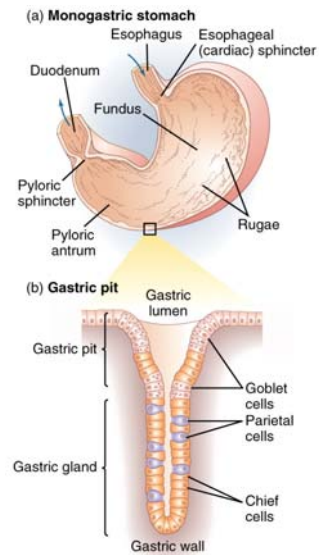


Lecture 41
28 April 2008

Vertebrate Physiology
ECOL 437 (MCB/VetSci 437)
Univ. of Arizona, spring 2008

Kevin Bonine & Kevin Oh

1. Digestion (Ch4)



http://eebweb.arizona.edu/eeb_course_websites.htm

1

Housekeeping, 28 April 2008

Upcoming Readings

Wed 30 Apr: Ch 8, Thermal Physiology

LAB 30 Apr, 07 May: [Funding Panel](#)

Fri 02 May: Ch 8

Mon 05 May: Ch 8

Wed 07 May: [Review for FINAL EXAM](#)

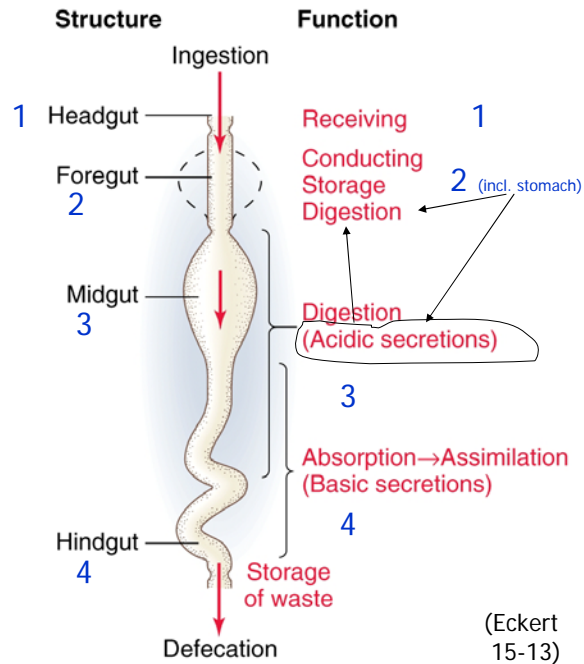


2

Generalized Digestive System

Salivary glands (mucin) to lubricate

Tongue for chemoreception



Foregut

-Conducting, Storage, Digestion

-Esophagus and Stomach

↓
Crop in some for storage/regurgitation

e.g., Some birds use to grind with pebbles and sand

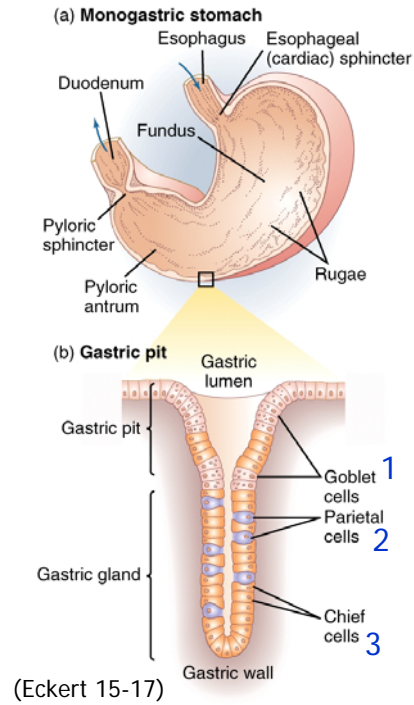
Stomach

- food storage
- begins digestion (e.g., pepsin)
- mechanical mixing (muscular walls)
- **Monogastric** (1 chamber, carnivores and omnivores)
- **Digastric** (> 1 chamber)

Foregut

Monogastric Stomach

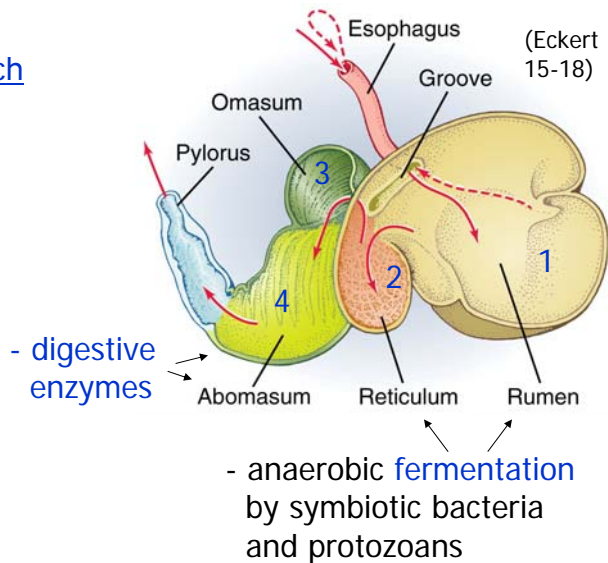
- strong muscular sac/tube
- sphincters at both ends
- 1 - mucus from goblet cells of gastric pit
- 2 - HCl from parietal cells of gastric gland
- 3 - pepsinogen from chief cells of gastric gland



Foregut

Digastric Stomach

- herbivores
- regurgitation



Domestic cattle,
1L/min gas!
(methane and CO₂)

(Carbohydrates -> sugars and gases)
sugars, amino acids, short FAs into blood

Midgut

-Chemical digestion and Absorption (~ small intestine)

-from stomach through **pyloric sphincter** into duodenum

-alkaline

1-Duodenum (mucus + secretions from liver, pancreas)

Bile duct from liver

-Bile breaks up fats and neutralizes acids

Pancreatic Juice

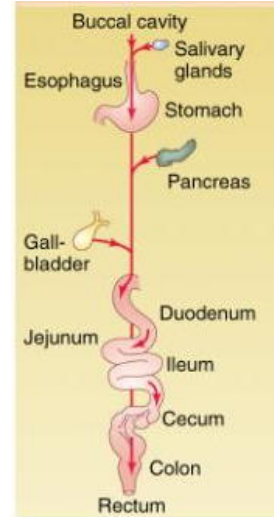
-proteases, lipases, carbohydrases, antacid

2-**Jejunum** (digestion and absorption)

3-**Ileum** (mostly absorption)

-Internal **symbionts** help digest, provide nutrition, vitamins

-Gas exchange in some **air-breathing** fishes



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(Eckert 15-31)

Midgut

Anatomy:

-**longitudinal** smooth muscle

-**circular** smooth muscle

-**epithelium**

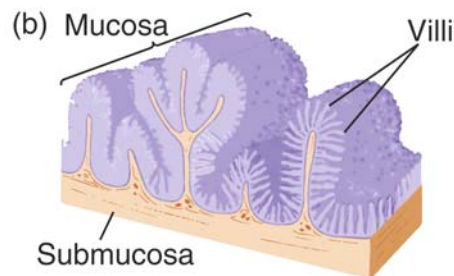
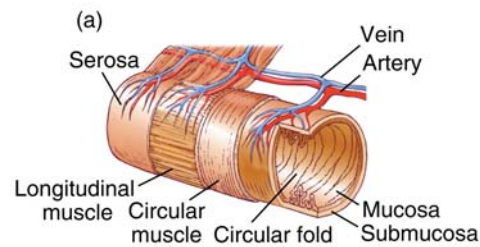
-**submucosa**

(connective tissue)

-**mucosa**

(mucous membrane)

Epithelial cells
sloughed rapidly
(2×10^{10} cells/day),
lining replaced
every few days



(Eckert 15-19)

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Midgut

- **Intestinal Epithelium**, SURFACE AREA

- aids **absorption** of digested nutrients

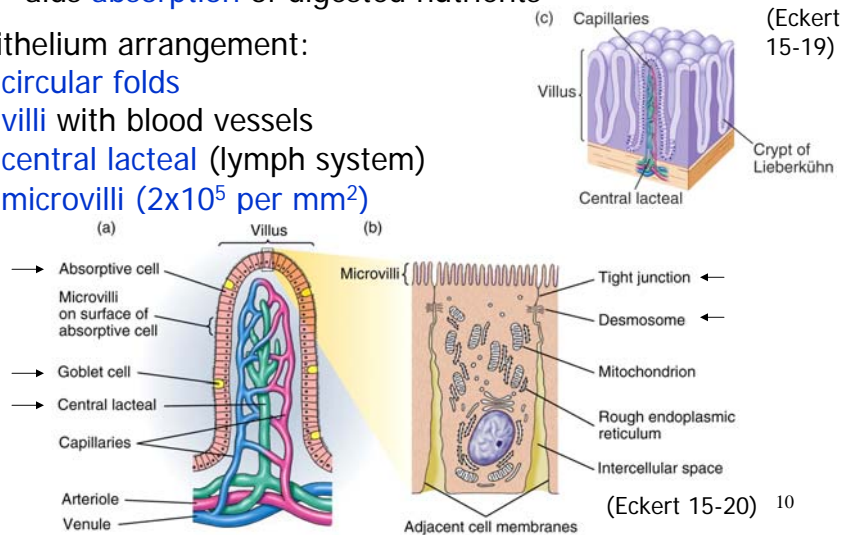
- epithelium arrangement:

- **circular folds**

- **villi** with blood vessels

- **central lacteal** (lymph system)

- **microvilli** (2×10^5 per mm^2)



Midgut

- **Intestinal Epithelium**, SURFACE AREA

- surface of **microvilli**:

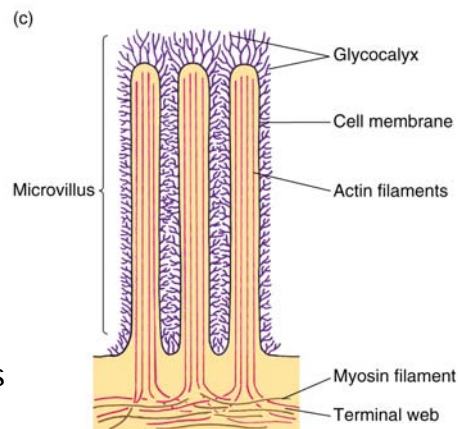
- covered with **glycocalyx**

- mucus and water mixed in

- absorption through epithelial cells

- intestinal **chyme**

- microvilli with **actin**, interacts with myosin for movement

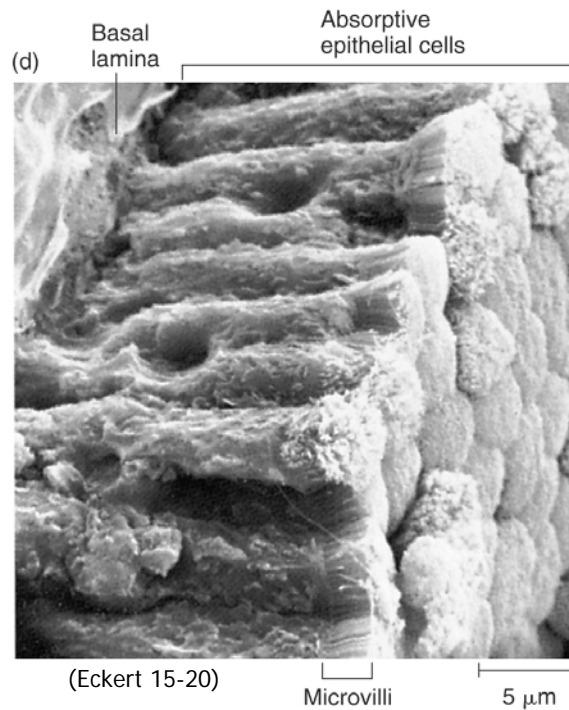


(Eckert 15-20)

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Villi with
microvilli

(brush border)



Hindgut

-Water and Ion absorption; Defecation

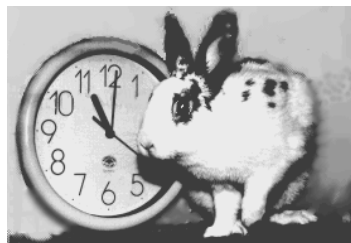
-**reabsorb** water and ions at end of small intestine (ileum) and from large intestine/colon

-**feces** into cloaca/rectum for excretion

-cloaca can also be site of **urine modification** (e.g., birds)

-bacterial digestion in **hindgut fermenters** (especially in **cecum**)

-**coprophagy/cecotrophy** (e.g., rabbits)

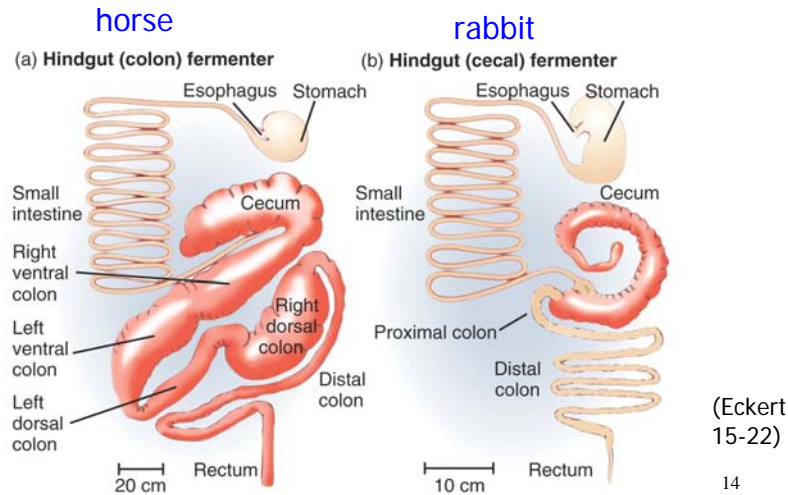


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Hindgut

-Water and Ion absorption; defecation

hindgut fermenters



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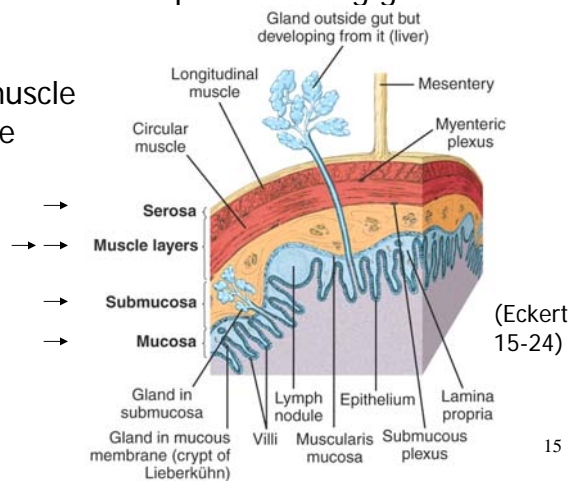
Motility

Contraction of gut and movement of contents:

1. **Propulsion**, expulsion
2. **Mixing** and grinding (enzymes, mechanical digestion)
3. **Stirring** so brush border/epithelial lining gets nutrients

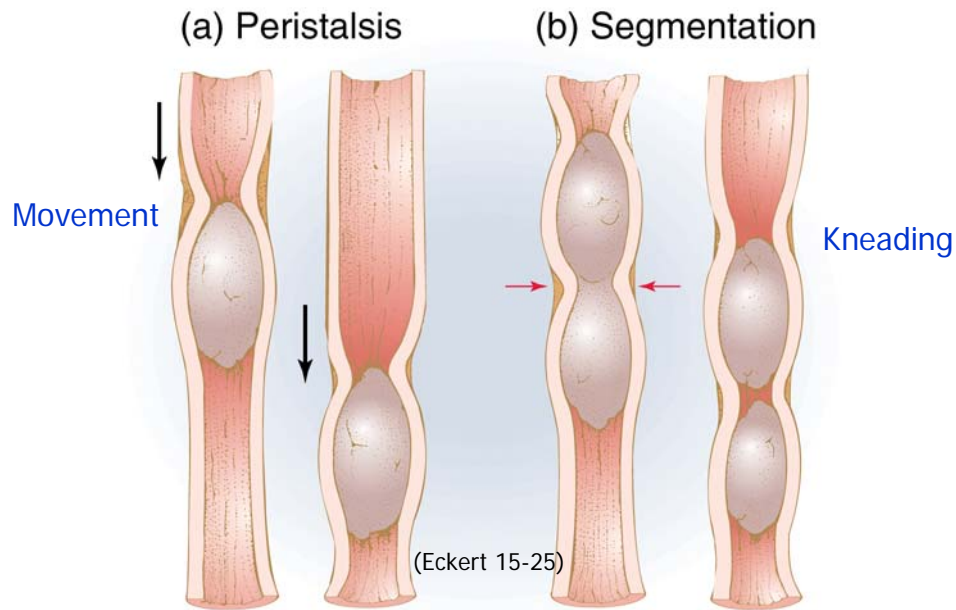
Peristalsis

- longitudinal muscle
- circular muscle



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Move food along...



Regurgitation, Vomiting?

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ABSORPTION:

- Across epithelium of brush border (microvilli)
- Glycocalyx has enzymes for final cleavage
disaccharidases, aminopeptidases, phosphatases

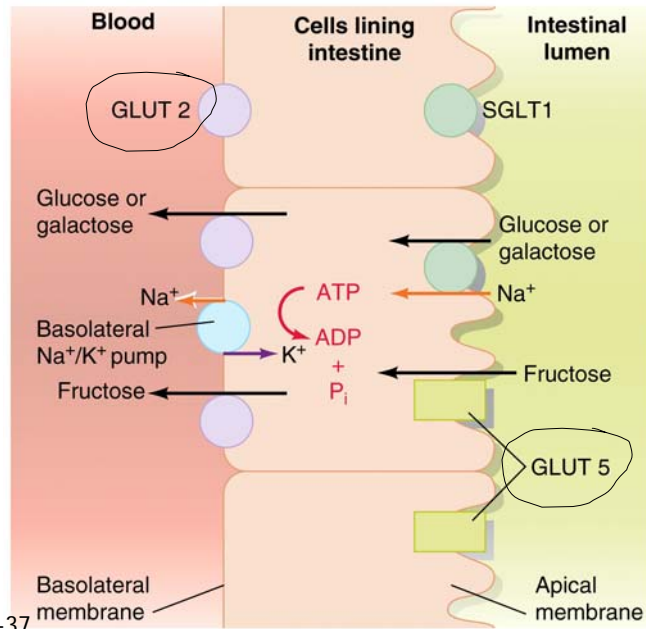
-Simple Diffusion

- 1 fat-soluble substances
- 2 small water soluble substances through regulated aquaporins
- 3 down concentration or electrochemical gradients

-Facilitated Diffusion and 2° Active Transport

- 1 monosaccharides and amino acids
- 2 transporter proteins
- 3 down conc. gradient or
- 4 coupled to Na⁺ gradient (Na/K-ATPase)

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(Eckert 15-37,
See Hill 4-19)

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ABSORPTION

-Active Transport

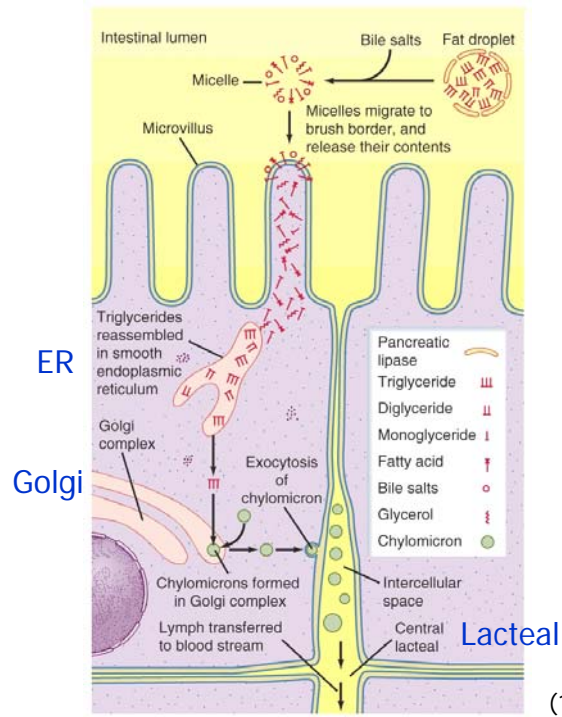
- amino acids with ~specific transporters coupled to Na⁺

-Lipids

- products cross into epithelial cells (monoglycerides, fatty acids, glycerol)
- reconstructed into triglycerides
- formed into chylomicrons using cholesterol and phospholipids
- chylomicrons exocytosed
- taken into central lacteal and into lymph system

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Lipids



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Nutrient Transport in Blood

-lipids (chylomicrons) into blood from lymph at
thoracic duct

-sugars and amino acids into capillaries of villi

-to liver via hepatic portal vein

sugars converted to glycogen for storage

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Water and Electrolyte Balance in Gut

-Lots of **water** and **electrolytes** secreted into lumen

-Need to **recover**

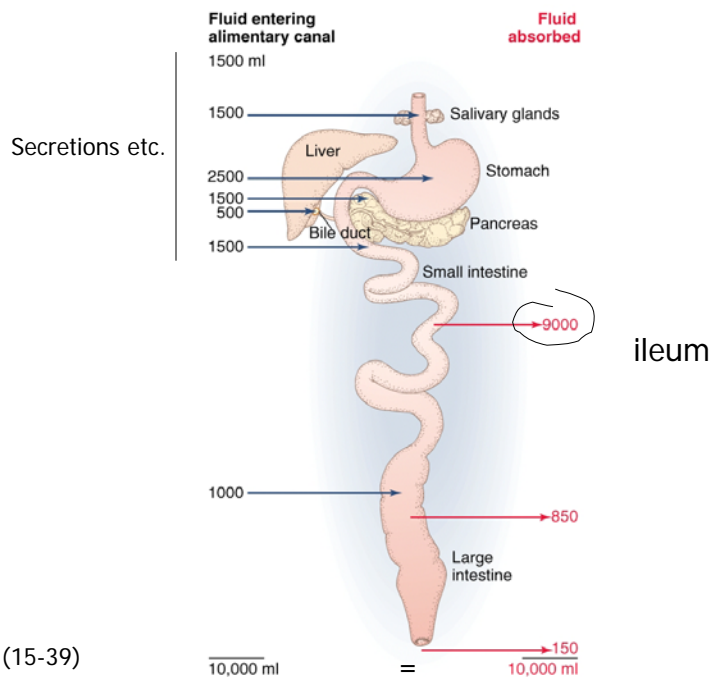
-Most via **lower small intestine** (ileum)

-Osmotic gradient b/c absorb salts, carbo, amino acids

-Tips of **villi**

-Countercurrent exchange with high **Na⁺** (Cl⁻ follows) to facilitate **water reabsorption**

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Los Secretions

Alimentary canal is largest endocrine and exocrine gland

Salivary gland

Secretory cells of stomach and intestine

Secretory cells of liver and pancreas

Water, ions, mucus, enzymes

Bile (fat digestion)

-created in liver, stored in gall bladder

-also gets rid of some waste products
metabolized by liver

-Why is your poop brown?

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Los Secretions (order and triggers)

Gastric

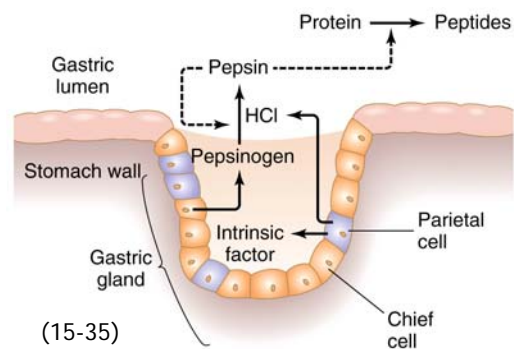
Pepsin (pepsinogen) from chief cells

-response to:

1 parasymp. stim.

2 gastrin

-breaks peptide bonds



Mucus from goblet cells

-protects gut lining

-works with alkaline electrolytes in glycocalyx

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Los Secretions (order and triggers)

Gastric

Gastrin from endocrine cells of distal stomach mucosa

-response to:

- 1 **gastric chyme** with proteins
 - 2 stomach **stretch** (gastric distension)
- binds to smooth muscle
 - stimulates stomach motility
 - stimulates HCl and pepsin release

~opposite effects

Intestine

Gastric Inhibitory Peptide (GIP) from duodenum

-response to:

- 1 entry of fats and sugars
- acts to stop gastric secretion and motility

(also **Enterogastric Reflex** and sympathetic stimulation)⁶

Table 15-1 Action of the major enzymes secreted in the mouth, stomach, pancreas, and small intestine

Enzyme	Site of action	Substrate	Products of action
Mouth			
Salivary α -amylase	Mouth	Starch	Disaccharides (few)
Stomach			
Pepsinogen:pepsin	Stomach	Proteins	Large peptides
Pancreas			
Pancreatic α -amylase	Small intestine	Starch	Disaccharides
Trypsinogen:trypsin	Small intestine	Proteins	Large peptides
Chymotrypsin	Small intestine	Proteins	Large peptides
Elastase	Small intestine	Elastin	Large peptides
Carboxypeptidases	Small intestine	Large peptides	Small peptides (oligopeptides)
Aminopeptidases	Small intestine	Large peptides	Oligopeptides
Lipase	Small intestine	Triglycerides	Monoglycerides, fatty acids, glycerol
Nucleases	Small intestine	Nucleic acids	Nucleotides
Small intestine			
Enterokinase	Small intestine	Trypsinogen	Trypsin
Disaccharidases	Small intestine*	Disaccharides	Monosaccharides
Peptidases	Small intestine*	Oligopeptides	Amino acids
Nucleotidases	Small intestine*	Nucleotides	Nucleosidases, phosphoric acid
Nucleosidases	Small intestine*	Nucleosides	Sugars, purines, pyrimidines

*Intracellular

Control of Los Secretions

Presence of **Food** stimulates:

Chemoreceptors lead to activation:

- 1 **Autonomic** Efferent Neurons
- 2 **GI hormones** into blood stream
-stimulates **liver, pancreas, gut**

Mental influences

- conscious decisions
- learned** smells, sounds
- Pavlovian** response



Gastrointestinal secretions controlled by hormones:

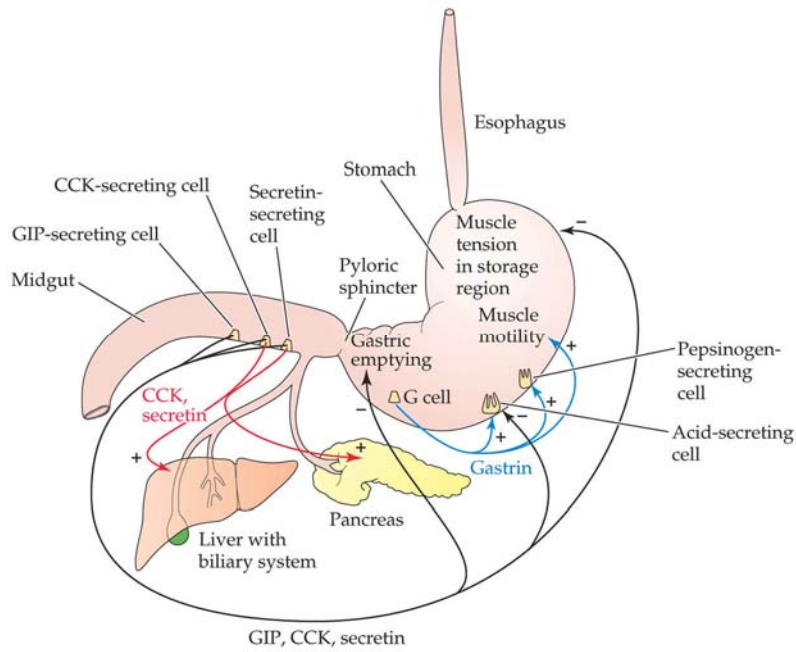
- endocrine cells** of **gastric and intestinal submucosa**
- complicated, varies in areas of gut

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Table 15-2 The major gastrointestinal peptide hormones

Hormone	Tissues of origin	Target tissue	Primary action	Stimulus to secretion
Gastrin	Stomach and duodenum	Secretory cells and muscles of stomach	HCl production and secretion; stimulation of gastric motility	Vagus nerve activity; peptides and proteins in stomach
Cholecystokinin (CCK)*	Upper small intestine	Gallbladder Pancreas	Contraction of gallbladder Pancreatic juice secretion	Fatty acids and amino acids in duodenum
Secretin*	Duodenum	Pancreas, secretory cells, and muscles of stomach	Water and NaHCO ₃ secretion; inhibition of gastric motility	Food and strong acid in stomach and small intestine
Gastric inhibitory peptide (GIP)	Upper small intestine	Gastric mucosa and musculature	Inhibition of gastric secretion and motility	Monosaccharides and fats in duodenum
Bulbogastrone	Upper small intestine	Stomach	Inhibition of gastric secretion and motility	Acid in duodenum
Vasoactive intestinal peptide (VIP)*	Duodenum	Stomach, intestine	Increase of blood flow; secretion of thin pancreatic fluid; inhibition of gastric secretion	Fats in duodenum
Enteroglucagon	Duodenum	Jejunum, pancreas	Inhibition of motility and secretion	Carbohydrates in duodenum
Enkephalin*	Small intestine	Stomach, pancreas, intestine	Stimulation of HCl secretion; inhibition of pancreatic enzyme secretion and intestinal motility	Basic conditions in stomach and intestine
Somatostatin*	Small intestine	Stomach, pancreas, intestine, splanchnic arterioles	Inhibition of HCl secretion, pancreatic secretion, intestinal motility, and visceral blood flow	Acid in lumen of stomach

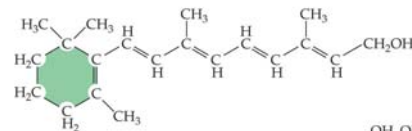
*These peptides are also found in central nervous tissue as **neuropeptides**. Additional unlisted neuropeptides identified in both brain and gut tissue include substance P, neurotensin, bombesin, **insulin**, pancreatic polypeptide, and ACTH.



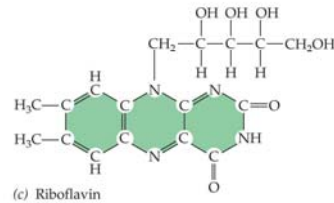
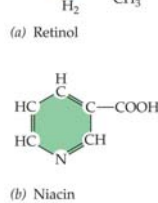
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Vitamins and Minerals

Vit A
(retinol, retinal; rhodopsin)



Water Soluble:
B Vitamins, Vitamin C



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Metalloproteins (e.g., hemoglobin)