 - fatty acids, monoglycerides, sugars, amino acids and nucleotides

Pancreas

- Proteolytic enzymes are secreted as zymogens
- Enterokinase: embedded in the apical membrane of the intestinal epithelial cells
 - Formation of trypsin from trypsinogen
- Trypsin:
 - activation of other zymogens
 - Digestion of ingested proteins
- Nonproteolytic enzymes (amylase and lipase) released in active form

Pancreas

- Secretion increase during meal
 - Stimulation by secretin and CCK
 - Secretin → HCO_3
 - CCK → acinar cells

Liver

- Liver
 - First station for absorbed water-soluble substances
 - Storage or further metabolism
 - Elimination of toxic substances
- Water-insoluble substances (i.e., triglycerides) absorbed into lymphatic vessels, bypass liver and enter cardiovascular system in large veins near the heart

Liver

- Bile;
 - HCO₃, cholesterol, phospholipids, bile pigments, number of organic wastes and bile salts
 - HCO₃ → neutralize acid
 - Bile salts → solubilize dietary fat

Liver

- Hepatic lobule
 - Functional unit of the liver
 - Portal triads: bile duct+hepatic and portal veins + hepatic artery
 - Substances absorbed from the small intestine wind up in the hepatic sinusoid
 - To reach the vena cava
 - Taken up by hepatocytes (liver cells) to be modified and secreted into bile canaliculi

Digestion and Absorption of Carbohydrate

- Average daily intake 250-300 g
 - 2/3 starch
 - Sucrose
 - Lactose

Digestion and Absorption of Carbohydrate

- Starch
 - 95% digested in small intestine by pancreatic amylase
 - 5% salivary amylase
- Intermediate product → maltose + short, branched glucose molecules (amylase)
- Final products → glucose, galaktose, fructose (enzymes located at the brush border of small intestine)

Digestion and Absorption of Carbohydrate

- Monosaccharides transported across the intestinal epithelium into the blood
- Fructose by facilitated diffusion via a glucose transporter (GLUT)
- Glucose and galactose; secondary active transport coupled to Na via the sodium-glucose cotransporter (SGLT)
- From epithelial cells to interstitial fluid by way of facilitated diffusion via various GLUT proteins
- Diffusion into the blood through capillary pores

Digestion and Absorption of Protein

- 60-90 g of protein intake/day
- Enzymes, mucus secreted to GI

- Pepsin (stomach) → partially broken down to peptide fragments

- Trypsin and Chymotrypsin (small intestine) → complete breakdown
 - Can be absorbed
 - Can be further digested to free amino acids
 - By carboxypeptidases (pancreas) or aminopeptidases (brush border)

Digestion and Absorbption of Protein

- Absorbed as short chains of amino acids by secondary active transport coupled to H⁺ gradient
- Free amino acids by secondary active transport coupled to Na⁺
 - Many transporters specific to different amino acids

Digestion and Absorption of Protein

- Within the cytosol of epithelial cell, dipeptides and tripeptides are hydrolyzed to amino acids
- Enter to interstitial fluid through facilitated diffusion transporters

Digestion and Absorbption of Protein

- Very small amounts of intact protein are able to cross the intestinal epithelium by endocytosis and exocytosis
- Capacity is much greater in infants ?
 - For absorption of antibodies secreted into the mother's milk

Digestion and Absorption of Fat

- 70-100 g lipid intake/day
 - Mostly fat (triglycerides)
- Digestion in small intestine
 - Pancreatic lipase: splitting of bonds linking fatty acids to the first and third carbon atoms of glycerol

Digestion and Absorbption of Fat

- Lipids in food are insoluble in water and aggregate into large lipid droplets in the upper portion of the stomach
- Pancreatic lipase is water soluble, can only act on surface of a lipid droplet
- If the lipid droplet is very large, the rate of digestion would be very slow (surface area to volume ratio)
- **Emulsification:** Division of lipid droplets into many very small droplets

Digestion and Absorption of Fat

- Emulsification
 - Mechanical disruption
 - Emulsifying agent to prevent reaggregating back into large droplets
 - GI motility
 - Phospholipids in food, phospholipids and bile salts secreted in bile

Digestion and Absorption of Fat

- Phospholipids and cholesterol are amphipatic
- Nonpolar portions of the phospholipids and bile salts associate with the nonpolar interior of the lipid droplets, leaving the polar portion exposed to the water
- Repel other coated droplets and preventing from reaggregation

Digestion and Absorbtion of Fat

- Coating impairs accessibility of lipase to its lipid substrate
- **Colipase:**
 - secreted by pancreas
 - Amphipathic
 - Binds to lipase and droplet
 - Holds lipase on the droplet surface

Digestion and Absorption of Fat

- Micelles
 - Smaller emulsion droplets
 - Bile salts, fatty acids, monoglycerides, phospholipids clustered together
 - In the core small amount of vitamins and cholesterol

Digestion and Absorption of Fat

- Free fatty acids and monoglycerides
- Micels
- Equilibrium; formation and breakdown
- Triglycerides are resynthesized (endoplasmik retikulum) in epithelial cells and released to interstitial fluid as chylomicrons by exocytosis
- Chylomicrons pass into lacteals

Digestion and Absorption of Vitamins

- No digestion
- Absorption in small intestine
- Fat-soluble vitamins (A-D-E-K) follow the pathway for fat absorption
- Water soluble vitamins are absorbed by diffusion or mediated transport
 - Exception, B12

Digestion and Absorption of Vitamins

- B12 is very large and charged
- Binds to intrinsic factor
- Complex binds to specific sites on epithelial cells and absorbed by endocytosis in the lower part of ileum

Digestion and Absorption of Water and Minerals

- 8000 ml water / day enters to small intestine, 80% is absorbed
- Water diffusion occurs across the epithelium
- Na⁺
 - Abundent in chyme
 - Primary active transport; Na⁺/K⁺ ATPase pump