Digestion
Organs - Glands

Monogastric
Ruminant
Nonruminant Herbivore

References
• Primarily notes
• Kellems & Church text
  ‣ Chapter 2 – The Gastrointestinal Tract and Nutrient Utilization
• Smith, Marks, & Lieberman -
  Basic Medical Biochemistry
  ‣ Pg. 22-24

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Liver and Pancreas connect to the digestive tract and are essential components.
Wall of Intestinal Tract has 4 Layers
(Will illustrate later in the small intestine)

- Serosa - smooth outside covering
- Muscle - mixing and movement
- Submucosa - connective tissue
  - Blood vessels, lacteals (lymph), nerves
- Mucosa
Mucosa layer of stomach is subdivided into 4 zones...

Simple Stomach (Pig) (Zones of mucosa layer)

- Cardiac Gland region (Mucus)
- Cuticular Region (Non-glandular)
- Pyloric Gland region
  - (Mucus, HCL & enzymes)
- Pyloric Region
  - (Mucus)

Gastric Glands from Fundus of Stomach

1. Mucus neck cells - secrete mucus
2. Parietal cells - produce HCl
3. Chief cells - produce the gastric enzymes

Gastric Glands (Located in fundic gland region)
D. Small Intestine

- Divided into three parts
  - Duodenum
  - Jejunum
  - Ileum

- Two sets of muscles
  - Circular – cause peristaltic movements
  - Longitudinal – aid peristaltic movements

D. Small Intestine – cont.

Main functions of small intestine...

- Move chyme along its course
  - Chyme –

- Continued digestion of chyme by...

- Absorption of nutrients

D. Small Intestine – cont.

- Surface anatomy –
  - Folds – Villi - Microvilli
**Crypts of Lieberkühn**

1. Serosa (Visceral peritoneum - smooth lining)
2. Muscule layer
3. Longitudinal
4. Circular
5. Submucosa (Connective tissue)
6. Mucosa
7. Lumen
8. Nerves, blood & lymph vessels
9. Submucosa

**Structure of the Small Intestine**

- Villi
- Villus Epithelial Cell
- Microvilli
- Capillaries
- Lymph Vessel
- Vein
- Artery
- Smooth Duct

**Lacteal**

- Capillary
- Artery
- Wall
- Lact-Crypt
E. Large Intestine
(Cecum – Colon – Rectum)

- Absorption of water and minerals
- Very few secretions
- Cecum of horse & rabbit enlarged
- Sows on pasture have enlarged cecum and significant microbial fermentation

F. Anus

- Regulates removal of waste
Secretions and Functions of Digestive Organs

Factors Promoting Digestion
• Mechanical

• Secretory

• Chemical

• Microbiological - Bacteria & Protozoa

A. Mouth
• Saliva
  • 3 main pair salivary glands
    • Parotid -
    • Submaxillary -
    • Sublingual -
  • Saliva composition
    • Water -
    • Mucin -
    • Salts - \( \text{PO}_4, \text{Cl}^-, \text{SO}_4 \) of K, Ca, Mg
• Enzymes
A. Mouth

- Enzymes
  - Salivary amylase (man & pig)
    - Produced by parotid glands
    - Starch digesting enzyme
    - Starch \[\text{Salivary amylase} \rightarrow \text{Malto} \text{se + Dextrin}\]
    - Opt. pH 5.6-6.5
    - Deactivated by HCl in stomach
  - Pregastric lipase (from base of tongue)
    - Produced by ruminants
    - Aids milk fat digestion

- No digestive enzymes in ruminant saliva

B. Esophagus

- No digestive function
C. Stomach (Gastric)

Discussed gastric glands in fundus previously

C. Stomach (Gastric)

Composition of Gastric Juice...

1. Mucus - no digestive function
2. Gastric proteases
   - Pepsin (from chief cells of fundic gland)
     - Pepsinogen $\rightarrow$ Pepsin
     - Zymogen
     - Diet Protein $\rightarrow$ Long-chain polypeptides
   - Rennin (abomasum of nursing calf)
     - Prorennin $\rightarrow$ Rennin
     - Casein $\rightarrow$ Ca-Paracaseinate (coagulated)

C. Stomach (Gastric)

Composition of Gastric Juice (cont.)

3. HCl
   - Activates pepsinogen and prorennin
   - Denatures dietary proteins
   - Stomach antiseptic
   - Promotes some hydrolysis (minor importance)
   - Stops action of salivary amylase

4. Gastric lipase (minor importance)
D. Small Intestine

1. Forces at work
   - Intestinal motility
   - Intestinal juice
   - Bile
   - Pancreatic juice

D. Small Intestine (cont.)

2. Two sets of glands
   - Brunner’s glands
     - Secrete viscous alkaline mucus
     - pH = 7-8
     - Neutralizes acid chyme
     - Also aids in fat emulsification
   - Crypts of Lieberkühn
     - Enterokinase - activates trypsin (discuss later)
     - Amylase - breakdown of starch (minor role)
     - Mucus

D. Small Intestine (cont.)

Intracellular enzymes
- Located on surface or inside epithelial cells (on microvilli)
- Several peptidases
  - Split small peptides into amino acids
    (Small peptides, mainly dipeptides and tripeptides)
- Disaccharidases – sugar splitting enzymes
  - maltase Ú
  - sucrase Ú
  - lactase Ú
E. Large Intestine

- No digestive secretions
- Glands produce mucus only
- Dehydrator in many species
- Several species have a significant microbial population

Liver and Pancreas
Pancreas

Two types of tissue in the pancreas

1. Acinar - produce pancreatic juice
   - Released into duodenum

2. Islets of Langerhans - produce hormones
   - Released into blood
     - Beta cells - produce insulin
     - Alpha cells - produce glucagon
Pancreas

Pancreatic juice
- Clear fluid, mostly water
- Contains digestive enzymes
  - Major enzymes in digestion

Pancreas

Digestive Enzymes
1. Proteolytic enzymes
   - Trypsin
     Trypsinogen → Enterokinase → Trypsin
     - Trypsin, once formed, is autocatalytic.
     - Enterokinase from Crypts of Lieberkühn
   - Chymotrypsin
     Chymotrypsinogen → Trypsin → Chymotrypsin
   - Carboxypeptidase
     Procarboxypeptidase → Trypsin → Carboxypeptidase

Pancreas

Proteolytic enzymes (cont.)
- Trypsin & chymotrypsin
  = endopeptidases
- Carboxypeptidase
  = exopeptidase
Pancreas
Digestive Enzymes
2. Pancreatic amylase
3. Pancreatic lipase

Liver
Functions
- Secretes bile
  - fat emulsification
  - aids in absorption of lipids and fat-soluble vitamins
- Regulation of glucose concentration in blood
  - Glycogen storage and release
  - Gluconeogenesis
- Deamination of AA to form urea
- Synthesis of fatty acids from CHO and protein
- Storage of vitamins A and D
- Detoxification

Liver (cont.)
- Storage and distribution of antipernicious anemia factor (Vitamin B₁₂)
- Formation of fibrinogen, prothrombin, other plasma proteins
- Storage of iron (ferritin)
- Degradation and excretion of steroid hormones
Bile

- Produced continuously by liver
- Stored and concentrated in gall bladder
- Empties into S.I. when digesta (especially fat) enters from stomach

About 94% of bile salts are reabsorbed (ileum) and are recycled back to gall bladder

Bile

Composition of Bile...

- Na⁺, K⁺, Ca²⁺, Cl⁻, HCO₃⁻
- Bile Salts – (Cholic acid & chenodeoxycholic acid)
  - Amphipathic – solubilize fats
    - Amphipathic = both polar and nonpolar regions; part hydrophilic & part hydrophobic
- Bilirubin – product of Hb breakdown
  - Primary bile pigment - yellow color - Modified by enzymes to give brown color in feces
- Cholesterol
- Fatty acids
- Lecithin

Regulation of Digestion
Neural Control

- Salivary secretions
- HCl secretion
- Pancreatic secretion

<table>
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<tr>
<th>Hormone</th>
<th>Origin</th>
<th>Releasing Mechanism</th>
<th>Function</th>
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<tr>
<td>Gastrin</td>
<td>Pyloric region of stomach or abomasum</td>
<td>Food in stomach esp. prot., caffeine, spices</td>
<td>Stim. flow of stomach acid &amp; enzymes</td>
</tr>
<tr>
<td>Gastric-inhibitory polypeptide (GIP)</td>
<td>Gastric antrum, duodenum, jejunum</td>
<td>Glucose in duodenum; fats, fatty acids, bile in duodenum</td>
<td>Insulin release; inhibit gastric secretion and motility</td>
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<tr>
<td>Secretin</td>
<td>Duodenum, jejunum</td>
<td>Acid chyme; large polypeptides</td>
<td>Secretion of pancreatic juice &amp; reduce gastric motility</td>
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<tr>
<td>Cholecystokinin</td>
<td>Duodenum, jejunum</td>
<td>Fat, fatty acids, polypeptides in duodenum</td>
<td>Bile flow, syn. of pancreatic juice &amp; enzymes</td>
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Overview of Regulation of Digestion

- Presence of food in stomach $\rightarrow$ HCl + Pepsin (gastrin)
- Glucose in S.I. $\rightarrow$ Insulin release + inhibit gastric secretion & motility (GIP)
- Decrease pH in duodenum $\rightarrow$ Secrete pancreatic juice (bicarbonate) (secretin)
- Fat and AA in duodenum $\rightarrow$ Bile + pancreatic enzymes (CCK)
Absorption of Nutrients

A. Places of absorption
B. Routes of absorption
C. Mechanisms of Absorption

A. Places of absorption
1. Mouth - no absorption
2. Esophagus - no absorption
3. Stomach
   a. Simple stomach
      • Essentially no absorption
        (H₂O, alcohol, some minerals)
   b. Ruminant stomach
      • Absorption of VFA, NH₃, gases, some AA
      • Some absorptions from abomasum (NH₃)
4. Small intestine - Primary site of absorption
5. Large intestine - Primarily water; some minerals
B. Routes of absorption

1. Portal blood (More correct...Hepatic Portal Blood)
   • Drains intestinal area and goes to the liver
2. Lymphatic system
   • Services stomach and S.I.
   • Empties into blood stream through thoracic duct
     (by-passes the liver)
3. Systemic blood
   • Blood that serves the entire system

C. Mechanisms of Absorption

1. Passive Transport
   - Movement of molecules from an area of greater concentration to an area of less concentration
     - Called “concentration gradient”
     - Diffusion always occurs “down” a gradient
   - Requires no energy from cell
   - Molecule must be small enough to pass through (diffuse) the pores of membrane
   - Diffusion of water across membrane = osmosis
C. Mechanisms of Absorption

2. Facilitated Transport (or Facil. Diffusion)
   - Most molecules cannot cross membrane by simple diffusion
   - Some carried across by carrier proteins embedded in cell membrane
     - Carrier proteins change shape when molecules attach to them
     - Change in shape enables molecule to cross membrane
   - Also occurs down a concentration gradient
     - Molecules can move into or out of a cell
   - Requires no energy from the cell

Illustration of Facilitated Transport

C. Mechanisms of Absorption

3. Active Transport
   - Cells often must move molecules up a concentration gradient
     - From area of low concentration to area of higher concentration
   - Involves carrier proteins
   - Requires energy (ATP)
   - Carrier proteins act as pumps that use energy to move ions and molecules
C. Mechanisms of Absorption

Example

- Transport of glucose **into** the villus epithelial cell is by active transport.
  - Requires energy
  - Glucose concentration in cell is greater than in S.I.
- Transport **across** the basolateral surface of the cell (into the blood) is by facilitated diffusion
  - Glucose concentration in blood is less than cell