

## Accessory Glands

### 1. Liver

- see *text p. 827-832* and *figure 25.23 and 25.24*
- largest, heaviest gland in the body (1-2 kg)
- located just below the diaphragm
- a. lobes:
  1. right lobe
    - larger, higher
    - a. caudate
    - b. quadrate -- covers the gall bladder
  2. left lobe
- b. ducts:
  1. hepatic duct
    - from the liver to the gall bladder and common bile duct
    - to common bile duct
  2. cystic duct
    - from the gall bladder → common bile duct
    - *cholecystectomy* = removal of the gall bladder
  3. common bile duct
    - formed from the union of the cystic and hepatic ducts
    - into duodenum at the sphincter of Oddi
  4. pancreatic duct
    - from pancreas
    - meets common bile duct
    - both enter duodenum at the sphincter of Oddi
- c. functions of the liver:
  1. bile production
    - bile is produced by the liver, but stored in the gall bladder
    - a. bile salts (24 C)
      - similar to cholesterol (27 C)
      - emulsify fats -- break large molecules to small molecules
      - activate *lipases*
        - these break down lipids (fats)
      - ↑↑ solubility of fats in bloodstream
    - b. bilirubin
      - from RBC breakdown
      - gives bile its green-yellow color
  2. glycogen storage
    - major storage area for glycogen
      - much more is stored in the muscles
    - glucose is made from glycogen
  3. vitamin storage
    - fat soluble: A, D, E and K
    - *hypervitaminosis* = excessive amounts of a fat soluble vitamin

4. metabolism
  - a. *anabolism* = build-up of substances
    - *gluconeogenesis* = new glucose synthesis
      - from fatty acids and glycerol
      - from certain amino acids
  - b. *catabolism* = breakdown of substances
    - *glycolysis* = breakdown of glucose
      1. anaerobic
        - glucose breakdown in the absence of O<sub>2</sub>
        - formation of lactic acid and 2 ATP
      2. aerobic
        - glucose breakdown in the presence of O<sub>2</sub>
        - formation of 36 to 38 ATP with aid of the Krebs cycle
    - *glycogenolysis* = glycogen → individual molecules of glucose
5. detoxification
  - certain “poisons” can be altered so that they may be excreted via urine or feces
  - many other substances altered by liver:
    - e.g. steroid-like molecules (cortisol, cortisone, estrogen, testosterone)
6. synthesis of certain plasma proteins
  - a. clotting factors
    - prothrombin, fibrinogen
  - b. albumin
    - major protein in bloodstream
  - c. globulins
    - many of these act as carrier molecules
      1. sex hormone binding globulins
        - overproduced during pregnancy
      2. transferrin
        - carries iron
      3. transcortin
        - carries glucocorticoids

\* note: more protein synthesis seen in muscle

## 2. Pancreas

- see *text p. 825-827* and *figure 25.22*
- retroperitoneal
- lies close to duodenum
- pancreatic duct
  - meets the common bile duct at the sphincter of Oddi
- yellowish in color, somewhat fish-shaped

a. functions of the pancreas

1. endocrine

- a ductless system

- hormones are released from the pancreas into the bloodstream

\* note: hormones are a blood-carried messenger system

- four major endocrine secretions:

a. insulin

- released from the  $\beta$ -islet cells of Langerhans

-  $\downarrow$  blood glucose levels

- moves glucose from bloodstream into fat and muscle cells

- this is absent or deficient in diabetics

-  $\uparrow$  glucose :  $\uparrow$  insulin

b. glucagon

- released from the  $\alpha$ -islet cells

-  $\uparrow$  blood glucose levels

- glycogenolysis will take glycogen and break it into glucose

-  $\downarrow$  glucose :  $\uparrow$  glucagon

c. pancreatic polypeptide

d. somatostatin

- released from the delta-islet cells

- 14 amino acids in length

- part of a larger class of molecules called “gut-brain peptides”

- these were first discovered in GI-tract

- found to be the same molecules present in the brain

- regulates levels of insulin and glucagon

\* note: in the brain, it inhibits growth hormone

2. exocrine

- uses ducts

- secretions:

a. watery secretion

- very rich in  $\text{HCO}_3^-$

- this  $\uparrow$  pH

- buffers the acidity of the contents coming from the stomach

b. enzyme-rich secretion

- contains enzymes that break down proteins, carbohydrates and fats

1. proteases

- many types (e.g. trypsin, carboxypeptidase)

- protein digestion

2. pancreatic  $\alpha$ -amylase

- carbohydrate digestion

3. pancreatic lipases

- fat digestion (begins in small intestine)

- contains RNAases and DNAases

- nucleic acid breakdown  $\rightarrow$  nucleotides

- b. cystic fibrosis (CF)
  - frequency of 1 in 2,000 births
  - disease of the pancreas, pulmonary and other systems
  - autosomal recessive gene -- not sex-linked
    - previously, death occurred so early it was primarily found in children
    - currently, individuals live to 30-40 yrs.
  - ↑↑↑ mucus secretion from the pancreas
    - this impairs the normal functioning of the other organ systems
    - effects: ↓ ability to respire, ↓ effects of enzymes in GI-tract
  - 1989 -- CF gene was cloned
    - it is 250,000 base pairs in length
    - the gene changes the way Cl<sup>-</sup> is transported in the pancreas
      - affects the movement of H<sub>2</sub>O and mucus
  - possible to screen a fetus for the presence of the CF gene via:
    - *amniocentesis* -- week 12 of gestation
      - samples fetal cells and moms's cells
    - *chorionic villus sampling* -- week 7 of gestation
      - samples only fetal cells
  - recent therapy: recombinant DNA injected into lungs

## Digestive Tract -- Functions

- See *table 25.6, p. 828*

### 1. Oral cavity

- carbohydrate digestion only (salivary amylase)
- saliva
  - consists of H<sub>2</sub>O, HCO<sub>3</sub><sup>-</sup>, NaCl, salivary amylase
  - pH of 7
  - secretion is regulated by the autonomic nervous system
    - SNS: ↓ secretion
    - PSNS: ↑ secretion
  - some cortical control
    - "Pavlovian" response -- thought or smell of food induces salivation

### 2. Esophagus

- no digestion occurs here
- mucus production only -- lubricates to allow easy passage of food

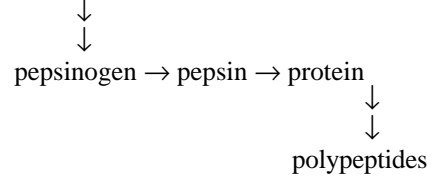
### 3. Stomach

- protein digestion primarily in stomach
- very little CHO digestion
  - low pH inhibits actions of salivary amylase
- no fat digestion
- 2-3 L of gastric juice are produced per day
- three phases of gastric juice production:
  - see *text 814-816* and *table 25.3*
  - a. cephalic phase
    - control occurs at brain level
    - smelling or thinking about food will ↑ gastric secretion
    - mediated via CN-X (vagus)

b. gastric phase

- physical presence of food in the stomach causes *distention*
- stretch receptors respond:

gastrin secreted → parietal cells → HCl produced



c. intestinal phase

- *enterogastric reflex*: inhibits gastric emptying
- feedback system between the small intestine and the stomach

1. processes:

- movement of *chyme* into small intestine
  - enzymes don't have time to break this material down
- small intestine negatively feeds-back on the stomach
  - reduces contractions of the stomach
  - slower food movement allows more time for thorough digestion

2. stimuli:

- movement of *chyme* (partially digested food) from stomach
- presence of protein breakdown products in the chyme
- ↑ concentration of HCl coming from the stomach

4. Intestine -- secretions

- 1-2 L of intestinal secretions produced each day

a. secretin

- discovered in 1902 by Bayliss and Starling

- ↑↑ HCl from the stomach
  - stimulates its release
- produced by the duodenum
  - enters the general circulation
- reaches pancreas where it has its effect
  - release of the watery bicarb solution into the duodenum
  - designed to neutralize the acidity which initiated its release
  - changes the duodenal pH from 2 to 7-8

b. cholecystokinin (CCK)

- released from the duodenum
  - enters the bloodstream
- effects on the gall bladder
    - causes contraction of the bile duct
    - releases bile to emulsify fats
  - also has effects on the pancreas
    - causes production and release of the enzyme-rich solution
      - contains pancreatic α-amylase
      - involved in polysaccharide breakdown into maltose, triose, etc.
      - also contains pancreatic lipase
        - breaks down triglycerides into fatty acids and glycerol

- c. enterokinase
  - produced by the duodenum
  - goes to the pancreas to activate other molecules
  - it also activates the RNases and DNases
- d. intestinal gastrin
  - ↑ parietal cell HCl

### Brush Border

- See *figure 25.16, p. 820*

- Refers to the microvilli present on the villi of the intestine

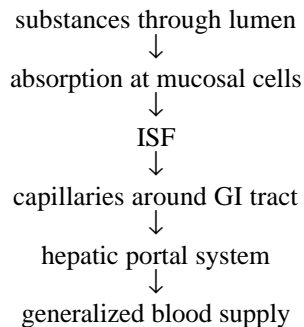
#### 1. Enzymes

- located in the membrane of mucosal cells
- complete final metabolism of molecules
  - macromolecules (starch) → smallest distinguishable units (such as glucose and fructose)
  - smallest units are absorbed into the capillaries

#### a. lactase

- a disaccharidase
- enzyme that allows for the conversion of **lactose** → **galactose + glucose**
- 1. *genetic lactase deficiency* = difficulty metabolizing lactose due to ↓↓ lactase
  - said to be “lactose intolerant”
  - processes:
    - unable to completely breakdown lactose
    - body unable to absorb lactose
    - lactose draws H<sub>2</sub>O with it -- diarrhea
  - environmental and genetic predisposition to lactose intolerance:
    - E. Asian = 90%
    - E. European = 80%
    - African American = 70%
    - Hispanic = 50%
  - what can be done:
    - pre-treated dairy products
      - lactose has already been broken down -- it can be easily digested
    - lactase pill taken with food so that lactose can be easily digested
      - \* note: if lactase pills are taken without food
        - they will be broken down in the stomach as lactase is a protein
- 2. *osteoporosis* = group of diseases resulting in bone demineralization
  - seen especially during post-menopausal period
  - highly correlated with reduction in estrogen
  - calcium requirements:
    - higher in youth
    - reduced from 25-35 years
    - increase again after menopause -- 1.2 g/day - 1.8 g/day
  - genetic predisposition:
    - highest incidence in small statured, Caucasian women of Northern European descent
    - lowest in African American women

- b. sucrase
    - a disaccharidase
    - found at intestinal brush border
    - enzyme that breaks down **sucrose** → **fructose + glucose**
  - c. maltase
    - a disaccharidase
    - enzyme that breaks **maltose** → **glucose** (2)
  - d. proteases
    - enzymes that break down **small peptones** → **dipeptides**
  - e. dipeptidases
    - enzyme that breaks **dipeptides** → **amino acids** (2)
    - these amino acids can be absorbed from lumen, into mucosal cell, into bloodstream
  - f. lipases
    - many types
    - enzyme that breaks **triglycerides** → **monoglycerides**
    - recall, molecules smaller than 20 C can be directly absorbed into the bloodstream
  - g. aminopeptidases
    - enzymes that work on certain **polypeptides** → **amino acids**
2. Absorption at the brush border
- see *text p. 821-824* and *figure 25.18, 25.19 and 25.20*
  - processes:



- a. glucose
  - absorption is **active**
  - processes:
    1.  $\text{Na}^+$  moves from lumen to mucosa (passive)
      - glucose is “co-transported” with  $\text{Na}^+$
      - via a carrier protein in membrane of mucosal cell
    2. sodium-and-glucose are pumped out of mucosal cell (active)
      - sodium-potassium pump required to get  $\text{Na}^+$  into blood -- ATP
      - glucose diffuses down concentration gradient into blood
- b. galactose
  - absorption is **active**

- c. fructose
  - moves by **facilitated diffusion**
    - moves from  $\uparrow$  to  $\downarrow$  concentration
    - movement is faster than expected by diffusion alone -- carrier molecule pulls fructose
- d. amino acids
  - absorption is **active**
  - also co-transported with  $\text{Na}^+$  -- similar to glucose

### Large Intestine

- See *text p. 833-838* and *figure 25.27*
- 1. Mucus secretion
- 2. Water absorption
  - 10 L of fluid are “presented” to GI tract each day
    - 8.5 L from GI secretions
    - 1.5 L from ingested substances
  - we must be able to absorb most of this water
    - 9.5 L reabsorbed each day
    - 0.5 L fluid in feces each day
  - \* note: amount of fluid in feces depends on the hydration of the body
- 3. Feces production

### Cholesterol

- 27 C molecule
- Produced in the liver, absorbed in the small intestine
- \* Note: important precursor for steroid hormones and other substances
- 1. Steroid nucleus
  - 4 cyclic structures:
    - 3 *hexacyclic* structures -- six-sided ring
    - 1 *pentacyclic* structure -- five-sided ring
  - also seen in bile salts, estrogen, progesterone, testosterone, cortisol, aldosterone
    - will see some side chains, etc., but the “steroid nucleus” is the same
- 2. Metabolism
  - usually in the form of triglycerides
    - glycerol backbone
    - 3 fatty-acid chains
  - bile salts break into smaller triglycerides
    - acted upon by lipases from pancreas
  - ultimately broken into monoglycerides, free fatty-acids and glycerol backbone
  - “micelles”
    - water soluble
  - lipoprotein lipase
    - acts on micelles (enzyme)
    - micelles into mucosal cells -- passive diffusion
    - produces “chylomicron”
      - into lymph system via lacteal
  - chylomicron
    - “very, very low density lipoprotein”
    - has protein, fats
    - higher percentage of fat than protein

3. Cell membrane
  - makes up 25-30% of cell membrane
  - the need for an outside source of cholesterol is controversial
    - children:
      - need outside source of cholesterol for normal growth
    - adults:
      - may not need an outside source of cholesterol
        - able to synthesize cholesterol from acetate (2 C)
        - some feel the body will overproduce cholesterol if no exogenous source
      - adults should not exceed 250 mg/day
        - \* note: one egg yolk contains 200 mg
4. Source of cholesterol
  - a. animal products
    - only source of cholesterol
    - examples: skin, egg yolks, fat (lard), shellfish
  - b. plant products
    - **do not contain cholesterol**
    - contain *sterols* -- similar to cholesterol; not actually cholesterol
    - some do contain certain saturated fatty acids (e.g. avocados)
      - these will ↑ the endogenous stores of cholesterol
      - need an equal proportion of each type of fatty acid
        - 1/3 saturated : 1/3 polyunsaturated : 1/3 monounsaturated
        - 1. saturated fatty acids
          - e.g. tropical plants / oils
        - 2. polyunsaturated fatty acids
          - e.g. safflower oil and sunflower oil
        - 3. monounsaturated fatty acids
          - e.g. olive oil
5. Circulating concentrations of cholesterol
  - a. Western Caucasians
    - actual intake is 200 mg/dL on average
    - should be <200 mg/dL doctors say
  - b. South African Indigenous Peoples and South American Indians
    - take in <160 mg/dL on average
      - most of the calories taken in are derived from carbohydrates
      - 65% of their total diet is carbohydrates
        - recall, our ratio of carbohydrate:fat:protein should be 60:30:10
6. Carrying cholesterol in bloodstream
  - not very soluble in bloodstream
  - lipoproteins ↑ solubility in water
    - a. VLDL (very low density lipoprotein)
      - only found in small amounts
    - b. LDL (low density lipoprotein)
      - major carrier of cholesterol in bloodstream
        - carries 2/3 of total cholesterol
      - considered the “bad” cholesterol
        - unloads cholesterol to the endothelium of blood vessels
          - this will ↓ the diameter of the lumen -- ↑ blood pressure, etc.
      - <150 mg/dL preferred

- c. IDL (intermediate density lipoprotein)
  - carries very small amount of cholesterol
- d. HDL (high density lipoprotein)
  - carries 1/3 of cholesterol
  - *HDL-cholesterol* is considered the “good” cholesterol
    - this is a cholesterol scavenger
    - high affinity to cholesterol
    - draws cholesterol off of endothelial walls of blood vessels
  - 38-60 mg/dL preferred
- \* note: increased ratio of HDL:LDL is most healthy
  - when an  $\uparrow$  LDL is seen (or more importantly, a  $\downarrow$  HDL) then greater cardiac risk
  - exercise can increase ratio of HDL / LDL

### Absorption / Secretion in the GI Tract

- Similar to processes in renal system
- 1. Sodium ( $\text{Na}^+$ )
  - active absorption
  - co-transported with molecules like simple sugars, amino acids
- 2. Potassium ( $\text{K}^+$ )
  - active secretion into lumen of small intestine
- 3. Calcium ( $\text{Ca}^{2+}$ )
  - active absorption
  - a. parathyroid hormone (PTH)
    - $\uparrow$   $\text{Ca}^{2+}$  absorption from small intestine
  - b. vitamin  $\text{D}_3$ 
    - often added to milk
    - $\uparrow$  production of *calcium-binding protein*
      - pulls  $\text{Ca}^{2+}$  from lumen of GI into bloodstream
    - steroid-like molecule
- 4. Chloride ( $\text{Cl}^-$ )
  - passively follows  $\text{Na}^+$
  - active in the thick ascending limb of the Loop of Henle (poss. via chloride pump)
- 5. Bicarbonate ( $\text{HCO}_3^-$ )
  - passive
- 6. Water
  - osmosis
  - most absorption in the large intestine
  - some in the small intestine