The Vertebrate (mostly human) Digestive System

Mouth - mastication, lubrication, digestion
Pharynx and Esophagus - swallowing
Stomach - some digestion
Small intestine - most digestion and absorption
Large intestine - some absorption
Rectum - packaging

Liver - produces bile - aids in fat digestion
Pancreas - produces many digestive enzymes

Gastrointestinal tract has a layered structure

Lumen - interior space
Mucosa - innermost layer of epithelium
Submucosa - connective tissue
Muscularis - double layer of smooth muscle circular and longitudinal
Serosa - connective tissue covers exterior
Nerve plexuses - in submucosa, regulate activities
Glands - in submucosa and outside serosa - secrete substances into lumen
The Mouth
The teeth cut and grind food - mastication
Tongue mixes food with saliva
Salivary glands produce saliva - empty through mucosa of mouth
  salivary amylase initiates breakdown of starch
  Secretion of saliva controlled by the nervous system
  low level continuous secretion keeps the mouth moist
  high level secretion stimulated by sight, smell, or idea of food

Swallowing
Food passes to the back of the mouth
  Palate elevates, pushes against rear of pharynx
    Seals off nasal cavity - a good thing
  Pressure on pharynx stimulates swallowing center in brain
    Swallowing center inhibits respiration - a good thing
    Seals trachea - raises larynx and closes glottis with epiglottis
Esophagus

Upper 1/3 of esophagus enveloped in voluntary skeletal muscle
Lower 2/3 enveloped in involuntary smooth muscle
Food propelled by peristaltic waves of muscular contractions

Entry of food into stomach controlled by gastric sphincter - prevents food in stomach from re-entering esophagus

Stomach
Sack-like, thick walled, muscular, with highly convoluted interior mucosa
Smooth muscle churns food

Glands in mucosa produce secretions several compounds
Parietal cells secrete HCl and intrinsic factor (for B\textsubscript{12} absorption)
Chief cells secrete pepsinogen, an inactive protease
Active proteases in stomach activate pepsinogen to pepsin
Digestion in stomach restricted to protein digestion
proteins reduced to smaller polypeptides
HCl aids protein digestion by denaturing proteins

Stomach produces 2 l
  gastric secretions/day
Stomach pH = 2
No digestion of carbohydrates or fats
The acidic food mixture produced in the stomach is called “chyme”

Little absorption occurs in stomach - some water, alcohol, aspirin
Chyme leaves stomach and enters duodenum through pyloric sphincter
Capacity of duodenum is small compared to stomach
Rate of dumping controlled by nervous system and hormones
Small Intestine
about 6 m long
composed of three sections - duodenum, jejunum, ileum
most digestion occurs in duodenum and jejunum
Duodenum is 25 cm long - remainder is jejunum and ileum
receives chyme, pancreatic enzymes, bile from liver

Epithelial wall has many folds - villi

Villi have cytoplasmic projections - microvilli

Both increase surface area for absorption and secretion

Epithelial wall also called “brush border”
Brush border has embedded enzymes that hydrolyze lactose, sucrose and other sugars
Accessory Organs

Pancreas
Pancreas - at junction of stomach and small intestine
Connected via pancreatic duct
Has both exocrine and endocrine functions
Fluid contains many enzymes proteases (trypsin and chymotrypsin)
pancreatic amylase and fat digesting lipase

Enzymes released as inactive zymogens, activated by brush border enzymes
Fluid also contains bicarbonate to neutralize HCl
Chyme in intestine becomes slightly alkaline

Absorption in the Small Intestine

Amino acids and simple sugars transported across brush border - through epithelial cells and into capillaries within villi

Blood carries digestion products to liver - via hepatic portal vein
Fats hydrolyzed into fatty acids and monoglycerides
Absorbed by intestinal epithelium and reassembled into triglycerides
New fats combined with proteins to form water-soluble chylomicrons
Absorbed into lymphatic capillaries
Contents of lymphatic system enter blood stream in veins near neck

Each day 9 liters of chyme passes small intestine
Nearly all fluids and solids are absorbed
8.5 liters absorbed in the small intestine
350 milliliters reabsorbed in the large intestine
50 grams of solids and 100 milliliters of liquid leave as feces
Large Intestine (colon)
Has no digestive function
absorbs 4% of fluids
Surface lacks villi
about 1 m long
Harbors symbiotic bacteria
Absorbs sodium, vitamin K,
other products of bacterial metabolism
Small intestine empties into
large intestine through
ileocecal valve just above
cecum and appendix

Primary function is to compact and store feces
Bacteria are incorporated into feces
Bacterial fermentation produces gas

Human colon evolved to process food with high cellulose content

Low fiber diets result in slower passage of food through colon

May be associated with high level of colon cancer in U. S.
The rectum - terminal portion of the large intestine
Feces pass into rectum by peristaltic contractions

Material exits anus through two sphincters
First sphincter is smooth muscle, opens involuntarily
Second sphincter is striated muscle
under voluntary control - a very good thing

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Pancreas is also an endocrine gland
Produces hormones that regulate blood sugar level
Produced in islets of Langerhans clustered throughout pancreas
Most important pancreatic hormones are insulin and glucagon

Insulin - produced by $\beta$-cells -
released in response to high blood sugar
stimulates sugar uptake by liver and muscles - converted to glycogen
Glucagon - produced by $\alpha$-cells -
released in response to low blood sugar
stimulates release of sugar from liver - from stored glycogen

Liver and Gallbladder
Main secretion of liver is bile - a fluid with bile pigments and bile salts
Bile pigments are waste products from destruction of red blood cells
Bile salts are lipid and water soluble - Emulsify fats - Allows faster digestion of fat
Bile is stored and concentrated in gall bladder
Fatty food in duodenum triggers contraction of gallbladder to release bile

Contraction of gallbladder may result in pain under right shoulder blade
**Regulatory Functions of the Liver**

Hepatic portal vein carries blood from stomach and intestine to liver
Liver absorbs or chemically modifies substances
Alcohol, drugs, toxins metabolized by liver cells
Ammonia from intestinal bacteria converted into urea
Controls level of many substances produced by body
Steroid hormones converted into less active forms
Terminal products of metabolism eliminated in feces or through kidneys
Produces proteins found in blood plasma
Includes most blood clotting factors
Maintains blood protein concentration within narrow limits

**Neural and Hormonal Regulation of Digestion**

**Nervous Control**
Sight/Smell of food stimulates salivary and gastric secretions

**Hormonal Control**
Food in stomach stimulates secretion of gastrin by stomach
Gastrin stimulates secretion of pepsinogen and HCl
Low stomach pH reduces secretion of gastrin
Passage of chyme from stomach inhibits stomach contractions

Process mediated by neural impulses and enterogastrone proteins

Gastric inhibitory peptide (GIP) is one enterogastrone
GIP released by duodenum
Production stimulated most strongly by fat in chyme

Cholecystokinin (CCK) is secreted in response to fat in chyme
Stimulates contraction of gallbladder to release bile
Secretin released in response to low pH chyme
Stimulates pancreas to release bicarbonate and enzymes