Digestive Physiology
Enzymes of Digestion
Salivary Glands

Saliva
Ox produces up to 200 L/day
Man 1-2L/day

Pig and Horse saliva contains some amylase
Ruminants and carnivores have no salivary amylase

When present salivary amylase starts to break carbohydrates down into simple sugars

Stomach glands and secretions

- Protein digestion begins
  - HCl denatures (unfolds) protein molecules
  - HCl transforms pepsinogen into pepsin that breaks peptides bonds between certain amino acids
- Fat digestion continues
  - gastric lipase splits the triglycerides in milk fat
    - most effective at pH 5 to 6 (infant stomach)
- HCl kills microbes in food
- Mucous cells protect stomach walls from being digested with 1-3mm thick layer of mucous

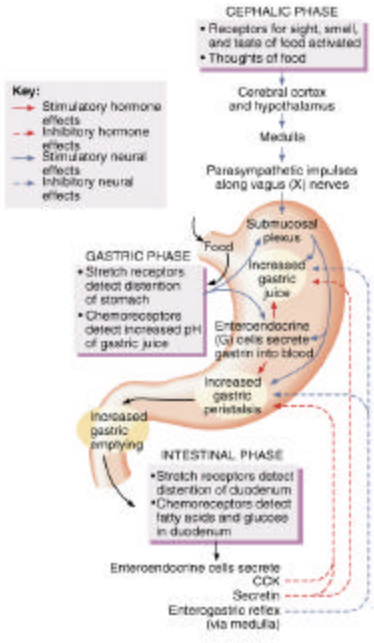
Other Stomach secretions

Gastrin
- produced by the G-cells
- stimulates HCL secretion

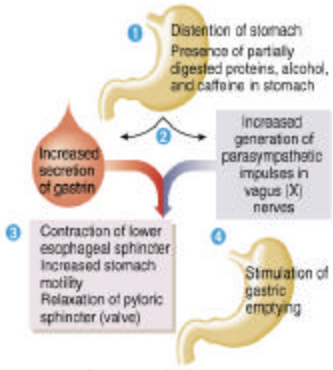
Rennin
- produced by young ruminant animals
- causes milk coagulation

Regulation of Gastric Secretion and Motility

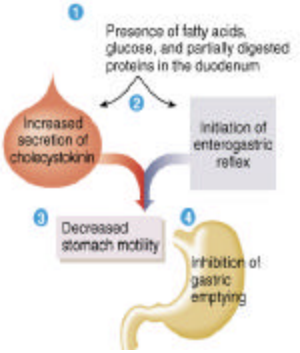
- Cephalic phase: "Stomach Getting Ready"
- Gastric phase: "Stomach Working"
- Intestinal phase: "Stomach Emptying"



Regulation of Gastric Emptying

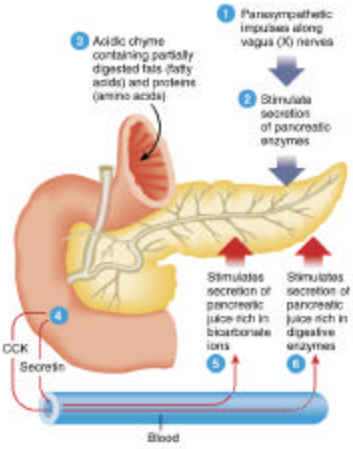


- Release of chyme is regulated by neural and hormonal reflexes
- Distention & stomach contents increase secretion of gastrin hormone & vagal nerve impulses
  - stimulate contraction of esophageal sphincter and stomach and relaxation of pyloric sphincter
- Enterogastric reflex regulates amount released into intestines
  - distension of duodenum & contents of chyme
  - sensory impulses sent to the medulla inhibit parasympathetic stimulation of the stomach but increase secretion of cholecystokinin and stimulate sympathetic impulses
  - inhibition of gastric emptying



Composition and Functions of Pancreatic Juice

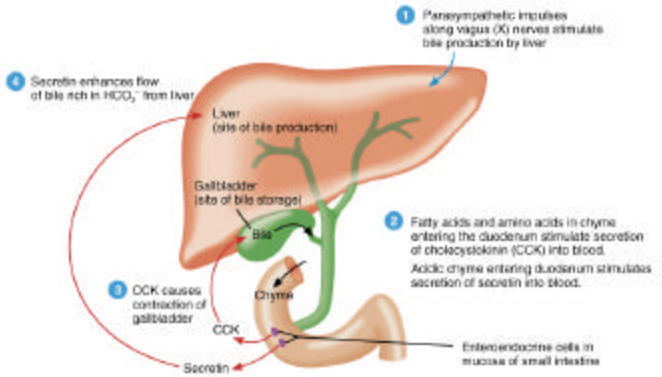
- 1 & 1/2 Quarts/day at pH of 7.1 to 8.2
- Contains water, enzymes & sodium bicarbonate
- Digestive enzymes
  - pancreatic amylase, pancreatic lipase, proteases
    - trypsinogen---activated by enterokinase (a brush border enzyme)
    - chymotrypsinogen----activated by trypsin
    - procarboxypeptidase---activated by trypsin
    - proelastase---activated by trypsin
    - trypsin inhibitor---combines with any Trypsin produced inside pancreas
  - ribonuclease----to digest nucleic acids
  - Deoxyribonuclease



Regulation of Pancreatic Secretions

- Secretin
  - acidity in intestine causes increased sodium bicarbonate release
- GIP
  - fatty acids & sugar causes increased insulin release
- CCK
  - fats and proteins cause increased digestive enzyme release

Regulation of Bile Secretion



Liver Functions--Carbohydrate Metabolism

- Turn proteins into glucose
- Turn triglycerides into glucose
- Turn excess glucose into glycogen & store in the liver
- Turn glycogen back into glucose as needed

Liver Functions --Lipid Metabolism

- Synthesize cholesterol
- Synthesize lipoproteins----HDL and LDL(used to transport fatty acids in bloodstream)
- Stores some fat
- Breaks down some fatty acids

Liver Functions--Protein Metabolism

- Deamination = removes NH2 (amine group) from amino acids so can use what is left as energy source
- Converts resulting toxic ammonia (NH3) into urea for excretion by the kidney
- Synthesizes plasma proteins utilized in the clotting mechanism and immune system
- Convert one amino acid into another

Other Liver Functions

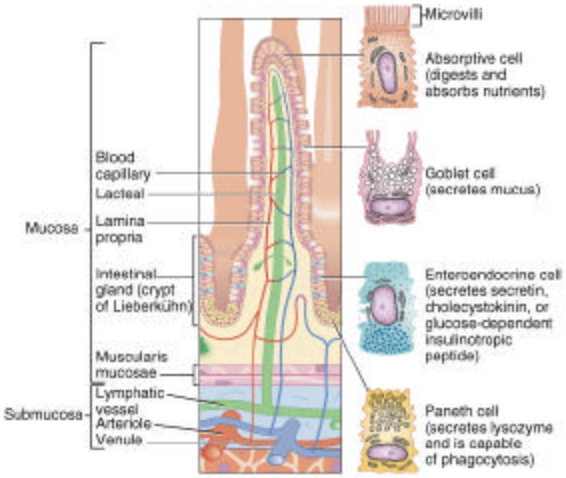
- Detoxifies the blood by removing or altering drugs & hormones(thyroid & estrogen)
- Removes the waste product--bilirubin
- Releases bile salts help digestion by emulsification
- Stores fat soluble vitamins-----A, B12, D, E, K
- Stores iron and copper
- Phagocytizes worn out blood cells & bacteria
- Activates vitamin D (the skin can also do this with 1 hr of sunlight a week)

Summary of Digestive Hormones

- Gastrin
  - stomach, gastric & ileocecal sphincters
- Gastric inhibitory peptide--GIP
  - stomach & pancreas
- Secretin
  - pancreas, liver & stomach
- Cholecystokinin--CCK
  - pancreas, gallbladder, sphincter of Oddi, & stomach

Cells of Intestinal Glands

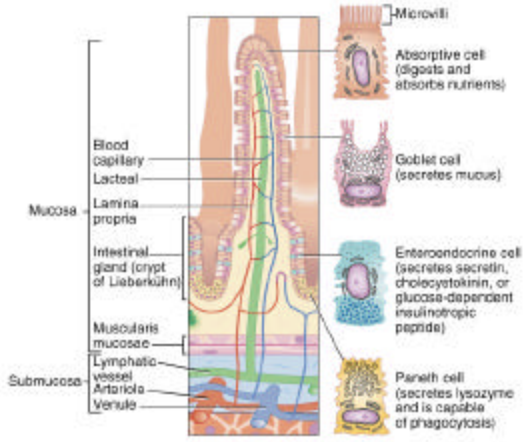
- Absorptive cell
- Goblet cell
- Enteroendocrine
  - secretin
  - cholecystokinin
  - gastric inhibitory peptide



- Paneth cells
  - secretes lysozyme

Goblet Cells of GI epithelium

Unicellular glands that are part of simple columnar epithelium



Roles of Intestinal Juice & Brush-Border Enzymes

- Submucosal layer has duodenal glands
  - secretes alkaline mucus
- Mucosal layer contains intestinal glands = Crypts of Lieberkuhn(deep to surface)
  - secretes intestinal juice
    - 1-2 qt./day------ at pH 7.6
  - brush border enzymes
  - paneth cells secrete lysozyme kills bacteria

Digestion of Carbohydrates

- Mouth---salivary amylase
- Esophagus & stomach---nothing happens
- Duodenum----pancreatic amylase
- Brush border enzymes (maltase, sucrase & lactose) act on disaccharides
  - produces monosaccharides--fructose, glucose & galactose
  - lactose intolerance (no enzyme; bacteria ferment sugar)--gas & diarrhea

Lactose Intolerance

- Mucosal cells of small intestine fail to produce lactase
  - essential for digestion of lactose sugar in milk
  - undigested lactose retains fluid in the feces
  - bacterial fermentation produces gases
- Symptoms
  - diarrhea, gas, bloating & abdominal cramps
- Dietary supplements are helpful

Digestion of Proteins

- Stomach
  - HCl denatures or unfolds proteins
  - pepsin turns proteins into peptides
- Pancreas
  - digestive enzymes---split peptide bonds between different amino acids
  - brush border enzymes-----aminopeptidase or dipeptidase------split off amino acid at amino end of molecule or split dipeptide

Digestion of Lipids

- Mouth----lingual lipase
- Small intestine
  - emulsification by bile
  - pancreatic lipase---splits into fatty acids & monoglyceride
  - no enzymes in brush border

Digestion of Nucleic Acids

- Pancreatic juice contains 2 nucleases
  - ribonuclease which digests RNA
  - deoxyribonuclease which digests DNA
- Nucleotides produced are further digested by brush border enzymes (nucleosidease and phosphatase)
  - pentose, phosphate & nitrogenous bases
- Absorbed by active transport

Regulation of Secretion & Motility

- Enteric reflexes that respond to presence of chyme
  - increase intestinal motility
  - VIP (vasoactive intestinal polypeptide) stimulates the production of intestinal juice
  - segmentation depends on distention which sends impulses to the enteric plexus & CNS
    - distention produces more vigorous peristalsis
    - 10 cm per second
- Sympathetic impulses decrease motility

Mechanical Digestion in Large Intestine

- Smooth muscle = mechanical digestion
- Peristaltic waves (3 to 12 contractions/minute)
  - haustral churning----relaxed pouches are filled from below by muscular contractions (elevator)
  - gastroilial reflex = when stomach is full, gastrin hormone relaxes ileocecal sphincter so small intestine will empty and make room
  - gastrocolic reflex = when stomach fills, a strong peristaltic wave moves contents of transverse colon into rectum

Chemical Digestion in Large Intestine

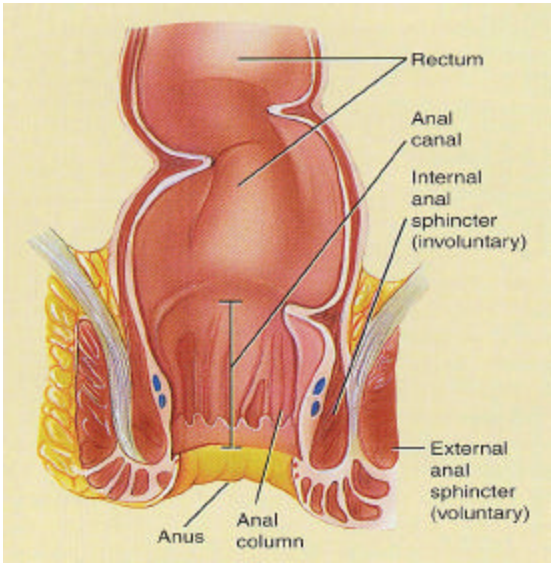
- No enzymes are secreted only mucous
- Bacteria ferment
  - undigested carbohydrates into carbon dioxide & methane gas
  - undigested proteins into simpler substances (indoles)----odor
  - turn bilirubin into simpler substances that produce color
- Bacteria produce vitamin K and B in colon

Absorption & Feces Formation in the Large Intestine

- Some electrolytes---Na^+ and Cl^-
- After 3 to 10 hours, 90% of H_2O has been removed from chyme
- Feces are semisolid by time reaches transverse colon
- Feces = dead epithelial cells, undigested food such as cellulose, bacteria (live & dead)

Defecation

- Gastrocolic reflex moves feces into rectum
- Stretch receptors signal sacral spinal cord
- Parasympathetic nerves contract muscles of rectum & relax internal anal sphincter
- External sphincter is voluntarily controlled



Defecation Problems

- Diarrhea = chyme passes too quickly through intestine
  - H_20 not reabsorbed
- Constipation--decreased intestinal motility
  - too much water is reabsorbed
  - remedy = fiber, exercise and water

Absorption

- no food is absorbed prior to stomach
- very little is absorbed in stomach; some drugs, alcohol, electrolytes
- most absorption occurs in small intestine of all animals, esp. carnivores and omnivores
- herbivores: large intestine absorption very important as most of the digestion takes place in colon/cecum
- small amounts of water are absorbed in large intestine
- large intestine secretes mucus for lubrication and protection

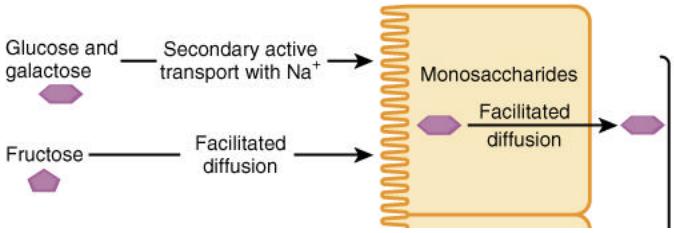
Proventriculus (forestomach) of ruminant Unique as it absorbs

- a number of drugs
- salts of sodium and potassium
- carbonates
- chlorides of various substances
- glucose
- short-chain FA (acetic, propionic and butyric)

Neonatal Absorption
macromolecules from colostrum

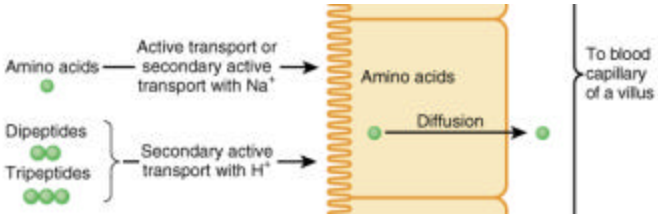
Absorption of Monosaccharides

- Absorption into epithelial cell
  - glucose & galactose----sodium symporter(active transport)
  - fructose-----facilitated diffusion
- Movement out of epithelial cell into bloodstream
  - by facilitated diffusion

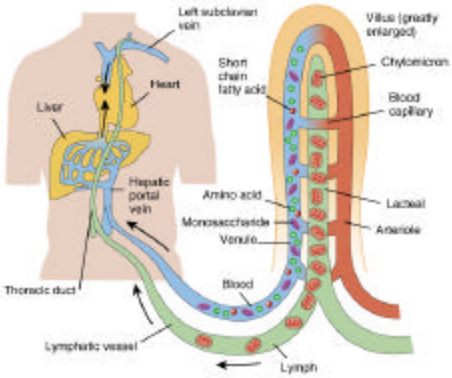


Absorption of Amino Acids & Dipeptides

- Absorption into epithelial cell
  - active transport with Na+ or H+ ions (symporters)
- Movement out of epithelial cell into blood
  - Diffusion



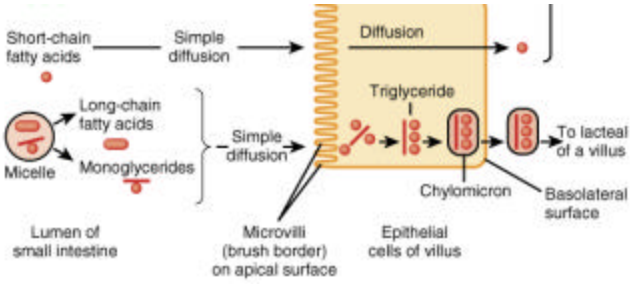
Where do all the nutrients/substances that are absorbed go to?
Amino acids and simple sugars enter portal veins→liver



Fats are a little more complicated
Bile salts emulsify fat into smaller droplets
gastric, lingual and pancreatic lipase degrade
Triglycerides (TG)

Diglycerides, Monoglycerides, Fatty Acids and Glycerol

- Chylomicrons leave intestinal cells by exocytosis into a lacteal
  - travel in lymphatic system to reach veins near the heart
  - removed from the blood by the liver and fat tissue



Absorption of Electrolytes

- Sources of electrolytes
  - GI secretions & ingested foods and liquids
- Enter epithelial cells by diffusion & secondary active transport
  - sodium & potassium move = Na+/K+ pumps (active transport)
  - chloride, iodide and nitrate = passively follow
  - iron, magnesium & phosphate ions = active transport
- Intestinal Ca+ absorption requires vitamin D & parathyroid hormone

Absorption of Vitamins

- Fat-soluble vitamins
  - travel in micelles & are absorbed by simple diffusion
- Water-soluble vitamins
  - absorbed by diffusion
- B12 combines with intrinsic factor before it is transported into the cells
  - receptor mediated endocytosis

Absorption of Water