I. Definitions
   A. Digestion
   B. Absorption

II. Overview
   A. Alimentary Canal
      Mouth -> Esophagus -> Stomach -> Sm. Intestine -> Lg. Intestine (Colon) -> Rectum -> Anus
   B. Accessory Organs
      1. Pancreas
      2. Liver & Gall Bladder

III. Structure and General Physiology of the Alimentary Canal
   A. Histology
      1. Mucosa - Epithelium
         - Lamina Propria
      2. Submucosa
      3. Muscularis Externa
         a. Circular Layer
         b. Longitudinal Layer
      4. Serosa
   
      B. Enteric Nervous System
      1. Submucosal Plexus (Meissners)
      2. Myenteric Plexus (Auerbach)
   
      C. Characteristics of the Alimentary Canal
      1. Movement
      2. Secretions

IV. Linear Processing (Regional Physiology of the Alimentary Tract)
   A. Mouth (oral cavity)
      1. Mastication
      2. Salivation - Mucins
         - Amylase
      3. Swallowing (deglutition)
   
   B. Esophagus (contents: bolus)
   
   C. Stomach (contents: chyme)
      1. Microscopic Structure (Gastric Pits)
         a. Mucous Cells
         b. Chief Cells (peptic cells)
         c. Parietal Cells
            - mechanism of acid secretion
         d. G cells
         e. D cells
         f. Enterochromaffin Cells
2. Regulation of Gastric Motility and Secretion
   a. Cephalic Phase
   b. Gastric Phase
   c. Intestinal Phase
      i. Distension
      ii. Secretin
      iii. Cholecystokinin (CCK)
      iv. Gastric Inhibitory Peptide (GIP)

E. Small Intestine
   1. Structure
      a. Plica Circularis
      b. Villi
      c. Microvilli
   2. Intestinal Secretions
      a. Crypts of Lieberkühn
      b. Brunners Glands
      c. Brush Border Enzymes
   3. Absorption

F. Large Intestine (colon)

V. Accessory Organs
   A. Pancreas
      1. Secretory Products
         a. Endocrine - Insulin
            - Glucagon
         b. Exocrine
            i. Bicarbonate
            ii. Pancreatic Amylase
            iii. Proteases - Trypsin
               - Chymotrypsin
               - Carboxypeptidase
            iv. Pancreatic Lipase
         v. Nucleases
   B. Liver and Gall Bladder
      1. Liver Functions
         a. Metabolism (of carbohydrates, lipids, proteins)
         b. Storage (vitamins, glycogen, iron)
         c. Detoxification
         d. RBC Destruction
         e. Blood Reservoir
         f. Bile Production

VI. Additional Key Terms / Topics (FYI)
   ascites      emulsification      mesentery      peristalsis     peritoneum
   peritonitis  segmentation       ulcer
**Study Questions – Digestive Physiology:**

1. Define “digestion”.
2. Compare and contrast mechanical digestion and chemical digestion.
3. Define “absorption”.
4. Describe all the structures that form the alimentary canal (digestive tract) from mouth to anus and briefly describe the function of each.
5. Identify all of the accessory organs of the digestive system and briefly describe the function of each.
6. Describe the four layers of the alimentary canal. Describe the location, structure, regional variations, and function of each layer.
7. Describe the enteric nervous system. Identify the divisions, location and general function of the enteric nervous system.
8. Describe the three types of movement characteristic of the alimentary canal.
9. Describe the role of the mouth in digestion. What are the functions of the teeth, tongue, and saliva?
10. Describe the process of swallowing. What prevents food from entering the airways?
11. Identify (name) the contents of the esophagus and stomach.
12. Describe the structure of the gastric pits. Identify all of the gastric pit cell types and the product they secrete.
13. Explain how proteolytic enzymes are prevented from digesting the cells that produce them.
14. Describe the mechanism of acid secretion.
15. Describe the three phases of gastric regulation. Identify the stimulus, mechanism and outcome (action) of each phase.
16. Identify the target and effect of the major GI tract hormones (gastrin, secretin, cholecystokinin, GIP).
17. Describe the structures of the intestines that are responsible for the large surface area of the intestinal mucosa. What is the significance of this large surface area?
18. Describe the function of the crypts of Lieberkuhn (aka intestinal crypts or glands).
19. Describe the function of Brunner’s glands (aka duodenal glands).
20. Describe the location and function of the brush border enzymes.
21. Describe the mechanism of digestion and absorption for each of the major macronutrients (carbohydrates, proteins and fats).
22. Where does the majority of chemical digestion take place?
23. Where does the majority of nutrient absorption take place?
24. What are the primary functions of the large intestine (aka colon)?
25. Where are the enzymes necessary for chemical digestion in the small intestine produced?
26. Describe the structure and hormones associated with the endocrine portion of the pancreas.
27. Describe the structure and secretory products associated with the exocrine portion of the pancreas.
28. Describe the mechanism of pancreatic proteolytic enzyme activation.
29. Where is bile produced? Where is it stored? What does it do?
30. What are the major functions of the liver?
# Summary of Digestion and Absorption of Different Macronutrients by Region

<table>
<thead>
<tr>
<th>Region</th>
<th>Protein</th>
<th>Carbohydrates</th>
<th>Lipids</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ORAL CAVITY</strong></td>
<td>-</td>
<td>Salivary Amylase</td>
<td>Lingual Lipase</td>
</tr>
<tr>
<td><strong>ESOPHAGUS</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>STOMACH</strong></td>
<td><strong>Protein</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stimulus:</td>
<td>Pepsin (secreted by</td>
<td></td>
<td></td>
</tr>
<tr>
<td>anticipation of</td>
<td>chief cells as</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a meal or arrival</td>
<td>pepsinogen,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>of bolus</td>
<td>converted to active</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hormone:</td>
<td>pepsin by HCl)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Polypeptides</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SMALL INTESTINE</strong></td>
<td><strong>Stimulus:</strong> arrival of</td>
<td><strong>Hormone:</strong> CCK</td>
<td></td>
</tr>
<tr>
<td>acidic chyme</td>
<td>acidic chyme</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hormone:</td>
<td>CCK</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Protein</strong></td>
<td>Trypsin</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Chymotrypsin</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Carboxypeptidase</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(all are secreted as</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>inactive proenzymes</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>– trypsin is activated</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>intially by enterokinase,</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>trypsin in turn activates</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>others)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Polypeptides</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>INTESTINAL MUCOSA</strong></td>
<td><strong>Peptidases</strong></td>
<td><strong>Lactase</strong></td>
<td><strong>Monoglycerides and</strong></td>
</tr>
<tr>
<td>(brush border</td>
<td></td>
<td>Malate</td>
<td>Fatty Acids</td>
</tr>
<tr>
<td>enzymes)</td>
<td></td>
<td>Sucrase</td>
<td></td>
</tr>
<tr>
<td><strong>Amino Acids</strong></td>
<td></td>
<td><strong>Monosaccharides</strong></td>
<td></td>
</tr>
<tr>
<td>**Facilitated</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diffusion and</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cotransport</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Amino Acids</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>**Facilitated</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diffusion and</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cotransport</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Monosaccharides</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Monosaccharides</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CIRCULATION</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Facilitated</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diffusion and</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cotransport</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Amino Acids</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In Capillaries</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Monosaccharides</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In Capillaries</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Chylomicrons</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
(a) The Cephalic Phase

Function:
Prepare stomach for arrival of food

Duration:
Short (minutes)

Mechanism:
Neural, via preganglionic fibers in vagus nerve and
synapses in submucosal plexus

Actions:
Primary: increased volume of gastric juice by
stimulating mucus, enzyme, and acid production
Secondary: stimulation of gastrin release by G cells

(b) The Gastric Phase

Functions:
Enhance secretion started in
cephalic stage; homogenize
and acidify chyme;
initiate digestion of proteins by pepsin

Duration:
Long (3-4 hours)

Mechanisms:
Neural: short reflexes triggered by
(1) stimulation of stretch receptors as stomach fills
(2) stimulation of chemoreceptors as pH increases
Hormonal: stimulation of gastrin
release from G cells by parasympathetic
activity and presence of peptides
and amino acids in chyme
Local: release of histamine by mast cells
as stomach fills (not shown)

Actions:
Increased acid and pepsinogen production;
increased motility and initiation of mixing waves

(c) The Intestinal Phase

Function:
Control rate of chyme entry
into duodenum

Duration:
Long (hours)

Mechanisms:
Neural: short reflexes (enterogastric
reflex) triggered by distension of
duodenum
Hormonal:
Primary: stimulation of cholecystokinin
(CCK), gastric inhibitory peptide (GIP),
and secretin release by presence of
acid, carbohydrates, and lipids
Secondary: release of gastrin stimulated
by presence of undigested proteins
and peptides (not shown)

Actions:
Feedback inhibition of gastric acid
and pepsinogen production; reduction
of gastric motility