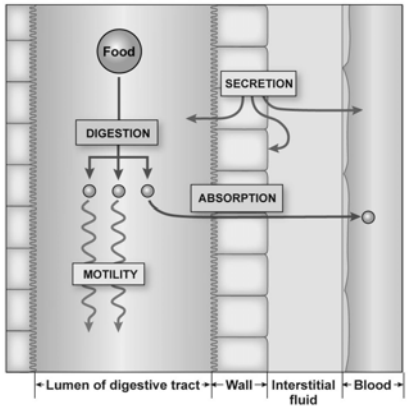
Digestive Physiology

Lecture Outline

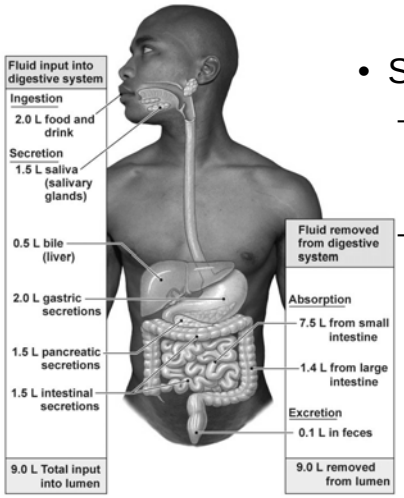
- **Basic GI functions**
- Regulation of GI function
- Phases of Digestion
- Absorption
- Protective Function of the GI tract

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



Basic GI Functions



- 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

Lecture Outline

- Basic GI functions
- **Regulation of GI function**
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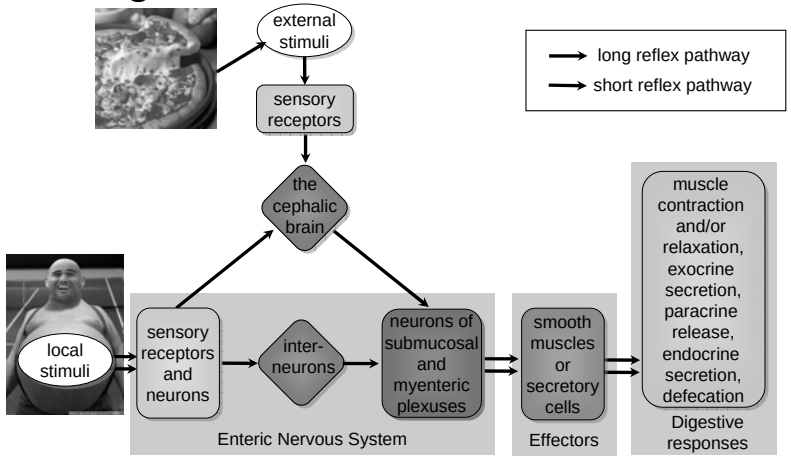
Regulation of GI Function

- 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
Long & Short Reflexes

- Long Reflexes
  - Integrated within in 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
Long & Short Reflexes



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
GI Peptide Reflexes

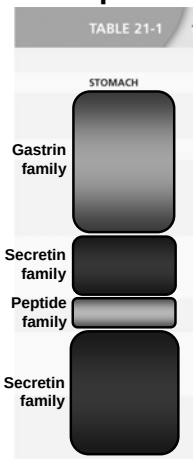


TABLE 21-1 The Digestive Hormones

	STIMULUS FOR RELEASE	PRIMARY TARGET(S)	PRIMARY EFFECT(S)	OTHER INFORMATION
Gastrin family	Peptides and amino acids; neural reflexes	ECL cells and parietal cells	Stimulates gastric acid secretion and mucosal growth.	Somatostatin inhibits release.
	Fatty acids and some amino acids	Gallbladder, pancreas, stomach	Stimulates gallbladder contraction and pancreatic enzyme secretion. Inhibits gastric emptying and acid secretion.	Promotes satiety. Some effects may be due to CCK as a neurotransmitter.
Secretin family	Acid in small intestine	Pancreas, stomach	Stimulates bicarbonate secretion. Inhibits gastric emptying and acid secretion.	
Peptide family	Fasting: periodic release every 1.5–2 hours	Gastric and intestinal smooth muscle	Stimulates migrating motor complex.	Inhibited by eating a meal.
Secretin family	Glucose, fatty acids, and amino acids in small intestine	Beta cells of pancreas	Stimulates insulin release (feedforward mechanism). Inhibits gastric emptying and acid secretion.	
	Mixed meal that includes carbohydrates or fats in the lumen	Endocrine pancreas	Stimulates insulin release. Inhibits glucagon release and gastric function.	Promotes satiety.

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

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Phases of Digestion
Cephalic Phase

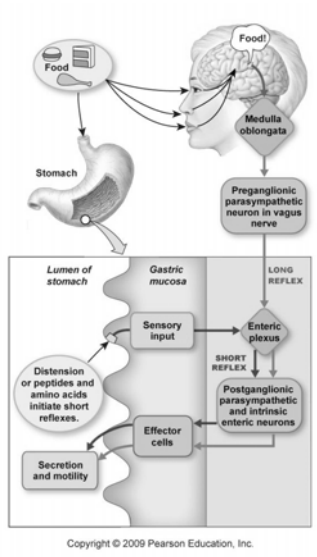
- Starts with the external stimulus of food
  - Response from cerebral cortex, hypothalamus and amygdala is to activate neurons [vagus nerve (X)] in the medulla oblongata which
    - Sends ANS signals to
      - Salivary glands via branches of facial n. & glossopharyngeal n. (parasympathetic), sympathetic 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

Phases of Digestion
Cephalic Phase

- 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

Phases of Digestion
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



Phases of Digestion
Gastric Phase

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

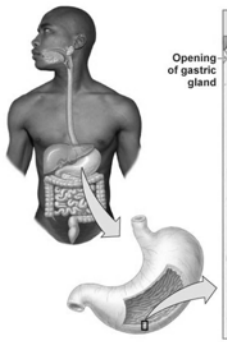
Phases of Digestion
Gastric Phase

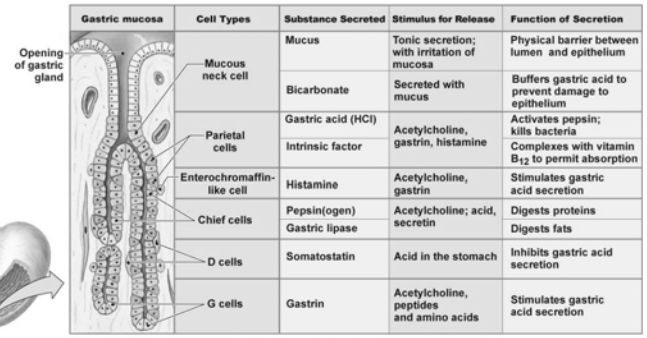
1. Stores incoming food
   - Fundus exhibits receptive relaxation
   - controls movement into the duodenum
     - Storage becomes important when more food than is required enters the stomach
     - Too much into the duodenum would spell colonic disaster!

Phases of Digestion
Gastric Phase

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 B_{12} 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
       - Secretes mucous for protection
       - Secretes bicarbonate for protection
     - Enterochromaffin-like cells
       - Secretes histamine in response to parasympathetic activity and gastrin and increases parietal cell
     - D cells
       - Secretes 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

Phases of Digestion
Cephalic Phase

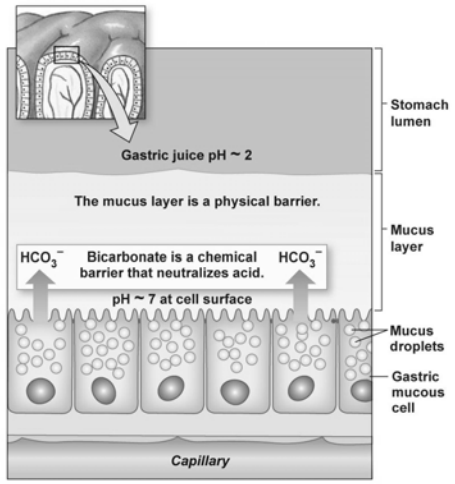




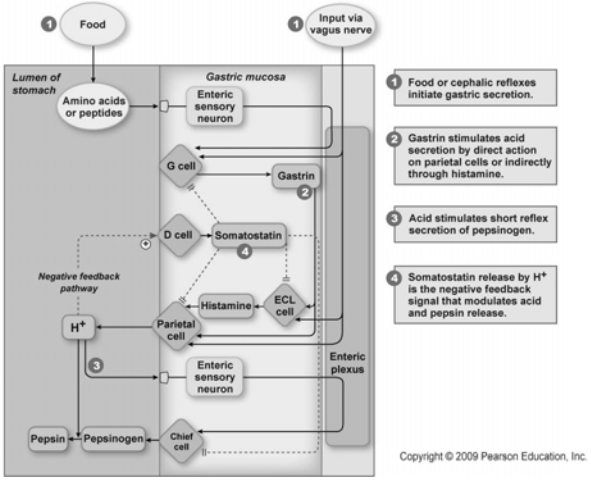
Gastric mucosa	Cell Types	Substance Secreted	Stimulus for Release	Function of Secretion
	Mucous neck cell	Mucus	Tonic secretion; with irritation of mucosa	Physical barrier between lumen and epithelium
		Bicarbonate	Secreted with mucus	Buffers gastric acid to prevent damage to epithelium
	Parietal cells	Gastric acid (HCl)	Acetylcholine, gastrin, histamine	Activates pepsin; kills bacteria
		Intrinsic factor		Complexes with vitamin B_{12} to permit absorption
	Enterochromaffin-like cell	Histamine	Acetylcholine, gastrin	Stimulates gastric acid secretion
	Chief cells	Pepsin(ogen)	Acetylcholine; acid, secretin	Digests proteins
		Gastric lipase		Digests fats
	D cells	Somatostatin	Acid in the stomach	Inhibits gastric acid secretion
	G cells	Gastrin	Acetylcholine, peptides and amino acids	Stimulates gastric acid secretion

Phases of Digestion
Gastric Phase

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



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

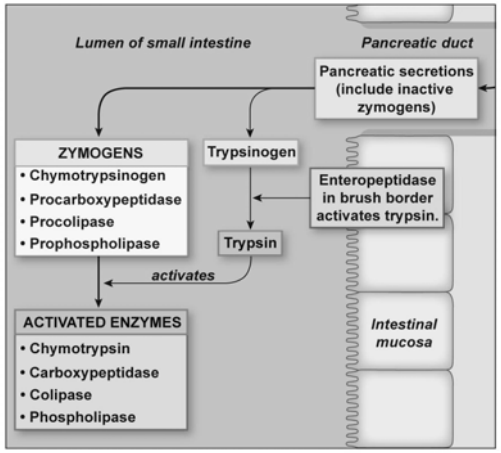
- Hormonal and neural aspects of the intestinal phase
  - entrance of chyme into duodenum gets the enteric nervous system going, secreting:
    - Secretin
      - slows gastric emptying & gastric acid production
      - Stimulates bicarbonate (HCO_3^-) production from pancreas to buffer acidic chyme
    - 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

Phases of Digestion
Intestinal Phase

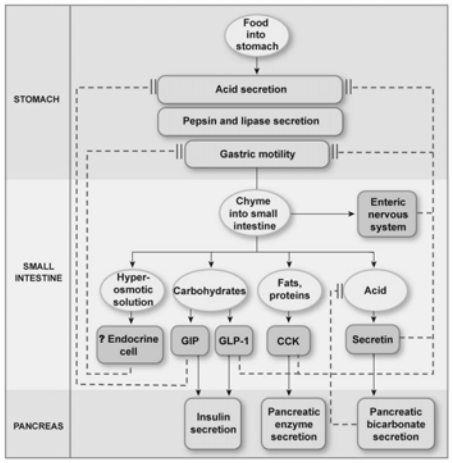
- Major processes occurring in the intestinal phase
  - Buffering
    - Via pancreatic exocrine secretion
  - Digestion
    - By pancreatic exocrine secretion
      - Trypsinogen, chymotrypsinogen, procarboxypeptidase, procolipase and prophospholipase
    - By bile release from gallbladder (stimulated 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



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 (CO_2, methane & HS)

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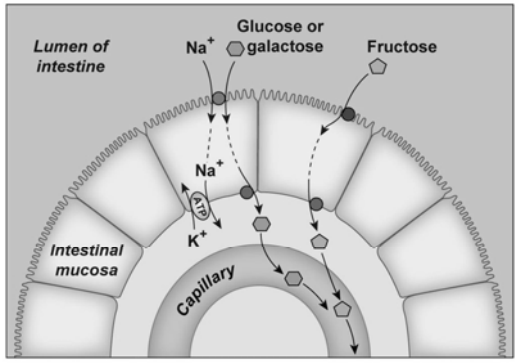
- Protective Function of the GI tract

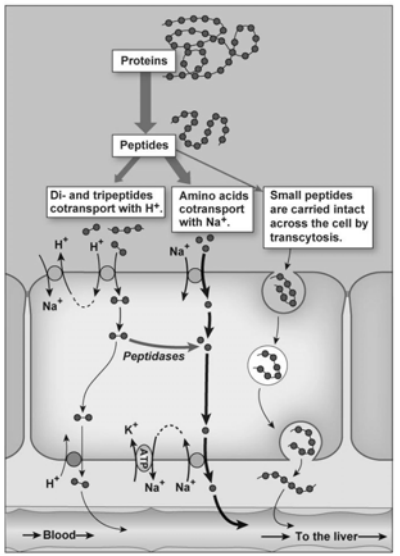
Absorption

- Carbohydrate absorption



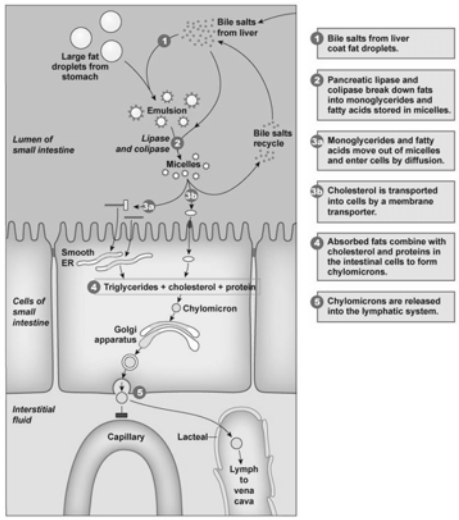
Absorption

- Protein absorption



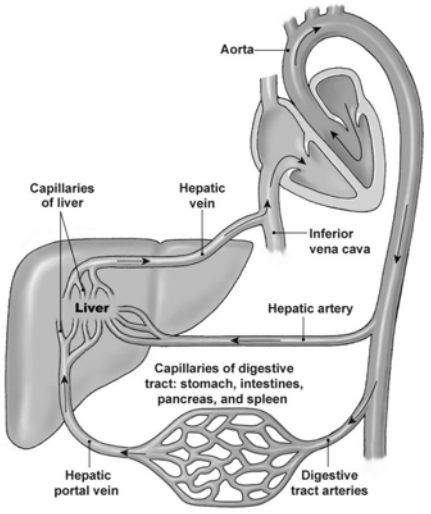
Absorption

- Lipid digestion & absorption



Absorption

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



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- **Protective Function of the GI tract**

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
      - Actiavated GALT increase Cl- secretion, fluid secretion and mucous secretion
        - » Results in diarrhea & potentially vomitting
        - » Both are protective reflexes