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...
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
LAYERS OF GI TRACT WALL

1. Serosa (Visceral peritoneum - smooth lining)
2. Muscle layer
   A. Longitudinal
   B. Circular
3. Submucosa (Connective tissue)
4. Mucosa
5. Lumen
6. Nerves, blood & lymph vessels
   (in the submucosa)

Structure of the Small Intestine

Villi
Villus Epithelial Cell
Microvilli
Capillaries
Lymph Vessel
Vein
Artery
Lymph Duct
Crypts of Lieberkühn

Jejunum with Villi
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 - $PO_4$, $Cl^-$, $SO_4$ of K, Ca, Mg

• Enzymes

A. Mouth

• Enzymes
  ‣ Salivary amylase (man & pig)
    ◆ Produced by parotid glands
    ◆ Starch digesting enzyme
    ◆ Opt. pH 5.6-6.5
    ◆ Deactivated by HCl in stomach

  ‣ Pregastric lipase (from base of tongue)
    ◆ Produced by ruminants
    ◆ Aids milk fat digestion

  ◆ Starch $\xrightarrow{Salivary~amylase}$ Maltose + Dextrin
    ◆ Opt. pH 5.6-6.5
A. Mouth

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  Protease??
   - Pepsin (from chief cells of fundic gland)
     - Pepsinogen \(\text{HCl}\) → Pepsin
     - Zymogen
     - Diet Protein \(\text{Pepsin}\) → Long-chain polypeptides
   - Rennin (abomasum of nursing calf)
     - Prorennin \(\text{HCl}\) → Rennin
     - Casein \(\text{Rennin & Ca}\) → 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 Ù
     - sucrase Ù
     - lactase Ù
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 $\xrightarrow{\text{Enterokinase}}$ Trypsin
     - Trypsin, once formed, is autocatalytic.
     - Enterokinase from Crypts of Lieberkühn
   - Chymotrypsin
     Chymotrypsinogen $\xrightarrow{\text{Trypsin}}$ Chymotrypsin
   - Carboxypeptidase
     Procarboxypeptidase $\xrightarrow{\text{Trypsin}}$ 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

Functions (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

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**Bile**

Composition of Bile...

- Na\(^+\), K\(^+\), Ca\(^{++}\), Cl\(^-\), HCO\(_3^-\)
- 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
### Regulation of Digestion

<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 mobility</td>
</tr>
<tr>
<td>Secretin</td>
<td>Duodenum, jejunum</td>
<td>Acid chyme; large polypeptides</td>
<td>Secretion of pancreatic juice &amp; reduce gastric motility</td>
</tr>
<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 → HCl + Pepsin (gastrin)
- Glucose in S.I. → Insulin release + inhibit gastric secretion & motility (GIP)
- Decrease pH in duodenum → Secrete pancreatic juice (bicarbonate) (secretin)
- Fat and AA in duodenum → 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 absorption from abomasum (NH₃)
4. Small intestine - Primary site of absorption
5. Large intestine - Primarily water; some minerals

Sites of Absorption

*Many additional nutrients may be absorbed from the large intestine depending on transit time.*
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

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