Digestive Physiology

Lecture Outline

• Basic GI functions
• Regulation of GI function
• Phases of Digestion
• Absorption
• Protective Function of the GI tract

Basic GI Functions

• Primary function
  – Movement of nutrient molecules from the external environment to the internal environment
  • Done through the processes of:
    – Motility
    – Secretion
    – Digestion
    – Absorption

• Secondary functions
  – Mass balance
    • Ensuring daily fluid input and output are equal
  – Protection
    • GI tract provides a huge external surface for pathogens to gain entrance into the internal environment
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Regulation of GI Function

**Long & Short Reflexes**

- **Long Reflexes**
  - Integrated within the CNS
  - May originate in or outside of the GI tract
  - Feedforward & emotional reflexes are initiated and integrated entirely outside the GI tract
    » Called cephalic reflexes
- **Short Reflexes**
  - Integrated in the enteric nervous system
  - Initiated by changes in pH, distension, osmolarity, products of digestion
  - Submucosal plexus contains the sensory neurons
  - Afferent information to ganglia
  - Efferent information to submucosal and myenteric plexuses for control of secretion, motility and growth

Regulation of GI Function

- What is regulated?
  - All aspects of the GI processes
- Regulated by
  - In general the signals are:
    • Neural
    • Hormonal
    • Paracrine
  - Specifically the controls and systems are:
    • The Long & Short Reflexes
    • GI peptide reflexes
    • The autonomous function of the enteric nervous system (ENS)
Regulation of GI Function

GI Peptide Reflexes

• Peptides released by the GI tract may act
  – As hormones
    • Secreted into the blood
    • Act on accessory organs, other parts of the GI tract or the brain
  – As paracrine signals
    • Secreted into the lumen or extracellular fluid
      – Lumenal signals bind to apical epithelial receptors
      – ECF signals act in the immediate vicinity of secretion
  – Effect
    • Peptides alter secretion and motility
    • Alter behavior related to eating

Regulation of GI Function

Enteric Nervous System

• Allows for the autonomous behavior of the digestive system
  – CNS control is not required for digestive functioning
  – Commonalities between ENS and CNS
    • Intrinsic neurons – similar to interneurons of CNS
    • Extrinsic neurons – composed of autonomic neurons
    • Neurotransmitters and neuropeptides
      – Nonadrenergic and noncholinergic receptors
        » Same as adrenergic and cholinergic in CNS
    • Glial support cells – similar to astrocytes in CNS
    • Diffusion barrier – cells around capillaries in the ganglia are tight, just as the capillaries in the brain, forming the BBB
    • ENS acts as its own integrating center, just as the CNS does

Regulation of GI Function

GI Peptide Reflexes

<table>
<thead>
<tr>
<th>TABLE 21-1 The Digestive Hormones</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>STIMULUS FOR RELEASE</strong></td>
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<tr>
<td>---------------------------</td>
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<tr>
<td><strong>Gastrin family</strong></td>
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<tr>
<td>Fatty acids and some amino acids</td>
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<tr>
<td><strong>Secretin family</strong></td>
</tr>
<tr>
<td>Acid and small intestine</td>
</tr>
<tr>
<td><strong>Peptide family</strong></td>
</tr>
<tr>
<td>Fasting periodic release every 1-2 hours</td>
</tr>
<tr>
<td>Glucose, fatty acids, and purines in small intestine</td>
</tr>
<tr>
<td><strong>Secretin family</strong></td>
</tr>
<tr>
<td>Mixed meal that stimulates cholecystokinin or fats in the lower intestine</td>
</tr>
</tbody>
</table>

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Phases of Digestion

Cephalic Phase

- Starts with the external stimulus of food
  - Response from cerebral cortex, hypothalamus and amygdala is to activate neurons [vagus nerve (X)] in the medulla oblongata which
    - Sends ANS signals to
      - Salivary glands via branches of facial n. & glossopharyngeal n. (parasympathetic), sympathetic innervation via branches from T1-3
        » Increases saliva production along with salivary amylase, lysozymes, immunoglobulins and lingual lipase
        » Starts chemical digestion
      - Enteric nervous system via vagus nerve
        » Gastric secretions and motility increase in preparation
        » Accounts for approximately 20% of gastric secretions while eating

- What goes on once food is in the mouth?
  - Secretion of saliva
  - Physical digestion via mastication
  - Chemical digestion via salivary amylase and lingual lipase (from Von Ebner’s Glands)
  - Preparation for swallowing (deglutition reflex)
    - Bolus pushed against soft palate by tongue to trigger reflex
    - UES (upper esophageal sphincter) relaxes, larynx elevates as epiglottis bends to cover trachea
    - Peristalsis and gravity moves bolus down esophagus to stomach

Gastric Phase

- Deglutition reflex (swallowing) moves food to the stomach to start the gastric phase
  - 3.5 liters of content/day enters fundus
  - Controlled by long (vagal reflex) and short (distention & peptides/amino acids) reflexes

- What does the stomach do?
  1. Stores incoming food
  2. Digests the food into chyme
    - By action of pepsin and mechanical digestion (churning)
  3. Protection
    - Acidic gastric environment
    - Mucous provides “self” protection
Phases of Digestion

Gastric Phase

1. Stores incoming food
   - Fundus exhibits receptive relaxation
   - Controls movement into the duodenum
   • Storage becomes important when more food than is required enters the stomach
   • Too much into the duodenum would spell colonic disaster!

2. Digests the food into chyme
   - By continuation of salivary amylase until denatured
   - By action of secretions
     • Parietal cells secrete HCl (gastric acid) and intrinsic factor
       - HCl dissociates into H⁺ and Cl⁻
       - Intrinsic factor required for B₁₂ absorption in the intestine
     • Chief cells secrete pepsinogen & gastric lipase
       - Pepsinogen is converted to pepsin by the action of H⁺
       - Pepsin is an endopeptidase
     • Mucous neck cells
       - Secrete mucus for protection
     • Enterochromaffin-like cells
       - Secrete histamine in response to parasympathetic activity and gastrin and increases parietal cell
     • D cells
       - Secrete somatostatin when pH drops to inhibit further parietal cell secretions
     • G cells
       - Secrete gastrin to stimulate parietal cells, also relaxes ileocecal sphincter, increases pyloric sphincter activity and lower stomach motility

Cephalic Phase

3. Protection
   - Acidic gastric environment
   - Mucous provides “self” protection

Gastric juice pH ~ 2

The mucus layer is a physical barrier.

HCO₃⁻ Bicarbonate is a chemical barrier that neutralizes acid.

pH ~ 7 at cell surface
Phases of Digestion
Integration of Cephalic & Gastric Phases

**Phases of Digestion**

Integration of Cephalic & Gastric Phases

**Phases of Digestion**

Intestinal Phase

- The final products of the cephalic and gastric phase is
  - Digestion of proteins
  - Formation of chyme
  - Controlled entry of chyme into the intestine
    - Starts the intestinal phase which contains loops that
      - Feed back to further control gastric emptying
      - Feed forward to promote digestion, secretion, motility and absorption of nutrients
      - Signals are hormonal & neural

**Phases of Digestion**

Intestinal Phase

- Hormonal and neural aspects of the intestinal phase
  - entrance of chyme into duodenum gets the enteric nervous system going, secreting:
    - Secretin
      - slows gastric emptying & gastric acid production
      - Stimulates bicarbonate ($\text{HCO}_3^-$) production from pancreas to buffer acidic chyme
    - cholecystokinin (CCK)
      - Secreted in response to lipids and slows gastric motility and gastric acid secretion
      - Acts hormonally on the hypothalamus,
    - Incretin hormones (GIP and GLP-1)
      - GIP (gastric inhibitory peptide)
      - GLP-1 (glucagon-like peptide1)
        - Slow gastric acid and emptying
        - stimulate insulin release from pancreas

**Major processes occurring in the intestinal phase**

- Buffering
  - Via pancreatic exocrine secretion
- Digestion
  - By pancreatic exocrine secretion
    - Trypsinogen, chymotrypsinogen, procarboxypeptidase, procolipase and prophospholipase
  - By bile release from gallbladder (stimulated by CCK)
    - Bile emulsifies the lipids, increasing surface area for pancreatic lipases
  - By intestinal mucosal enzymes (brush border enzymes) that are “anchored” to apical surface
    - Peptidases, disaccharidases, enteropeptidase
- Absorption
  - Most of the water & nutrients are absorbed in the small intestine
Phases of Digestion

Intestinal Phase

• Activation of pancreatic proteolytic enzymes

Phases of Digestion

Integration of Intestinal & Gastric Phases

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Phases of Digestion

Intestinal Phase

• The large intestines main processes are
  – Concentrating waste
    • Removal of water
      – Only about .1L of water lost daily through feces
  – Movement & defecation
    • Ileocecal valve controls chyme entrance into colon
      – Relaxes in sequence with intestinal peristalsis as well as when gastric emptying starts (gastrocolic reflex)
    » CCK, serotonin and gastrin are potential initiators of the gastrocolic reflex
    • Defecation reflex
      – Increases abdominal pressure, relaxes anal sphincters
  – Digestion and absorption
    • Digestion mainly through bacterial action which produces
      – Lactate and fatty acids which are absorbable by simple diffusion
      – Bacterial action also produces vitamin K
      – By product of bacterial fermentation is gas (CO₂, methane & HS)
Absorption

- Carbohydrate absorption

Absorption

- Protein absorption

Absorption

- Lipid digestion & absorption

Absorption

- Absorbed nutrients and water are returned via the hepatic portal system
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Protective Functioning

- Large surface area of GI tract warrants protective function
  - Salivary enzymes and immunoglobulins
  - Gastric acid
  - Toxins and pathogens in the intestine initiate
    - Diarrhea
    - Vomitting
  - GALT & M cells
    - M cells overly the immune cells in the GALT (Peyers patches)
      - M cells activate lymphocytes of GALT when pathogens are detected
      - Activated GALT increase Cl- secretion, fluid secretion and mucous secretion
        » Results in diarrhea & potentially vomiting
        » Both are protective reflexes