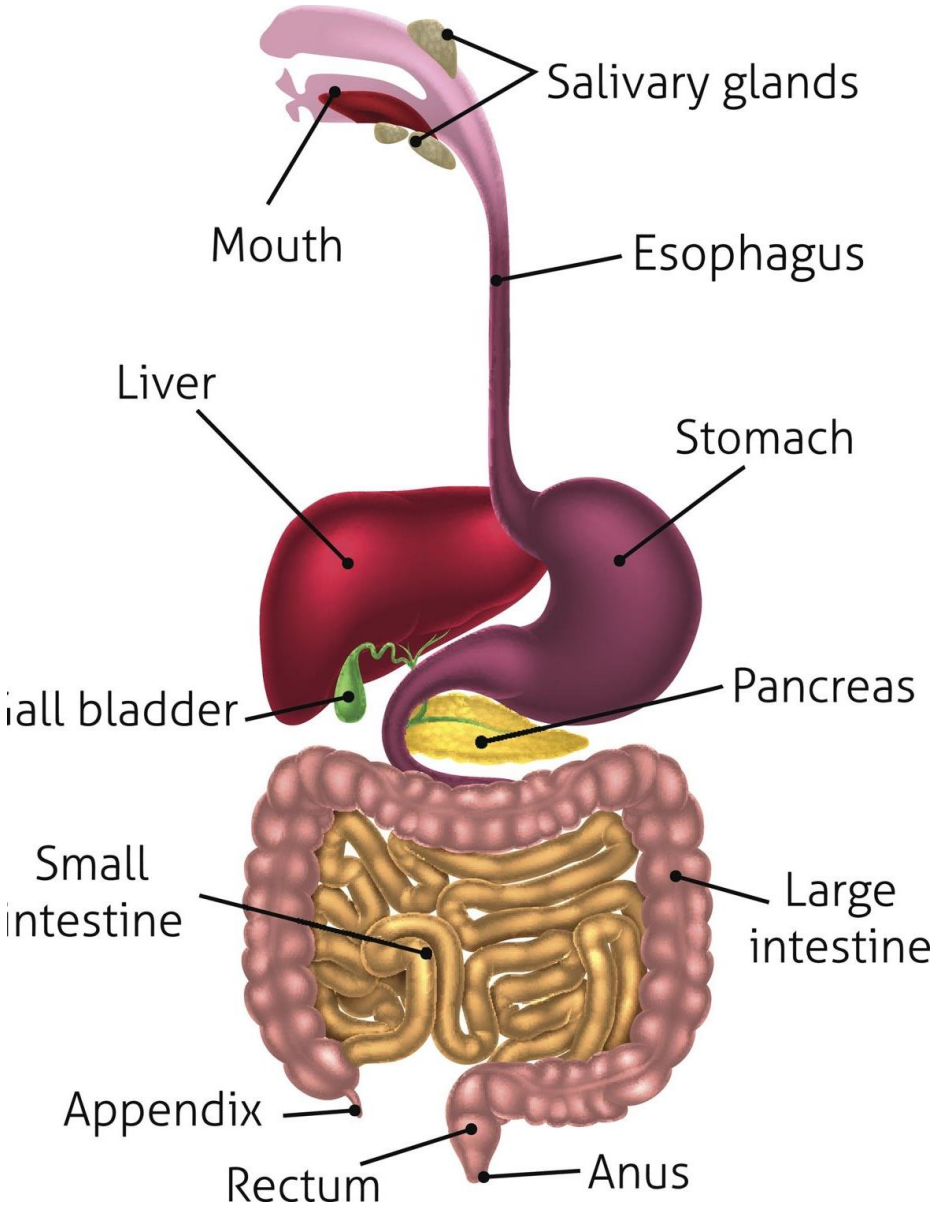
Chapter 33
Animal Nutrition

Human Digestion

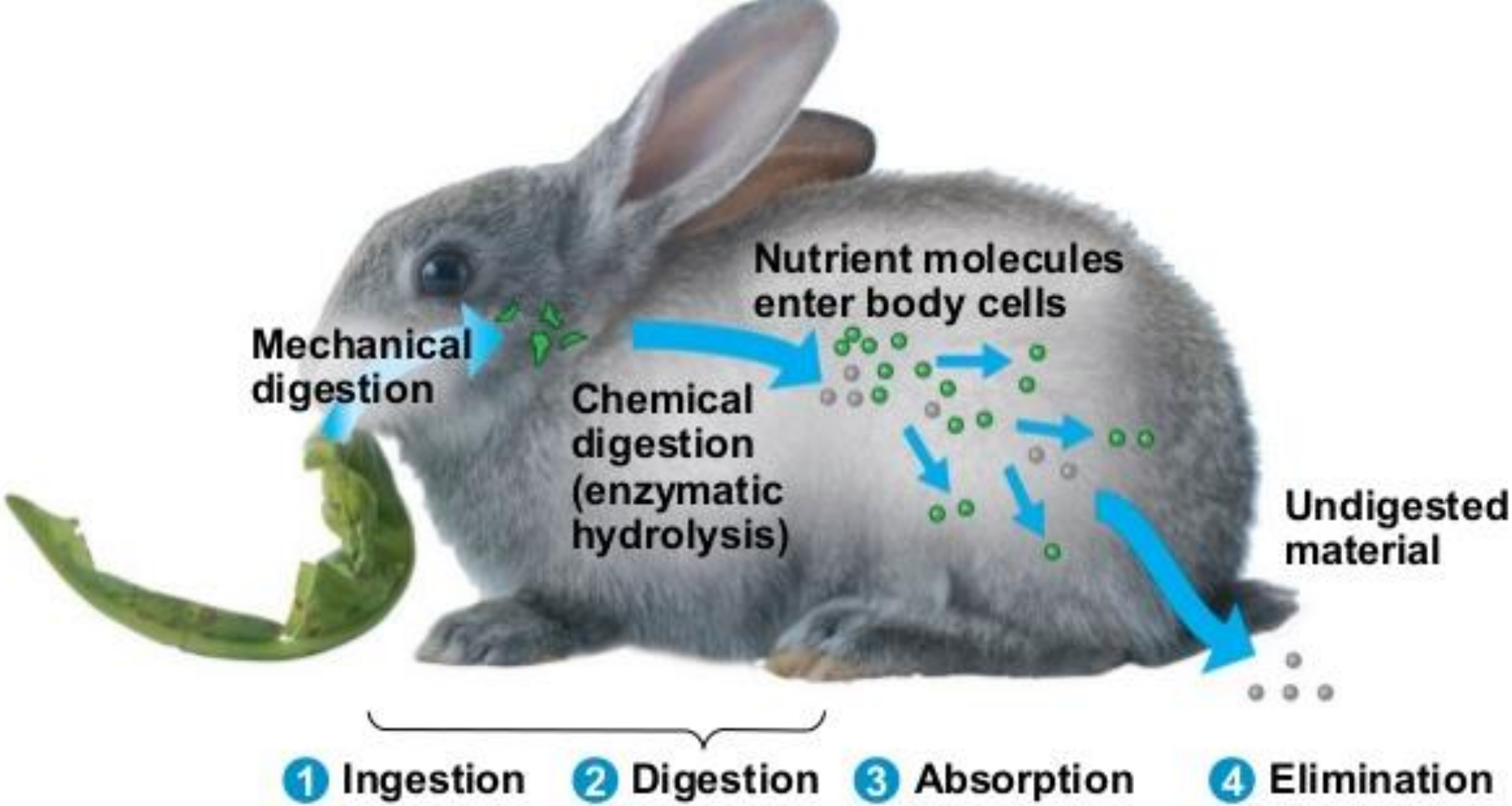


Key concepts

- **33.2** – Food processing involves ingestion, digestion, absorption and elimination
- **33.3** – Organs specialized for sequential stages of food processing form the mammalian digestive system
- **33.5** – Feedback, circuits regulate digestion, energy allocation, and appetite

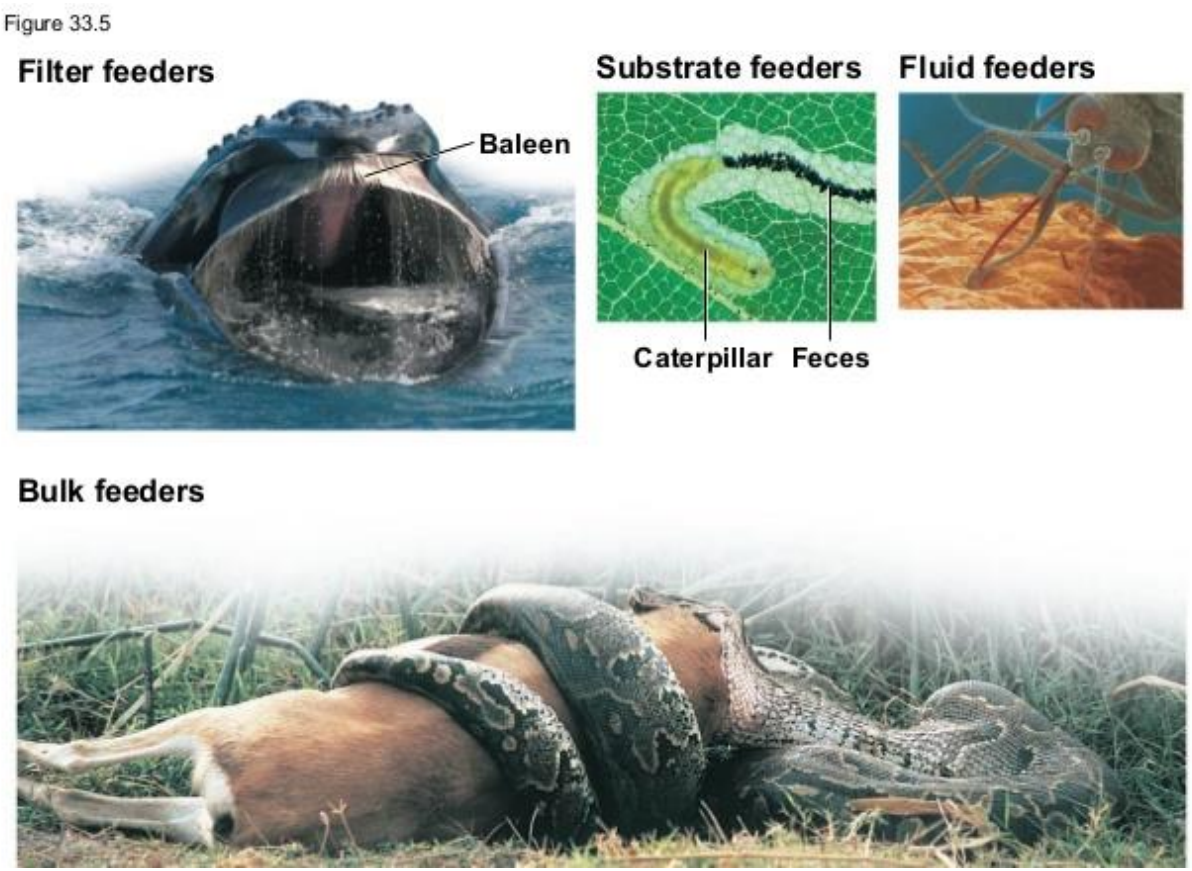
Food processing involves ingestion, digestion, absorption & Elimination

33.2


Mechanical digestion
Chemical digestion (enzymatic hydrolysis)
Nutrient molecules enter body cells
Undigested material
1 Ingestion
2 Digestion
3 Absorption
4 Elimination

1. Ingestion

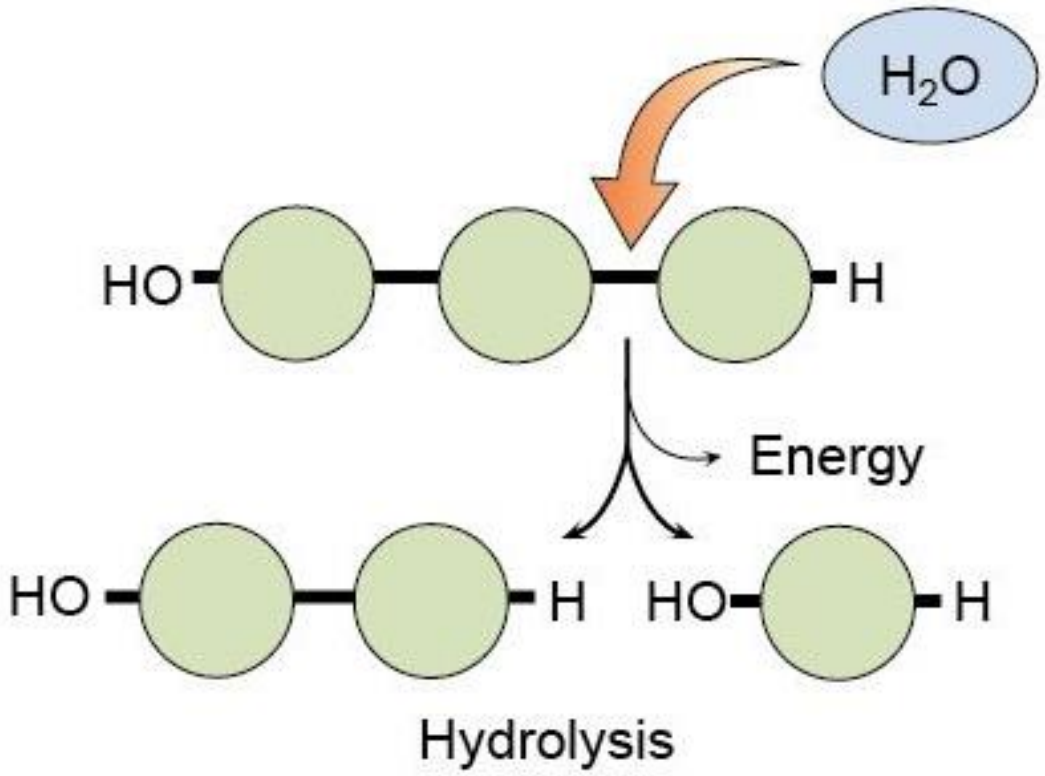
- Strategies for extracting resources from food differ widely among animal species
  - *Filter/Suspension feeders*
  - *Substrate feeders*
  - *Bulk feeders (you!)*



2. DIGESTION

- Food is broken down into molecules small enough for the body to absorb

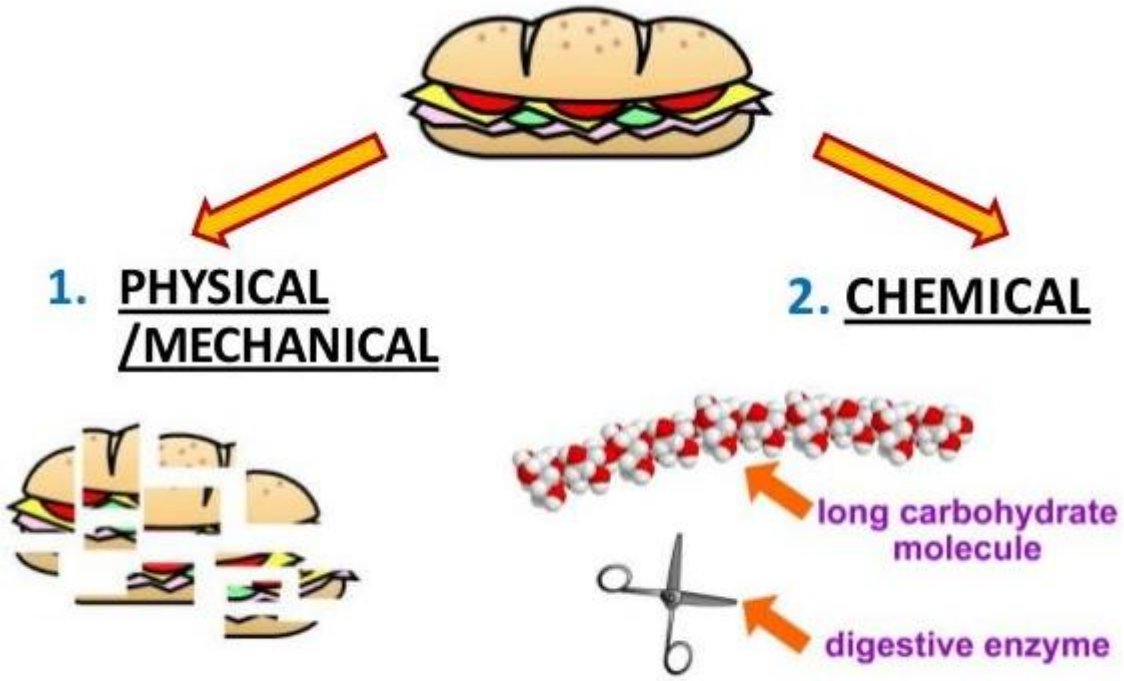
- Important because animals cannot directly use the carbohydrates, fats and proteins in food
  - Must be broken down and then reassembled into the large molecules they need.



2. DIGESTION

- ***Mechanical digestion*** breaks food down into smaller pieces by chewing or grinding
  - Leads to increased surface area!

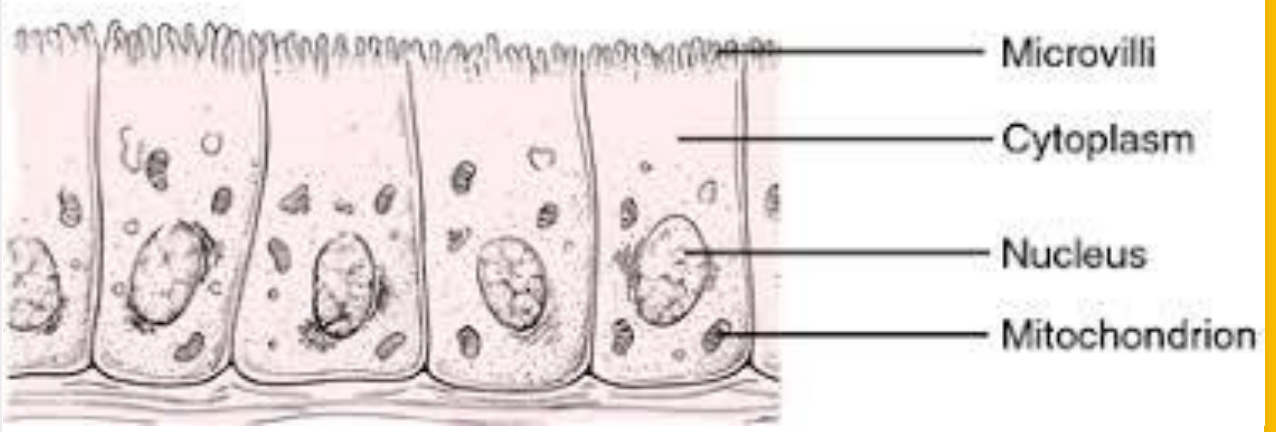
- ***Chemical digestion*** relies on <u>hydrolytic enzymes</u> to cleave macromolecules into smaller components



3. ABSORPTION

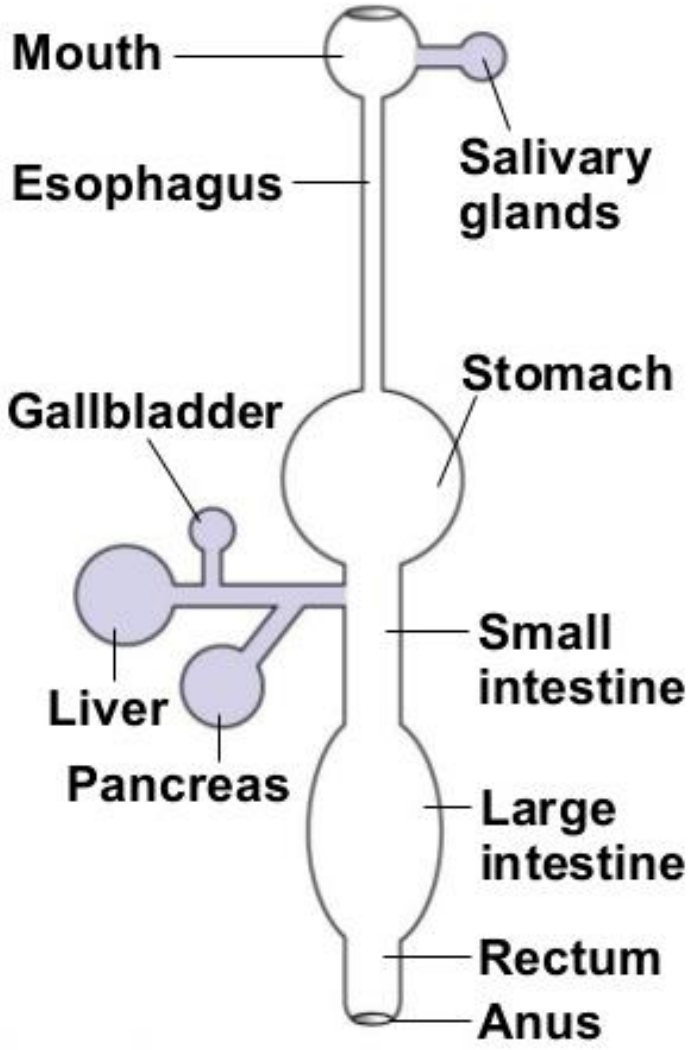
- The animal's cells take up small molecules like amino acids and monosaccharides

- In humans this takes place in the small intestine!



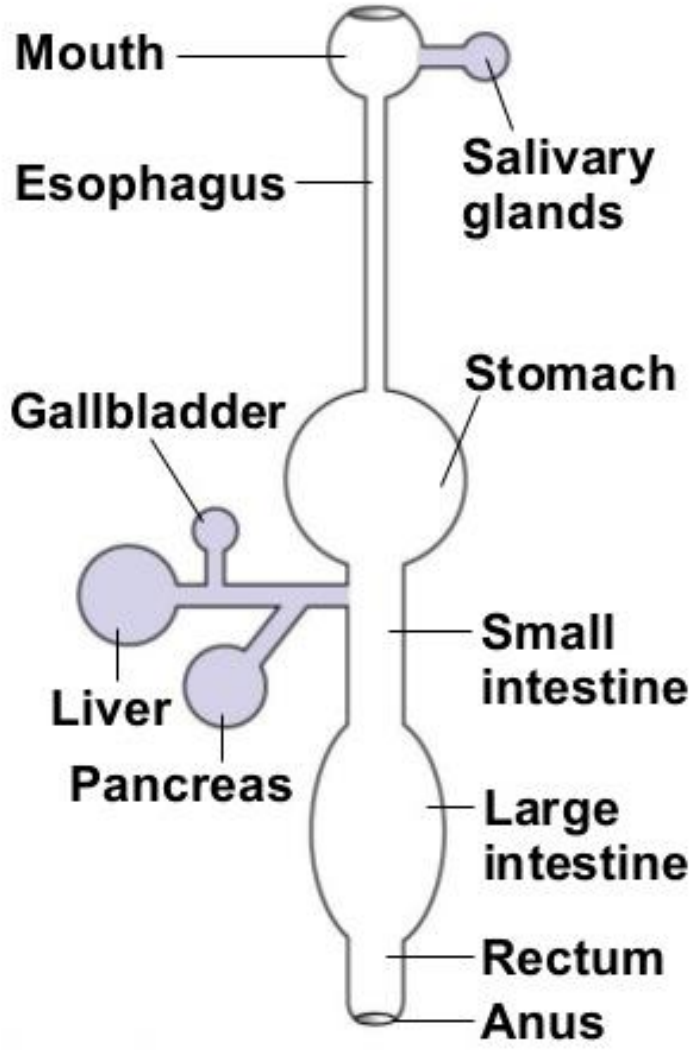
4. Elimination

- Undigested materials pass out of the digestive system



Digestive compartments

- Compartmentalization of the digestive tract is an evolutionary advantage
- Processing of food can take place within specialized intracellular or extracellular compartments



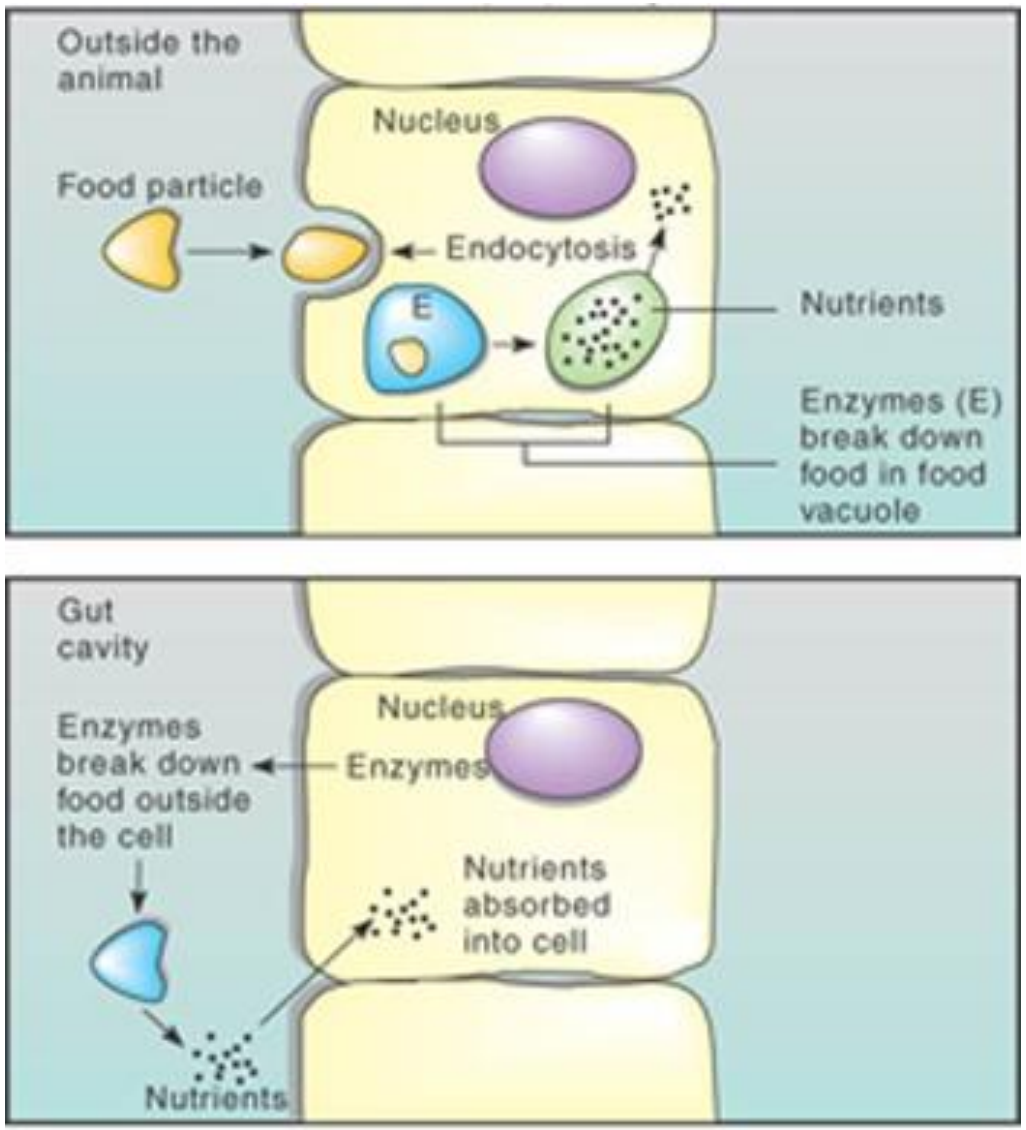
Intracellular Digestion vs. Extracellular Digestion

Intracellular

- Cells engulf solid food (phagocytosis) and then hydrolytic enzymes housed in lysosomes break the food down

Extracellular

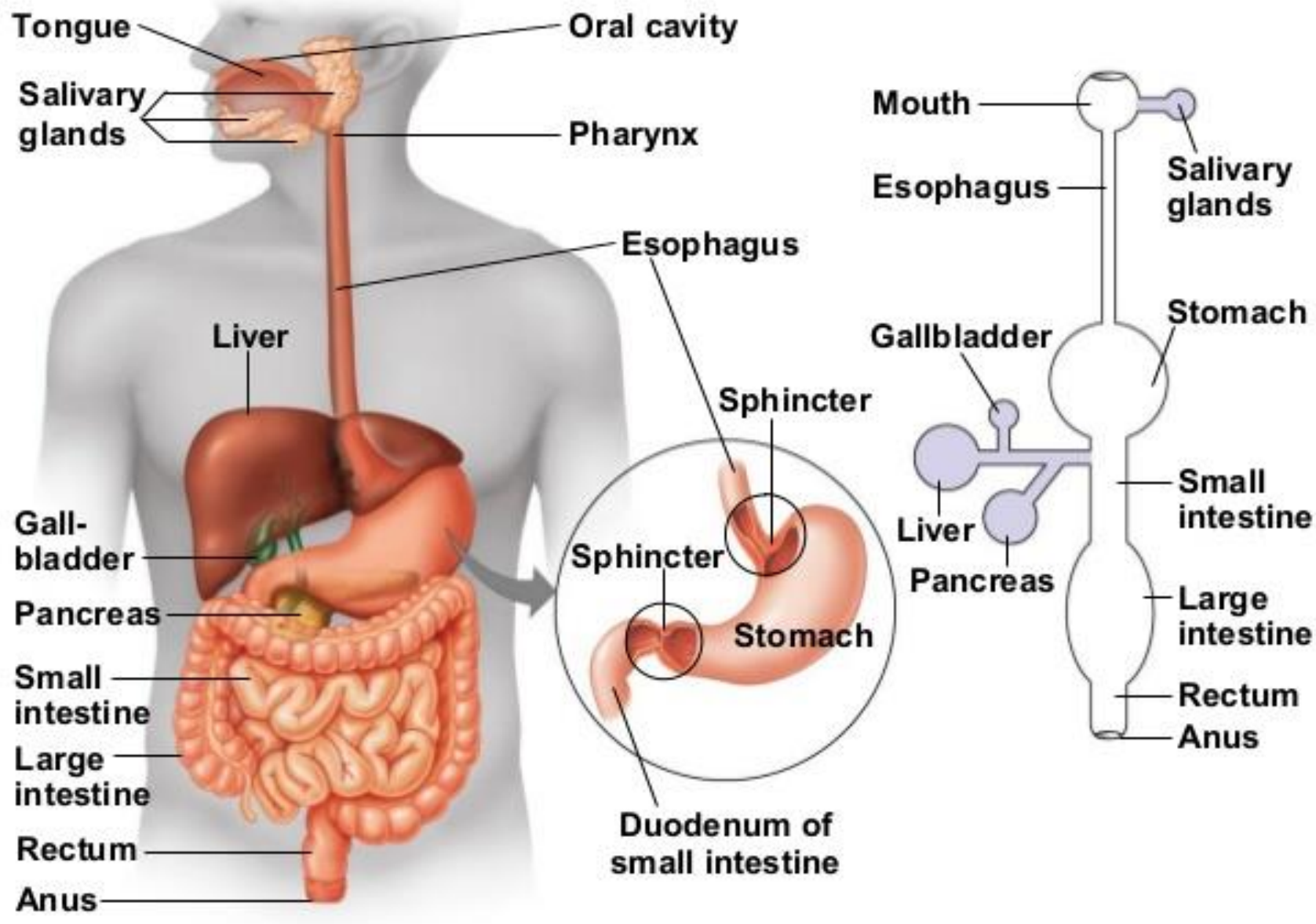
- The breakdown of food in compartments that are continuous with the outside of the animal's body
  - *Human-Donut Theory*



Organs specialized for sequential stages of food processsing form the mammalian digestive system

33.3

Figure 33.8



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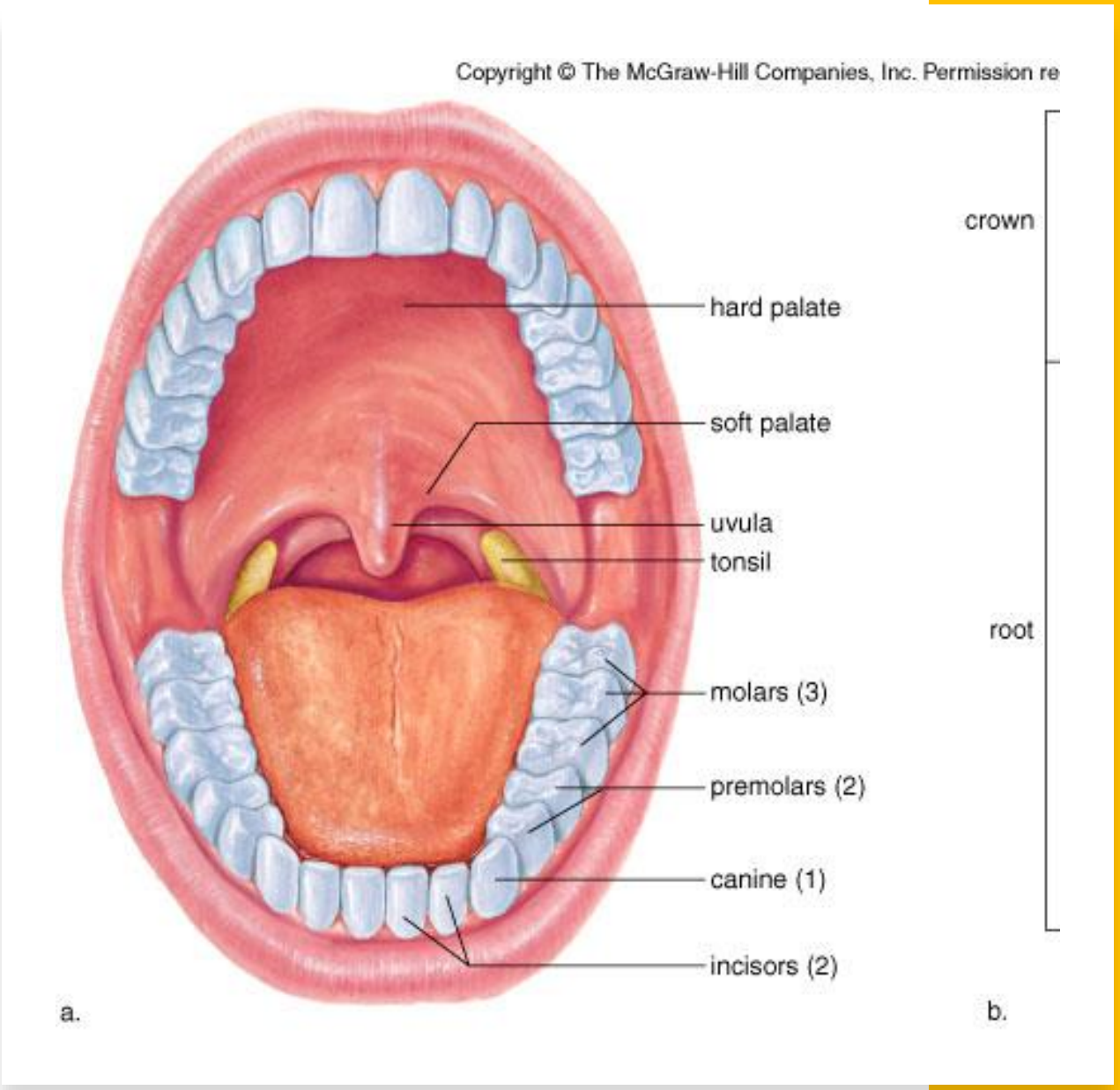
Oral Cavity
the mouth receives food

- *Tongue*
  - Taste buds- chemical sensation of taste
  - Rough surface- aids in mechanical digestion
  - Composed of skeletal muscle

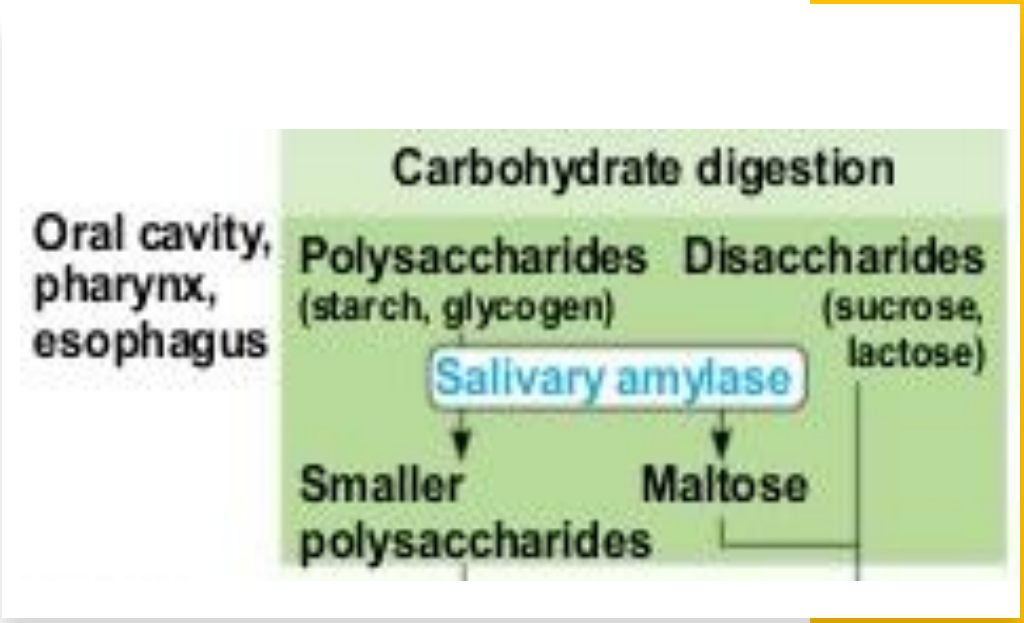
- *Roof of mouth*
  - Hard palate- composed of bone
    - Ridges for mechanical digestion
  - Soft palate- composed of muscle
  - Uvula
    - Closes off nares during swallowing

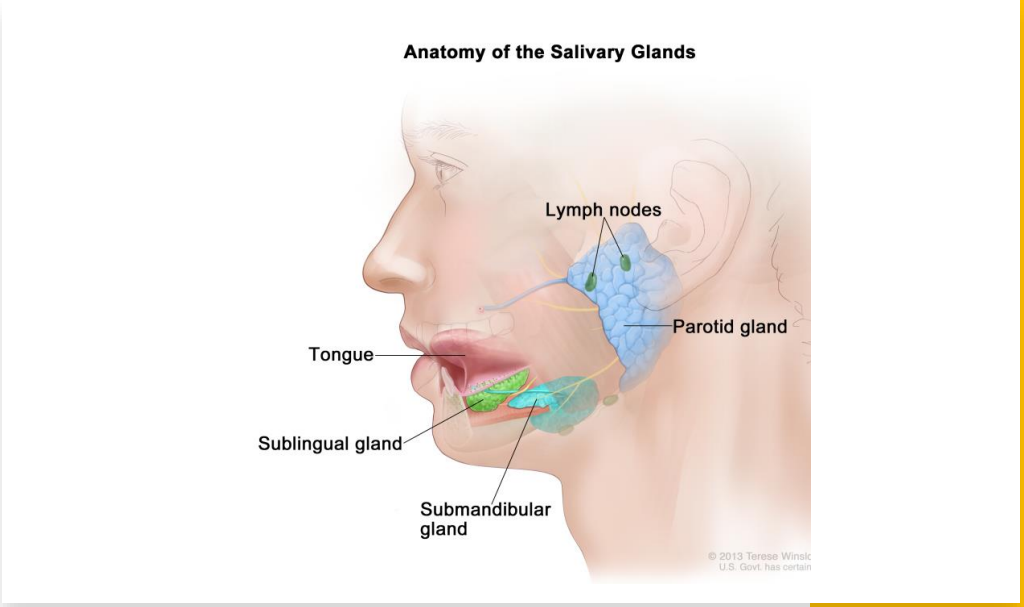


Oral Cavity

- *Salivary Glands*
  - Secrete saliva, a complex mixture with a vital function

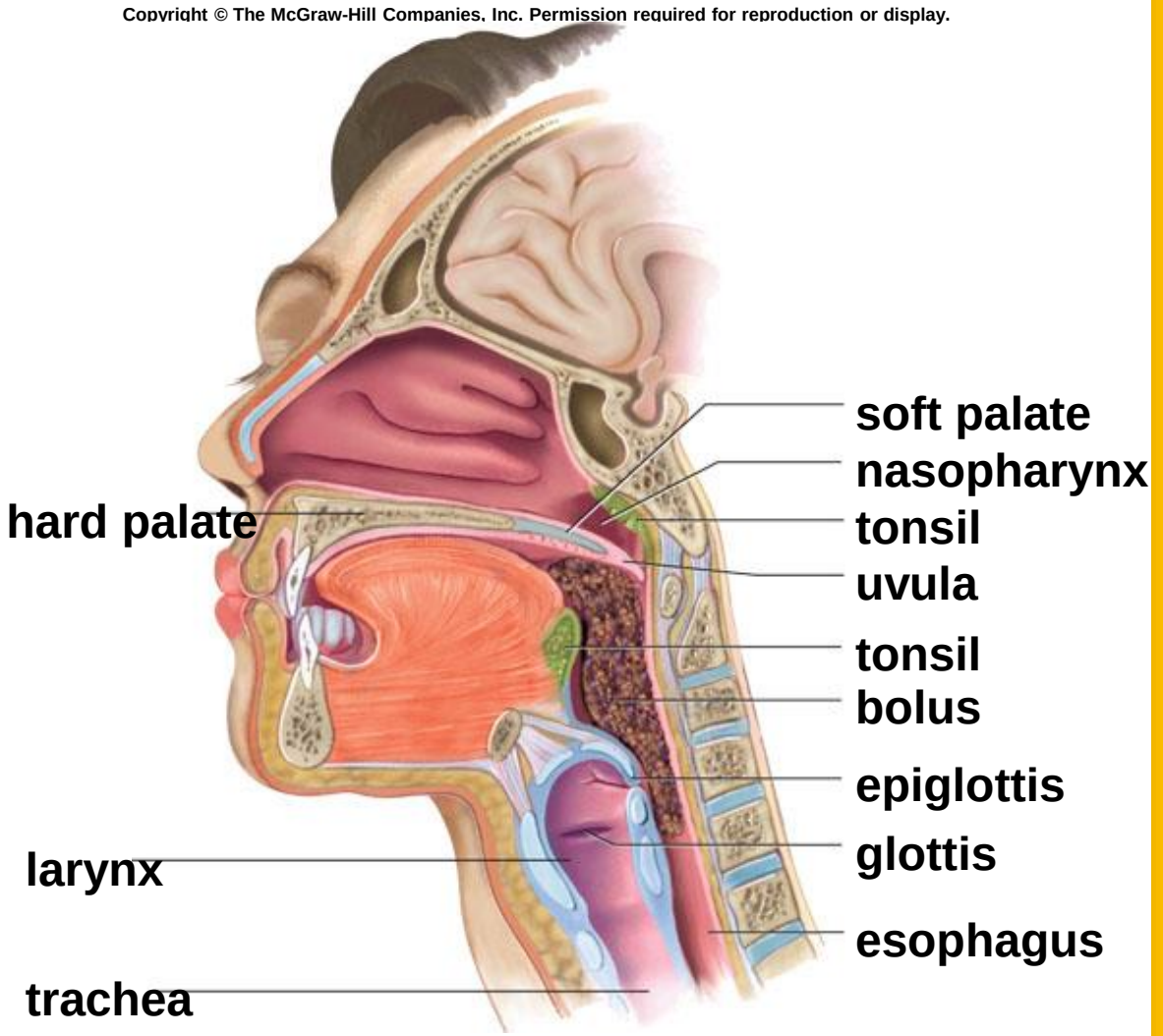
- *Saliva contains*
  - Mucus – water, salts, cells and glycoproteins
  - Buffers – neutralizes the pH
  - Salivary amylase – an enzyme that begins the ***chemical digestion*** of starch into disaccharides





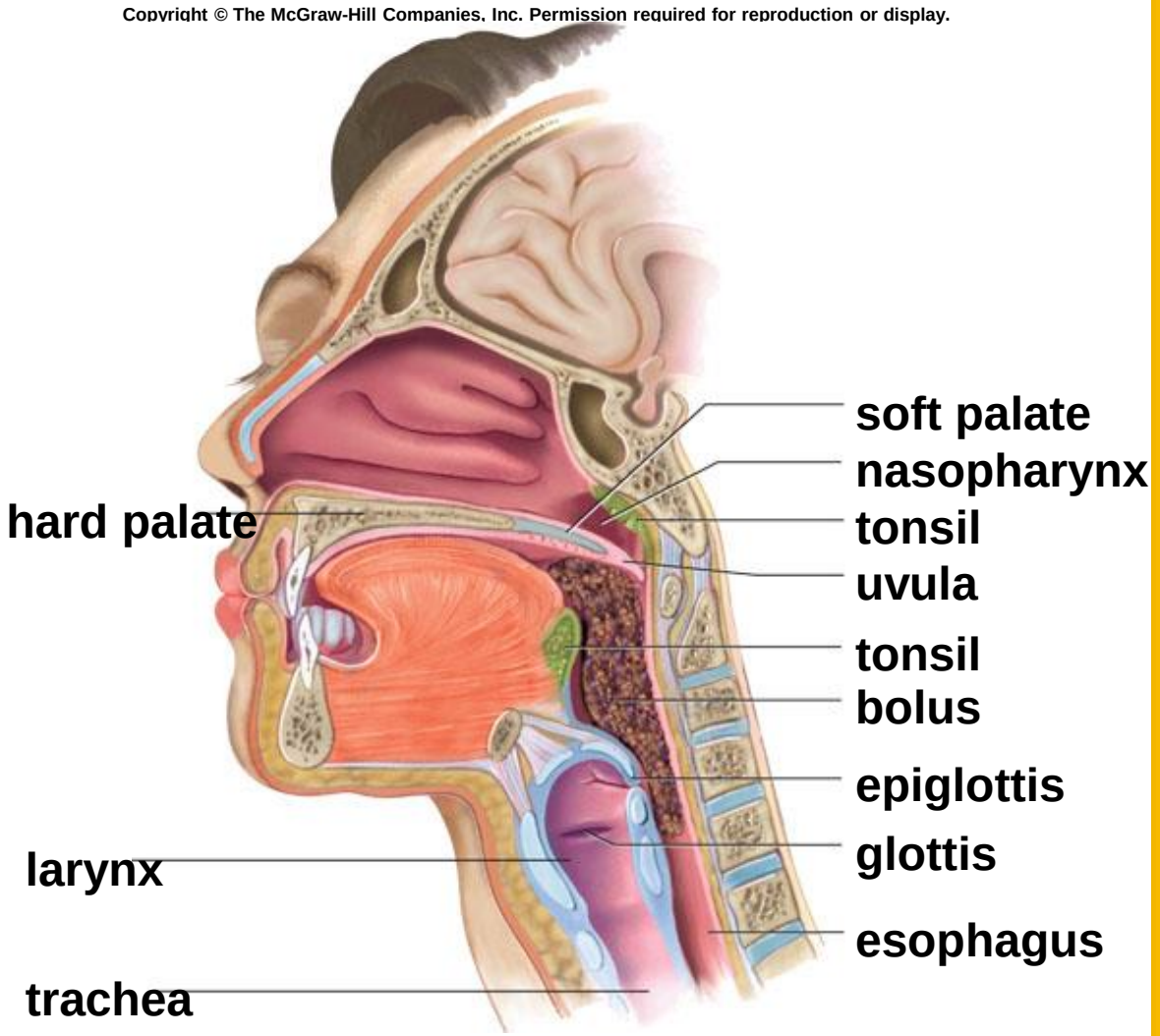
The tongue

- Evaluates ingested material
- Distinguishes which foods should be processed
- Pushes food into molars
- Pushes food into hard palate
- Pushes the ***bolus*** to the throat



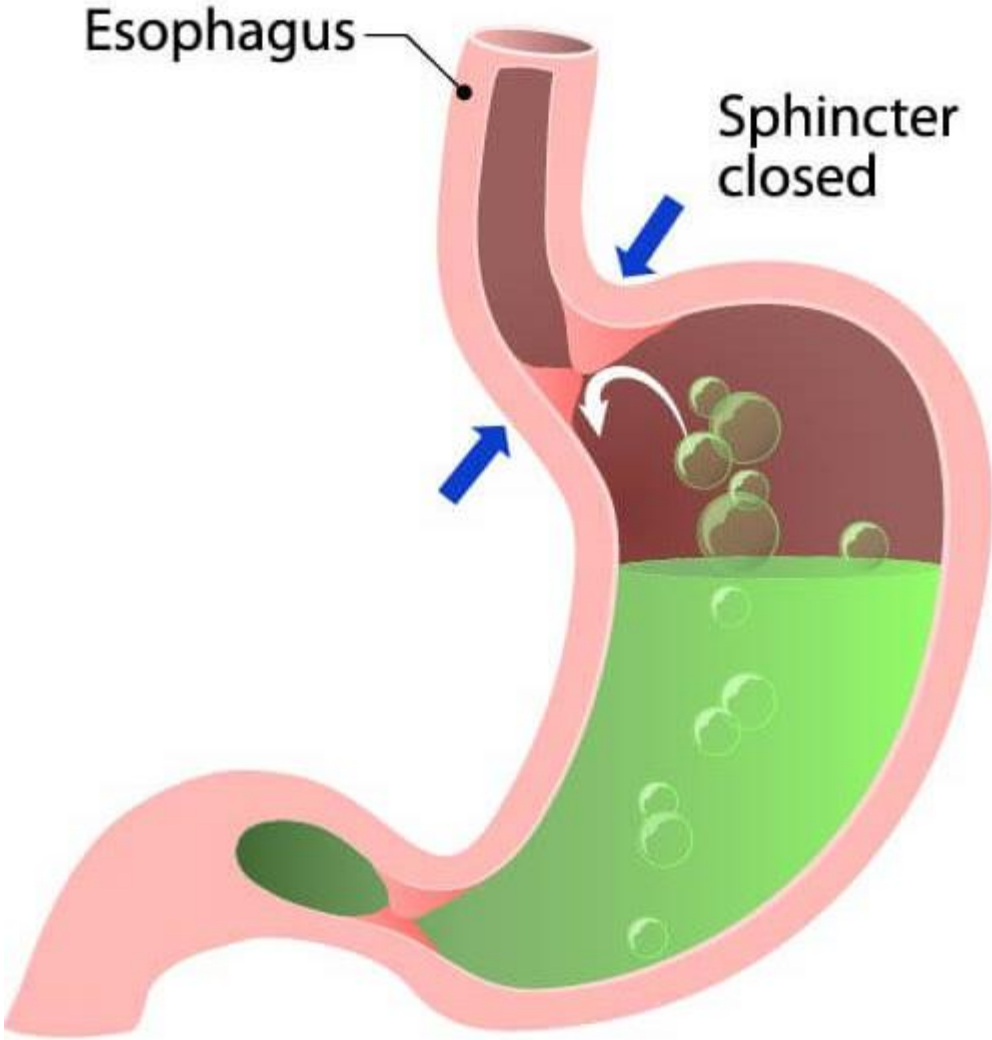
The Pharynx

- AKA: The throat
- Common passageway for food and air
- ***Swallowing reflex***
  - Uvula closes off nasopharynx
    - Prevents food from entering nasal cavities
  - Trachea moves upward under epiglottis
    - To cover the opening to the larynx → glottis
  - Bolus of food moves down esophagus



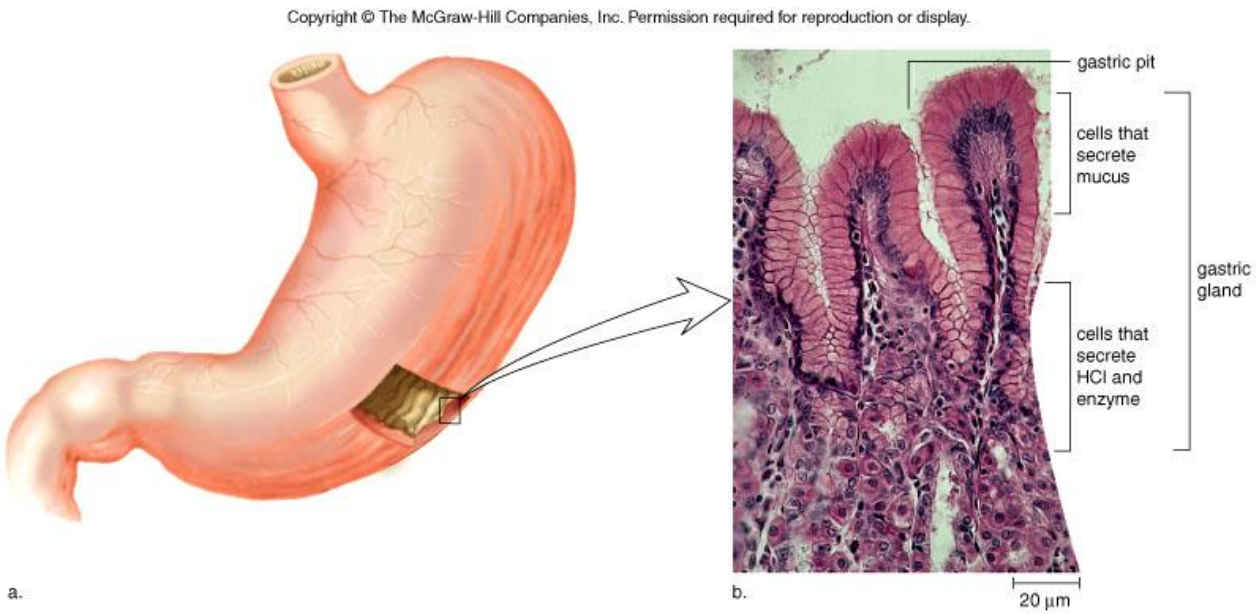
The Esophagus

- A muscular tube that leads to the stomach
- Food is pushed along by peristalsis
  - Waves of muscular contractions
- At the end is the ***esophageal sphincter*** (*cardiac sphincter*) which regulates the passage into the stomach



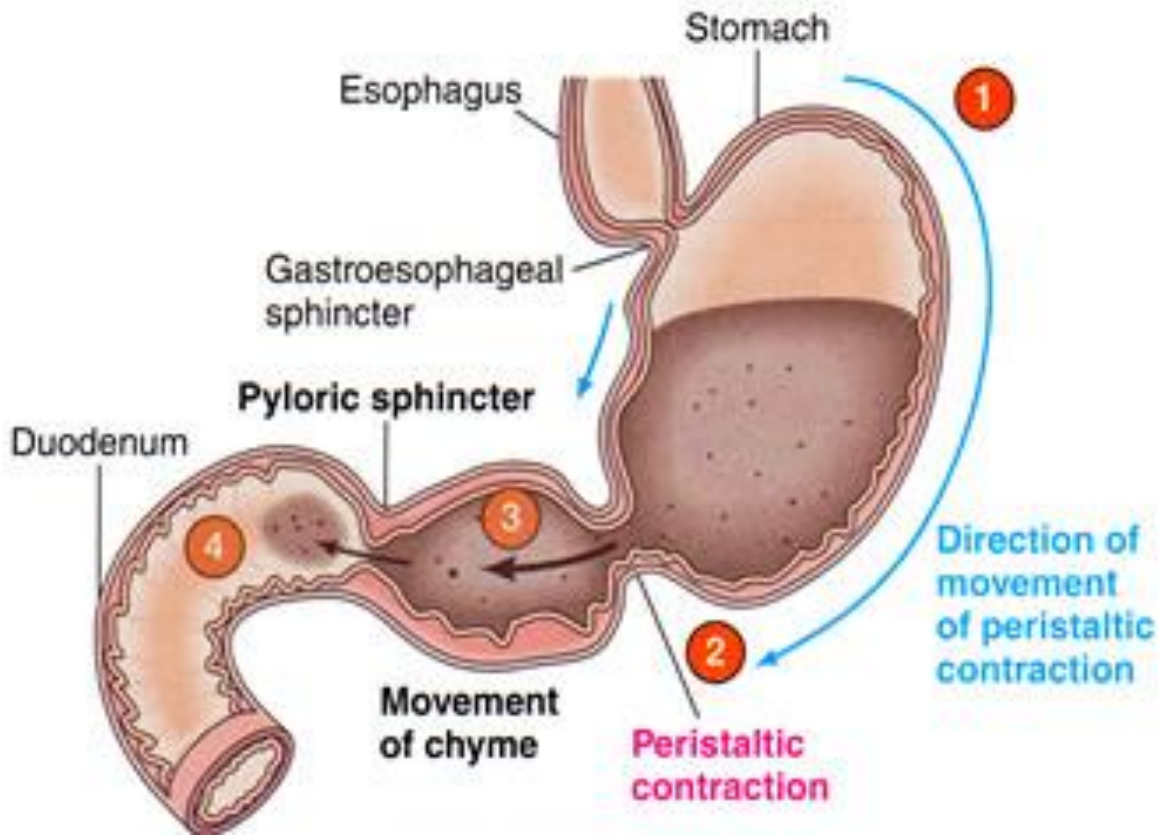
The stomach

- Thick-walled J-shaped organ
- Lies on left side of abdomen
- ***Rugae*** - folds in wall
  - Mechanical digestion-friction
  - Allows expansion
- 3 muscle layers
  - Longitudinal
  - Oblique
  - Circular



The Stomach

- The stomach secretes “gastric juice”
  - *HCl* – maintains a low pH and causes the protein in food to unfold
  - Protein – digesting enzyme: ***pepsin***
  - Mucus – protects the stomach lining
- It mixes these secretions with the food to produce ***chyme***
- *Peristalsis moves chyme to small intestine within 2-6 hours*



Chemical Digestion in the Stomach

- Protein Digestion begins in the stomach

- Pepsin hydrolyzes protein into small polypeptides & dipeptides
  - The optimal pH for pepsin is 2

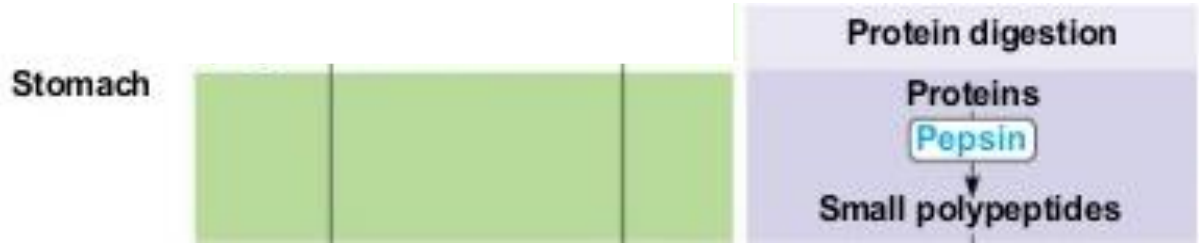
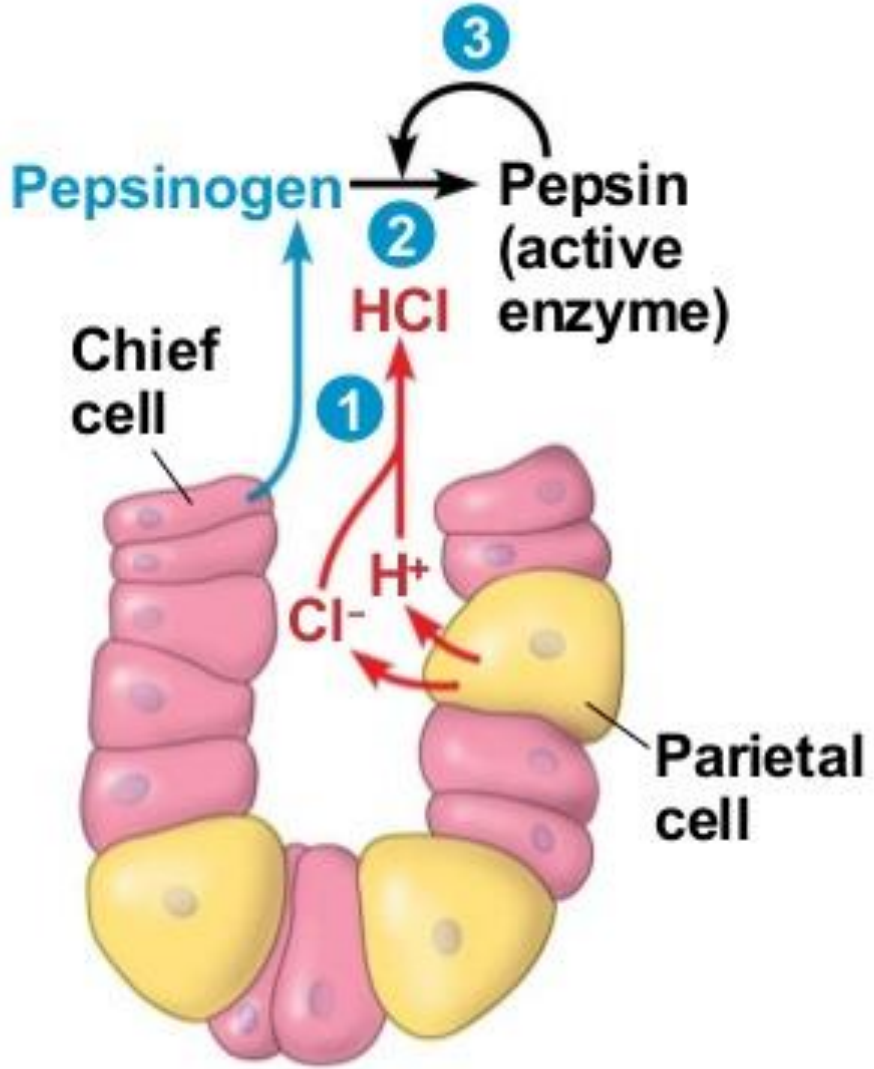


Figure 33.9b-3



Production of gastric juice

1. Pepsinogen and HCl secreted into lumen
2. HCl converts pepsinogen to pepsin.
3. Pepsin activates more pepsinogen, starting a chain reaction.

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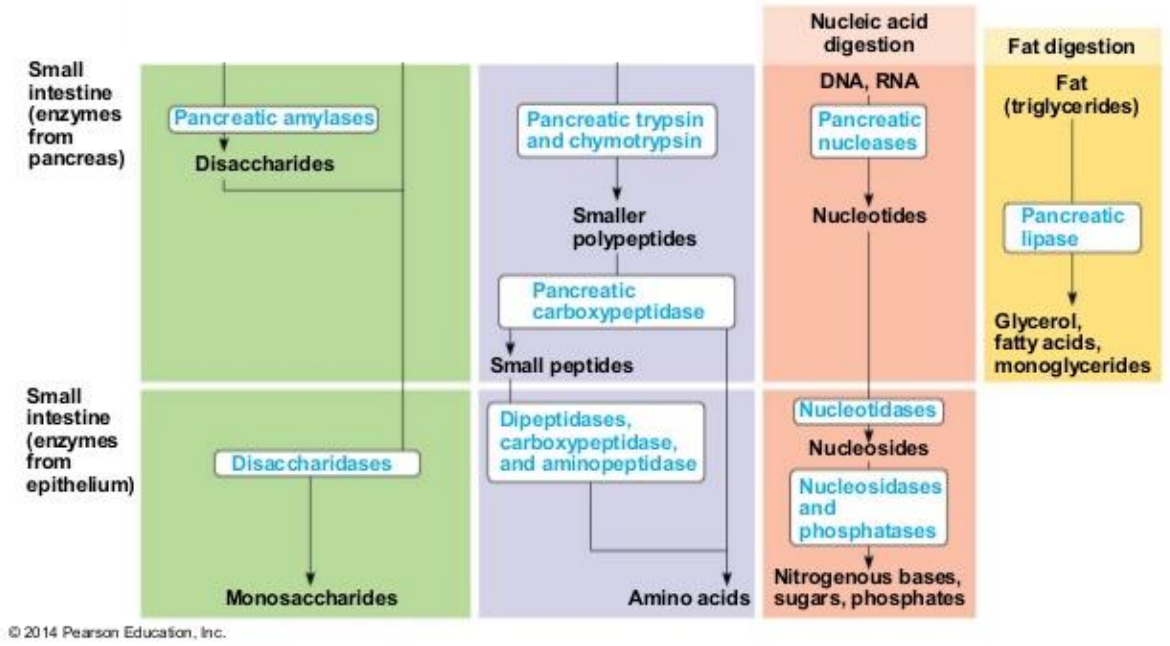
Digestion In the Small Intestine

- Majority of enzymatic hydrolysis of macromolecules occurs here
- Longest part of alimentary canal
- 6m in humans
- Smaller in diameter though
- First 10 cm is called the ***duodenum***



Digestion In the Small Intestine

- Chyme mixes with secretions from:
  - Pancreas
  - Liver
  - Gallbladder
  - Intestinal wall

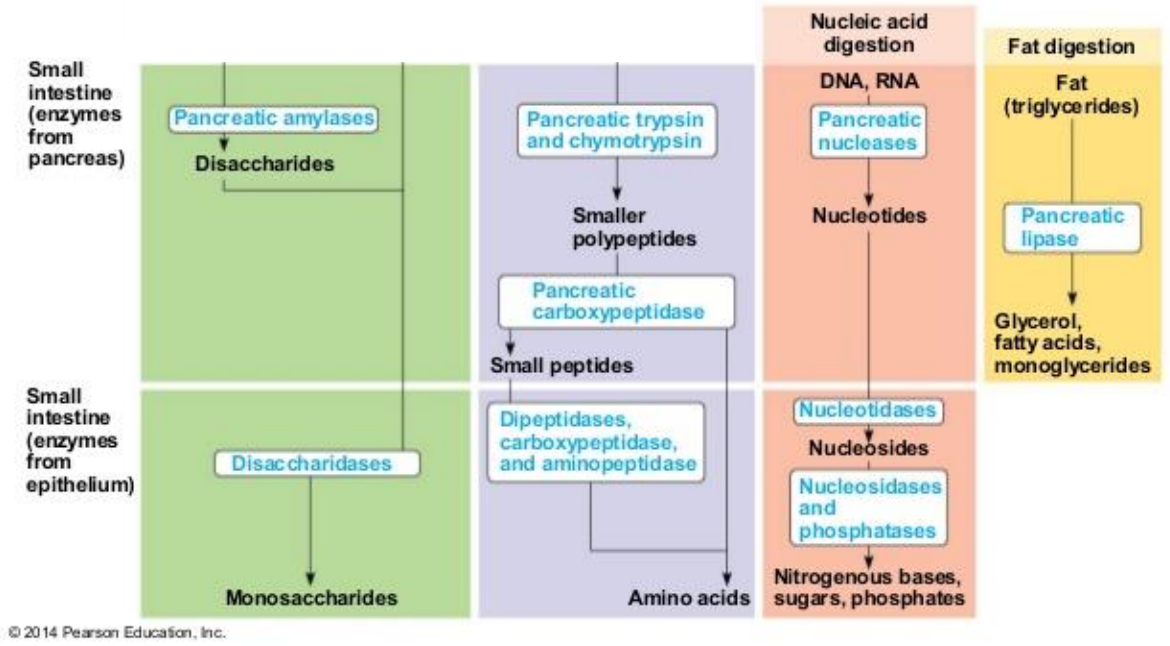
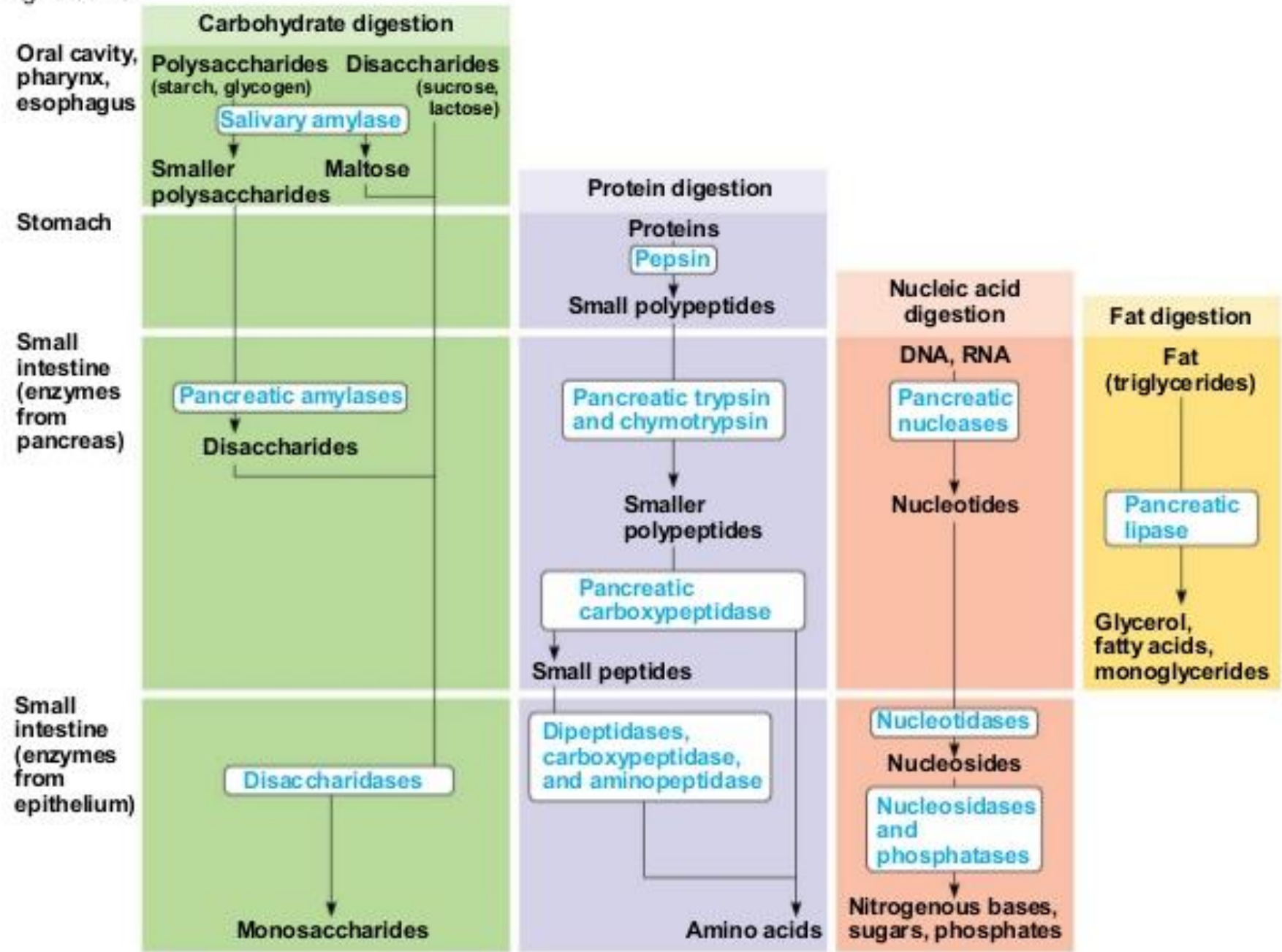


Figure 33.10



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The Role of Pancreatic Secretions

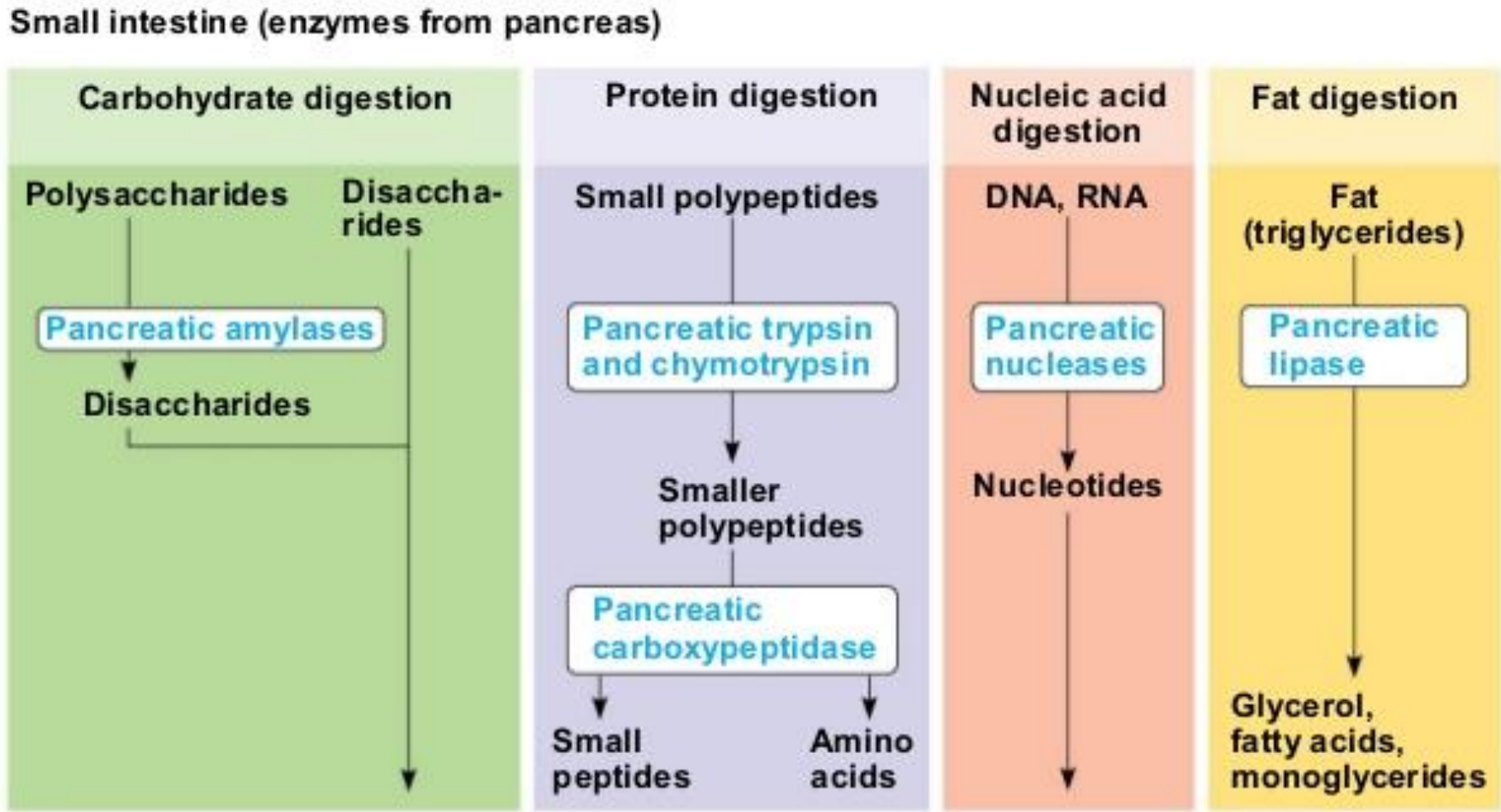
BICARBONATE

- Neutralizes the acidity of chyme
- Brings pH to 8

DIGESTIVE ENZYMES

- *Pancreatic Amylase (starch)*
- *Trypsin (protein)*
- *Chymotrypsin (protein)*
- *Pancreatic Carboxypeptidase (peptides)*
- *Pancreatic Nucleases (DNA & RNA)*
- *Pancreatic Lipase (Fat – triglycerides)*

Figure 33.10c



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The lining of the small intestine also contributes digestive enzymes

DIGESTIVE ENZYMES

- *Dipeptidases (peptides)*
- *Carboxypeptidase (peptides)*
- *Aminopeptidase (peptides)*
- *Nucleotidases (nucleotides)*
- *Nucleosidases (nucleosides)*
- *Phosphatases (nucleosides)*

Figure 33.10d

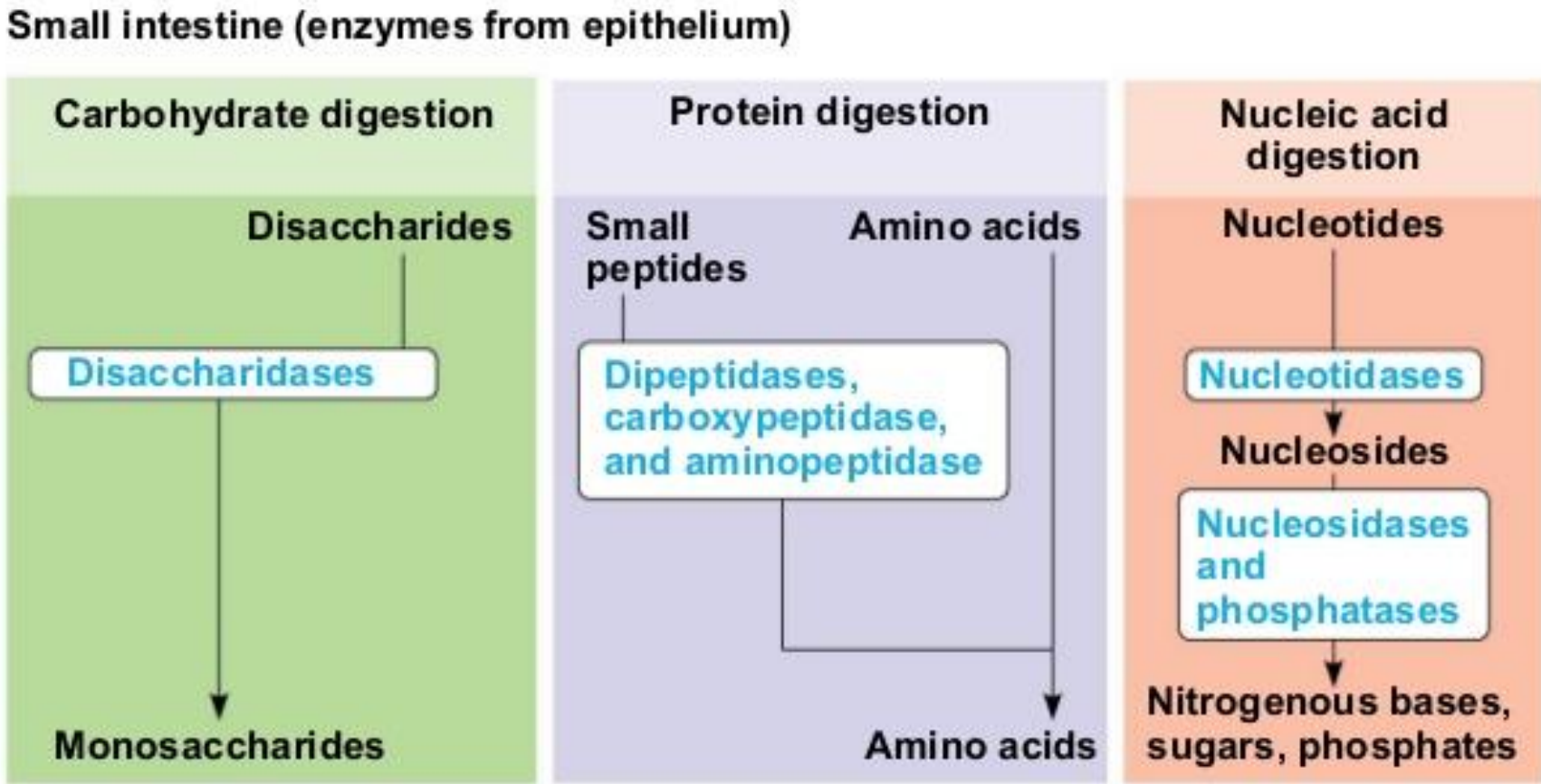

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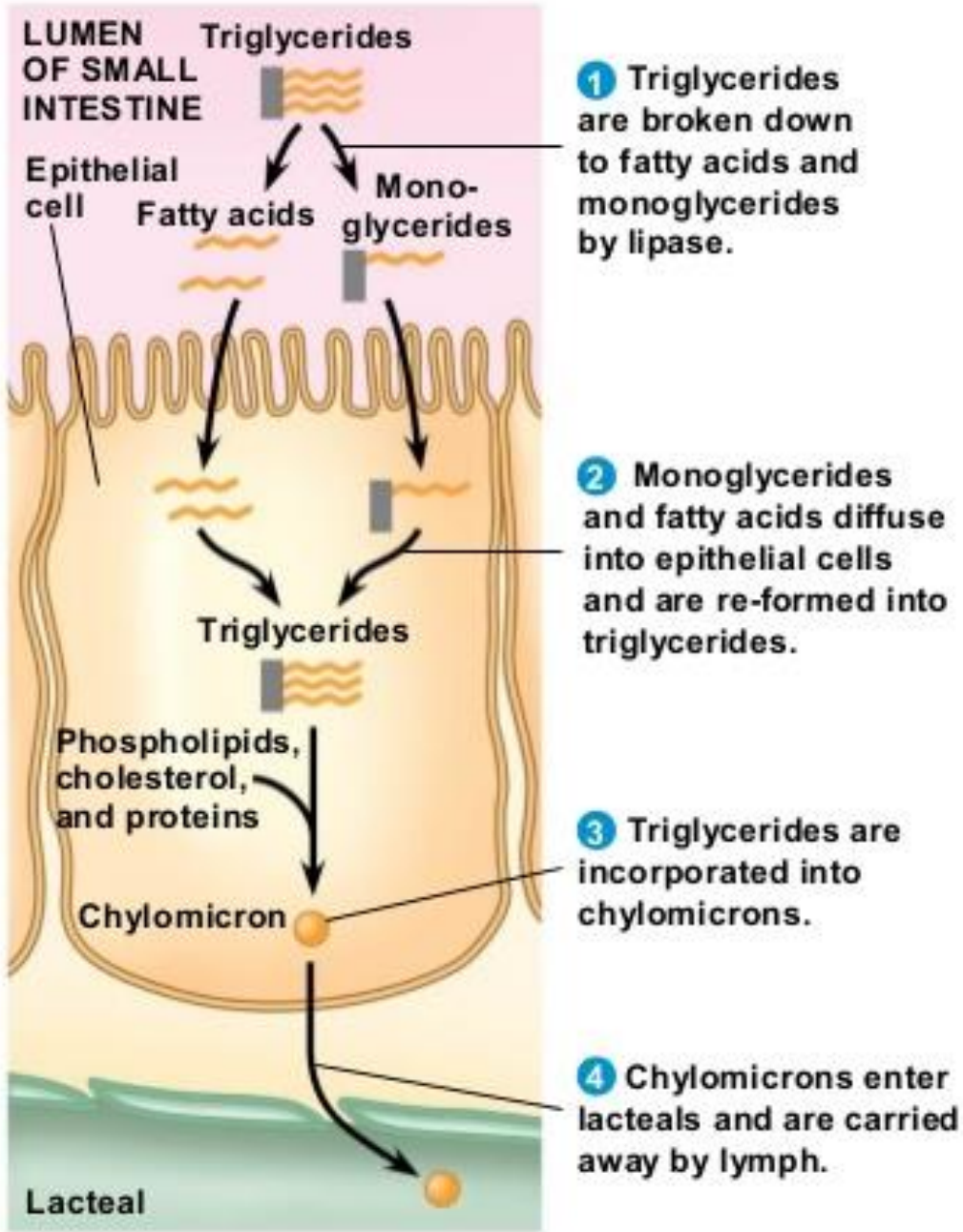
Figure 33.12



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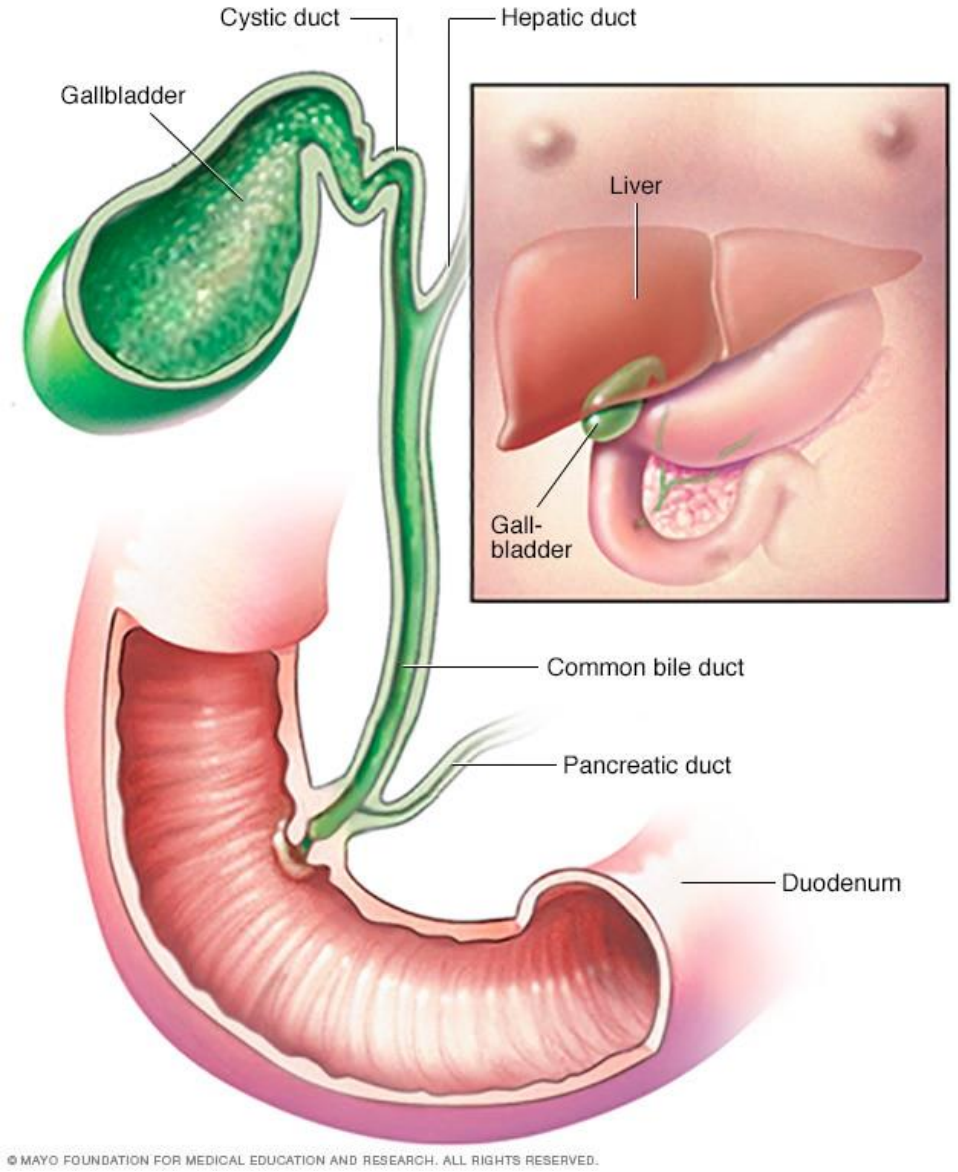
Role of the liver and Gallbladder

- The liver produces and secretes bile which is stored and concentrated in the gallbladder
- Bile production involves recycling pigments from the destruction of old red blood cells
- ***Bile emulsifies fats which increases it's surface area***
  - This enables more efficient chemical digestion by lipase



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Absorption in the Small Intestine

The "Brush Border"

- With digestion mostly complete, the contents moved to the ***jejunum*** and ***ileum***
- This part of the small intestine is specialized for absorption
  - *Long*
  - *Highly folded*
  - *Finger like projections called villi*
  - *Each epithelial cell has microscopic projections called microvilli*

Figure 33.11

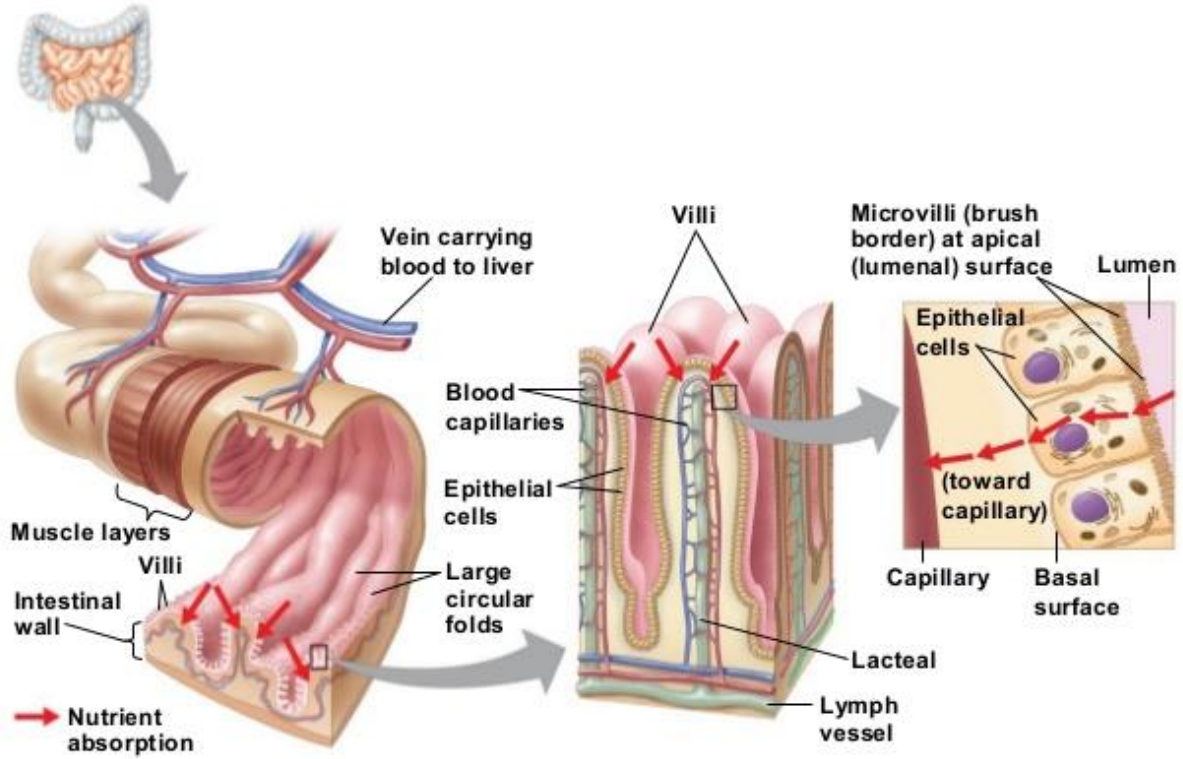

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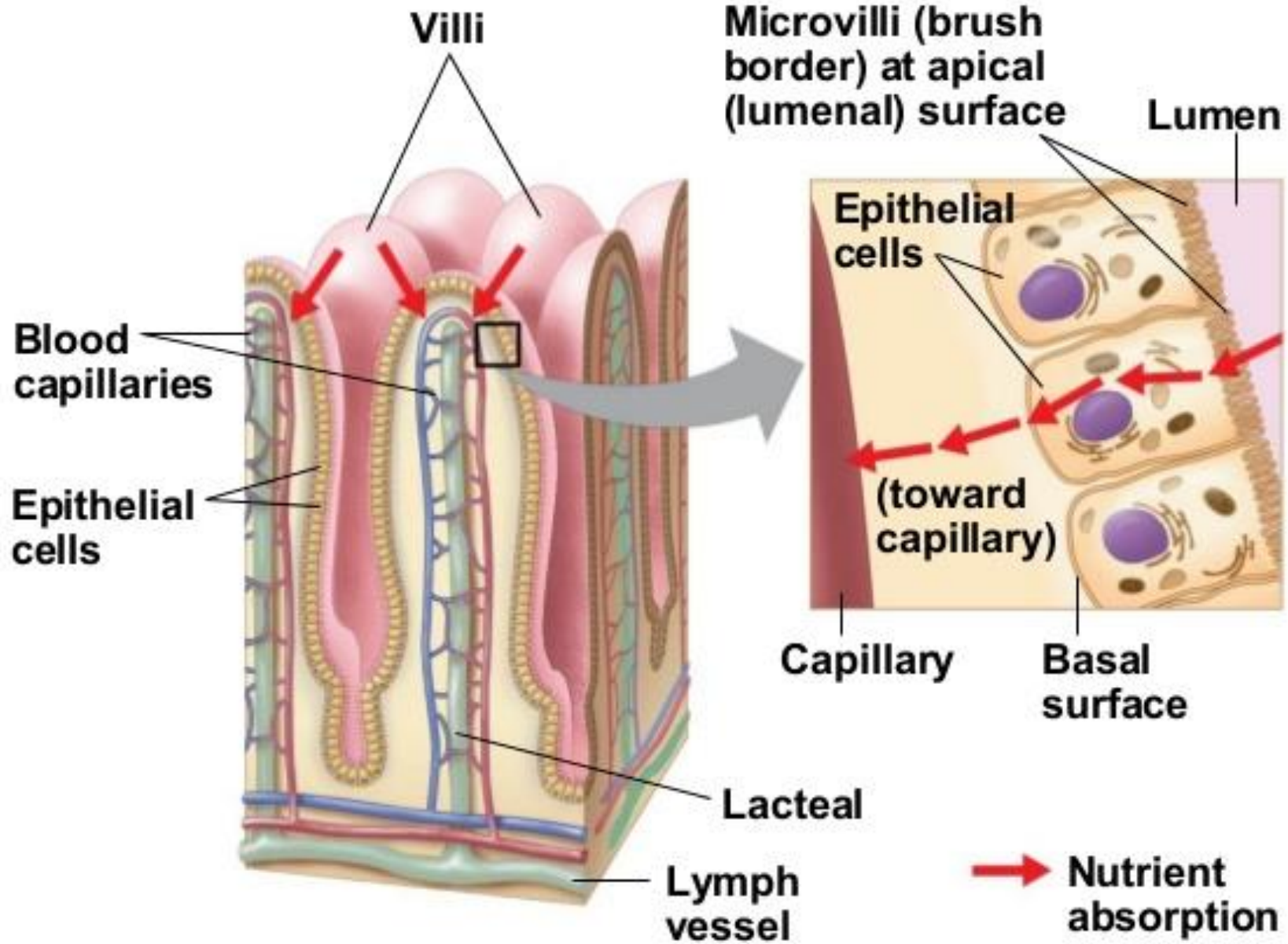
Figure 33.11b



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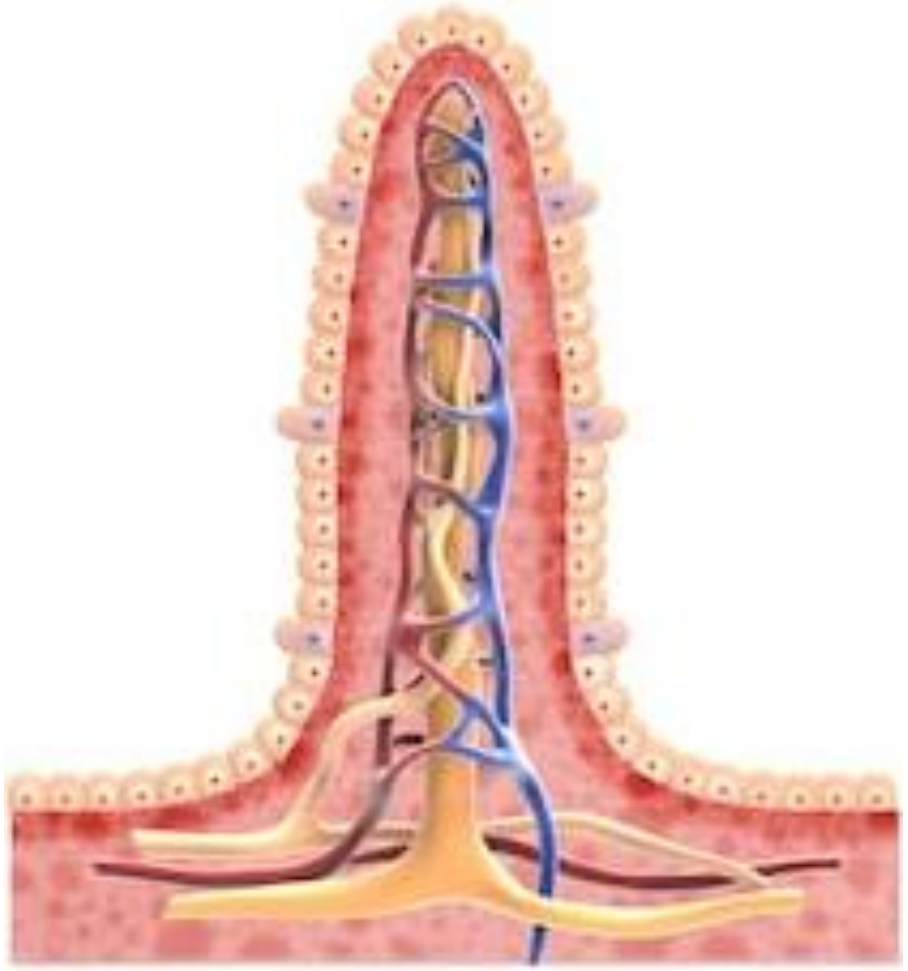
The brush border

- Together, the folds, villi and microvilli of the small intestine have a surface area of 200-300 m2
  - ~ size of a tennis court
- This enormous surface area increases the rate of nutrient absorption
- Transport across the intestinal epithelium can be passive or active
- Each villus has a dedicated capillary network and lacteal



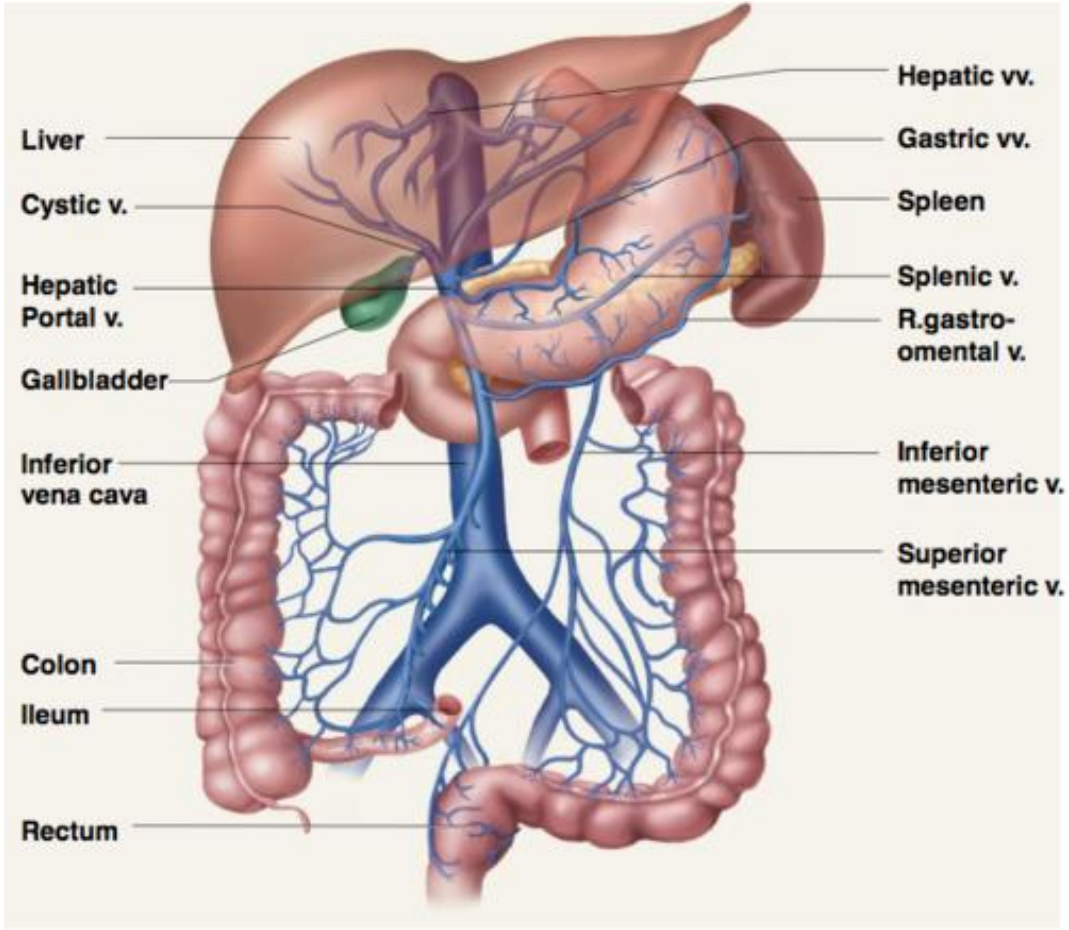
The Hepatic Portal System

- The capillaries and veins carry blood away from the intestine into the hepatic portal system a blood vessel that leads directly to the liver
- From the liver blood goes directly to the heart and then to other tissues and organs

<u>TWO MAJOR ADVANTAGES:</u>

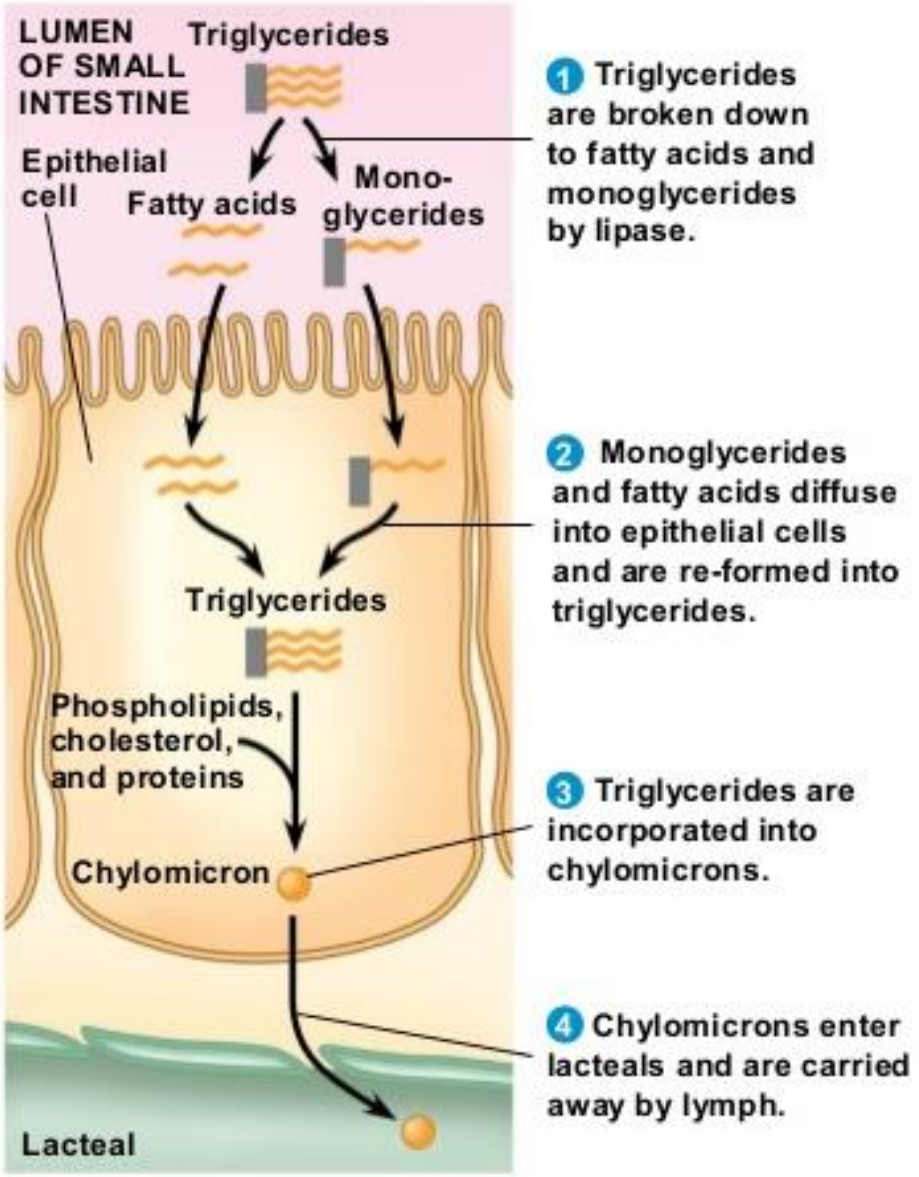
1. ***This allows the liver to regulate the distribution of nutrients to different forms***

2. ***This allows the liver to remove toxic substances from the blood before it circulates throughout the body***



Fats Do Not Enter the Bloodstream

- ***Fats are absorbed into the lacteal of the villi***
- Hydrolysis of a fat generates fatty acids and monoglyceride
  - These are absorbed by epithelial cells and recombined into triglycerides
- The triglycerides then combine with phospholipids, cholesterol, and proteins forming ***chylomicrons***
  - Chylomicrons enter the lacteal and enter the lymphatic system
- Eventually the lymphatic system delivers these chylomicron into the blood

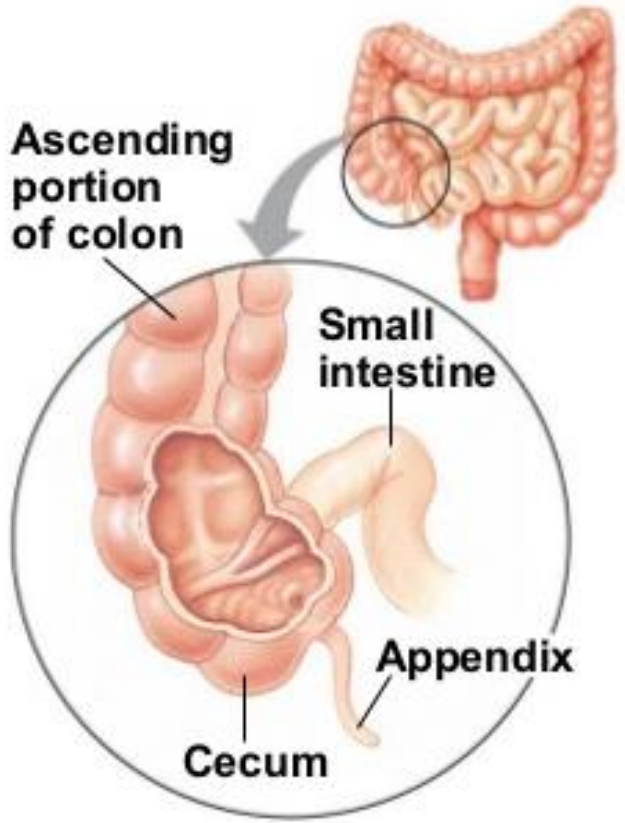


Additional Functions of the Small Intestine

- The small intestine recovers water and ions
- We typically consume about 2L of water a day
- We secrete another 7L of digestive juices
- All but 0.1 of this water is absorbed in the small intestine
- Water is reabsorbed by osmosis when sodium and other ions are actively pumped out of the lumen of the small intestine

Processing in the Large Intestine

- The alimentary canal ends with the large intestine
  - It is larger in diameter but much shorter than the small intestine
- The large intestine consists of the colon, cecum and rectum
  - The appendix is a small extension of the cecum has a minor and dispensable role in immunity



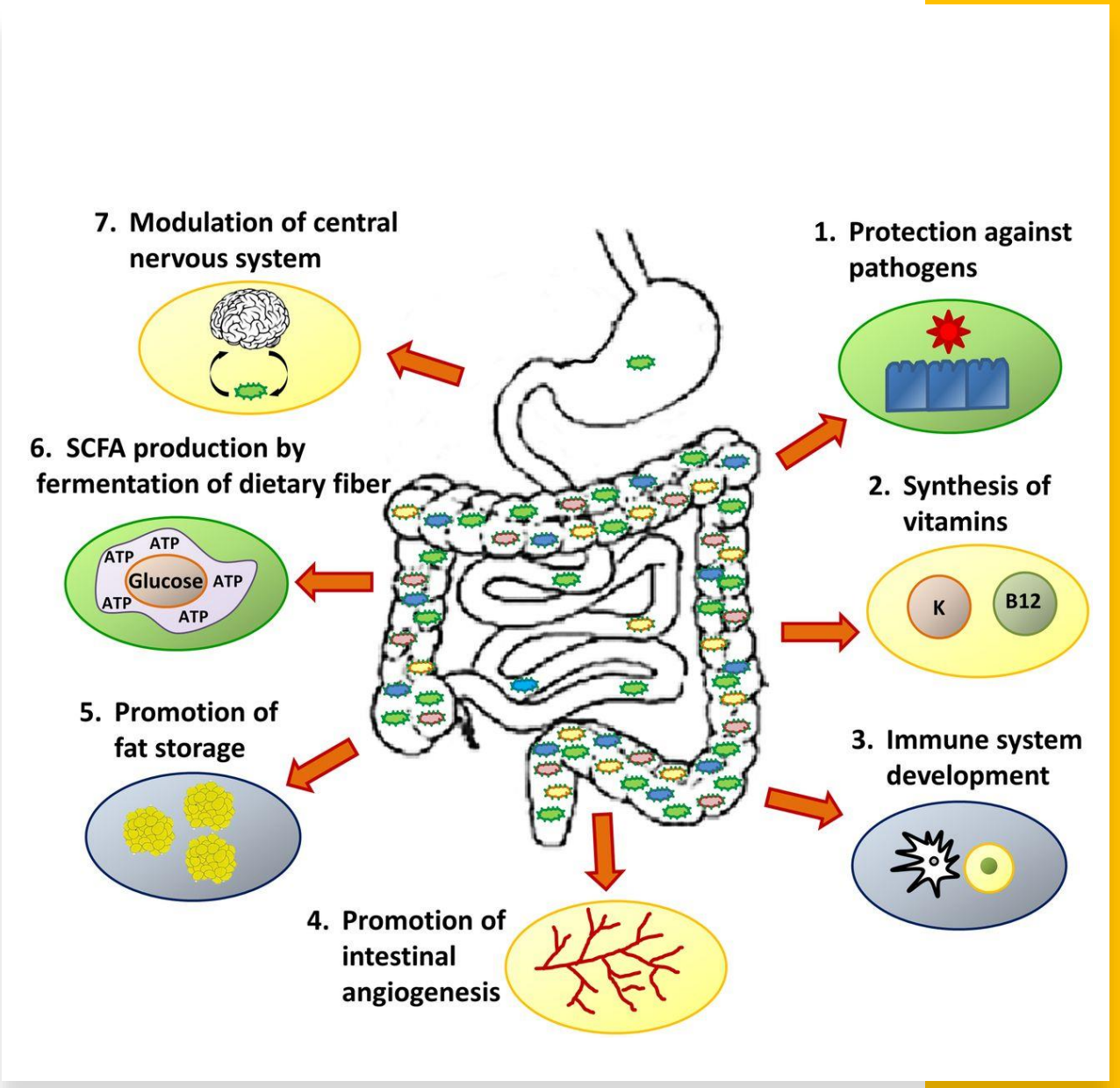
Junction of the small and large intestines

Indigestible Wastes

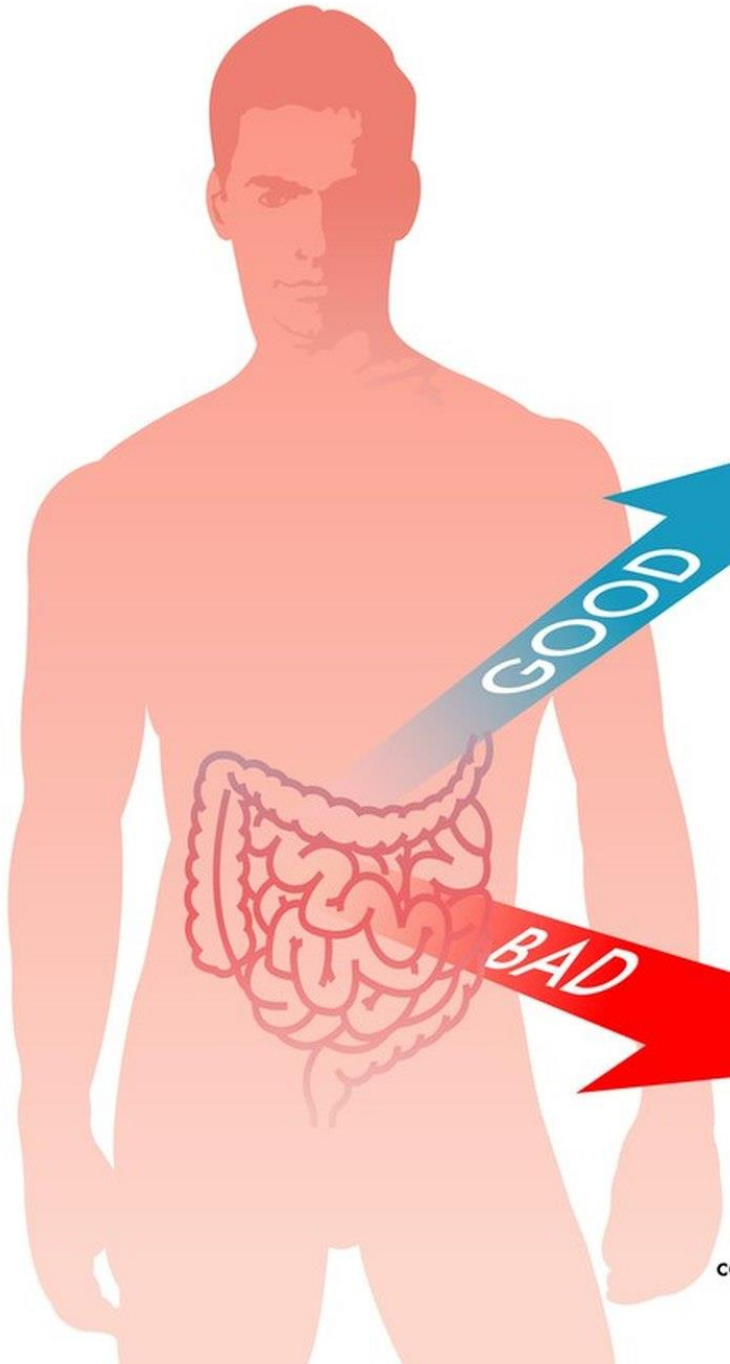
- The large intestine completes the remainder of water recovery
  - Material that remains after water is reabsorbed = ***feces***
- It takes approximately 12-24hrs for material to travel the length of the colon
- The undigested materials in feces include cellulose fibre

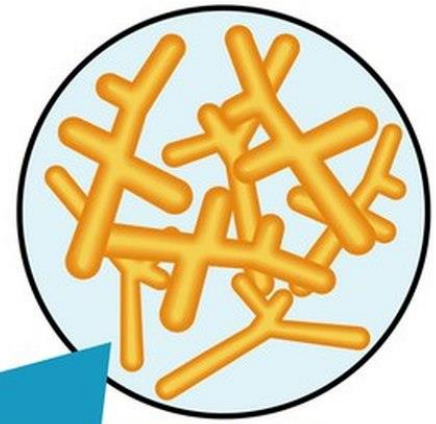
The Gut MicroBiota

- The large intestine is home to a rich community of mostly harmless bacteria
- Healthy gut flora is thought to be largely responsible in overall health
- These microbes have tremendous potential to impact our physiology, both in health and in disease.
- They contribute metabolic functions, protect against pathogens, educate the immune system, and, through these basic functions, affect directly or indirectly most of our physiologic functions.

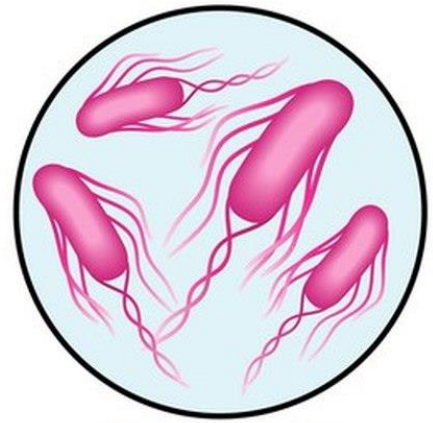


Good and Bad Bacterial Flora

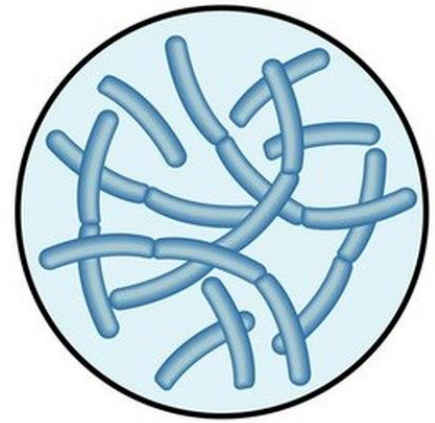




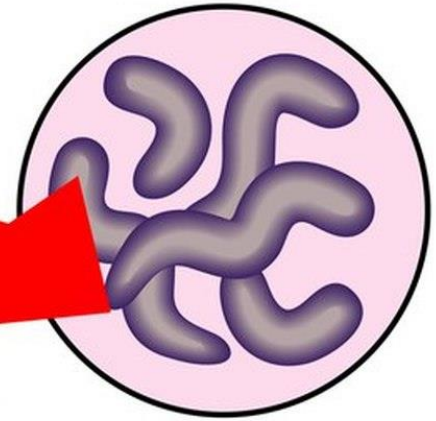
BIFIDOBACTERIA
The various strains help to regulate levels of other bacteria in the gut, modulate immune responses to invading pathogens, prevent tumour formation and produce vitamins.



ESCHERICHIA COLI
Several types inhabit the human gut. They are involved in the production of vitamin K2 (essential for blood clotting) and help to keep bad bacteria in check.
But some strains can lead to illness.

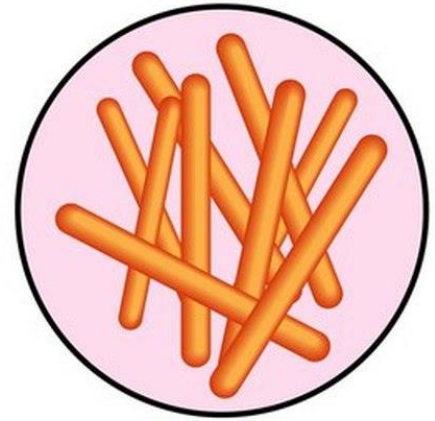


LACTOBACILLI
Beneficial varieties produce vitamins and nutrients, boost immunity and protect against carcinogens.



CAMPYLOBACTER
C Jejuni and C coli are the strains most commonly associated with human disease. Infection usually occurs throught the ingestion of contaminated food.

ENTEROCOCCUS FAECALIS
A common cause of post-surgical infections.



CLOSTRIDIUM DIFFICILE
Most harmfull following a course of antibiotics when it is able to proliferate.

Feedback circuits regulate digestion, energy allocation, and appetite

33.5

Regulation of Digestion

- For many animals there are long gaps between meals
- Therefore there is no need for digestion to take place continuously
- As food reaches each new compartment it triggers the secretion of digestive juices for the next stage of processing
- Hormones help to regulate digestive secretions
  - Like all hormones they are transported through the bloodstream

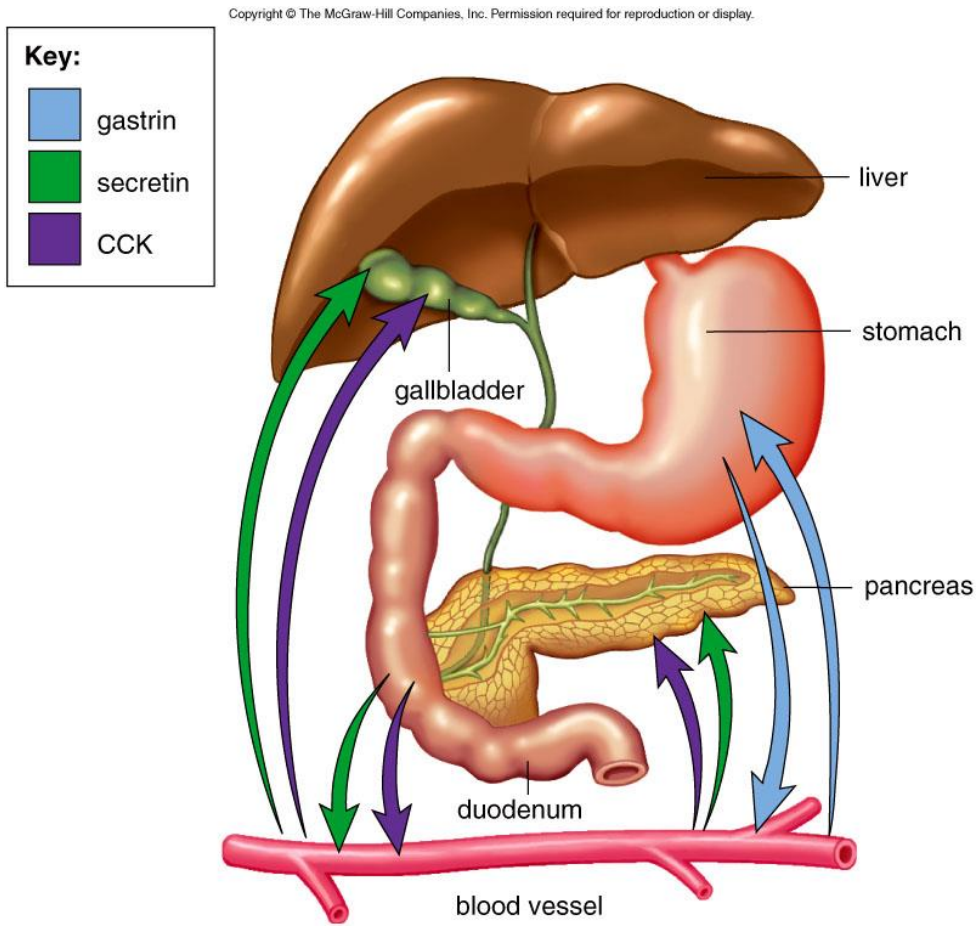


Figure 33.17

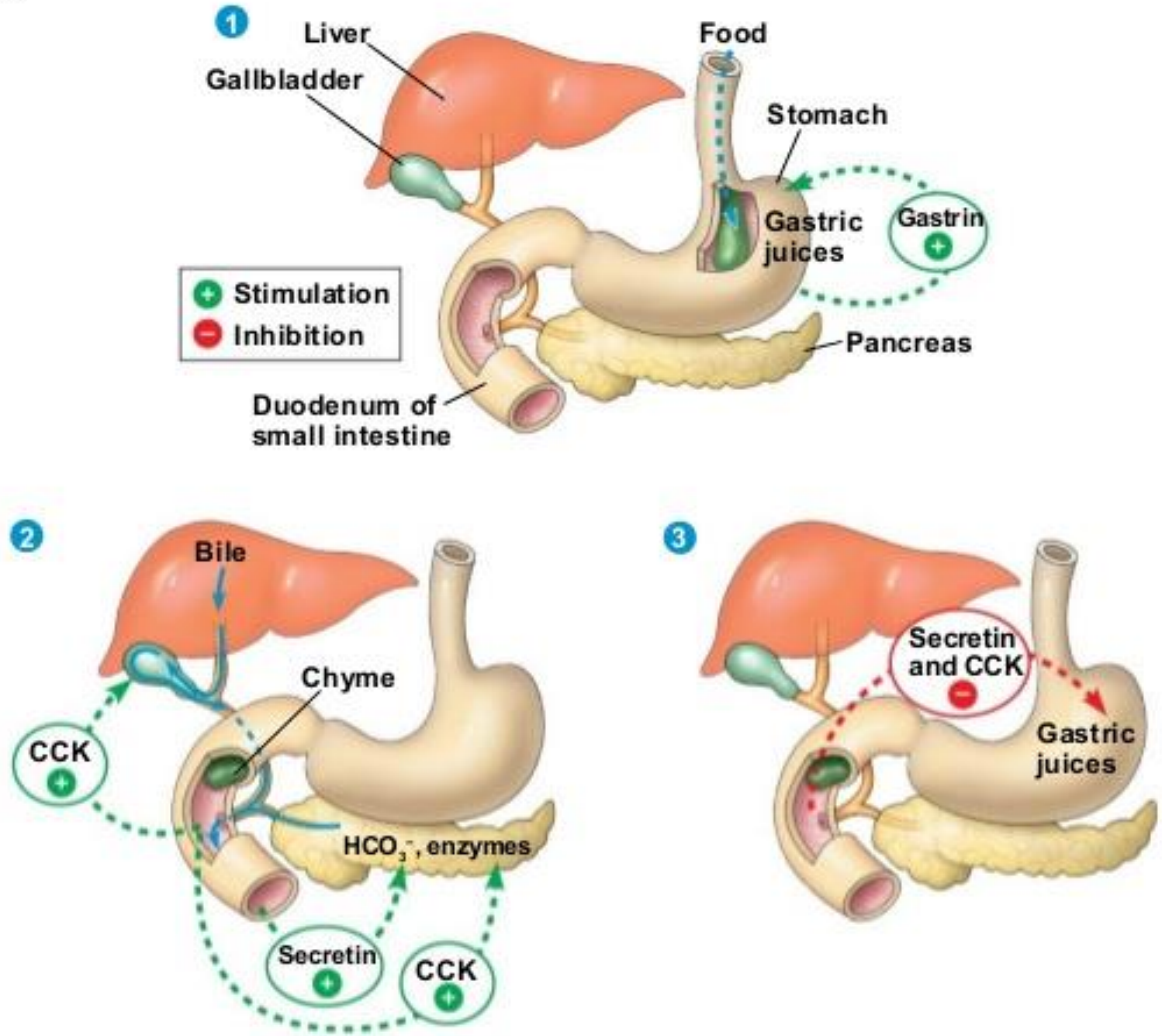


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Figure 33.17a

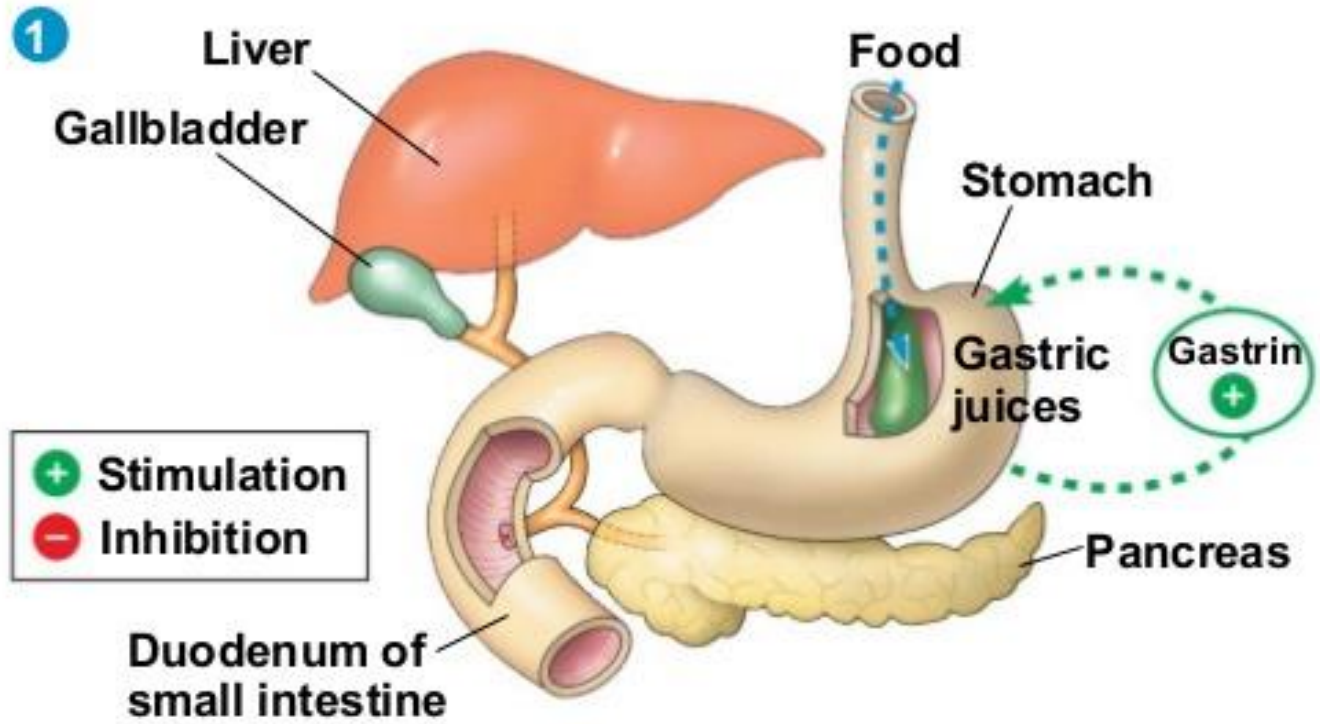

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Figure 33.17b

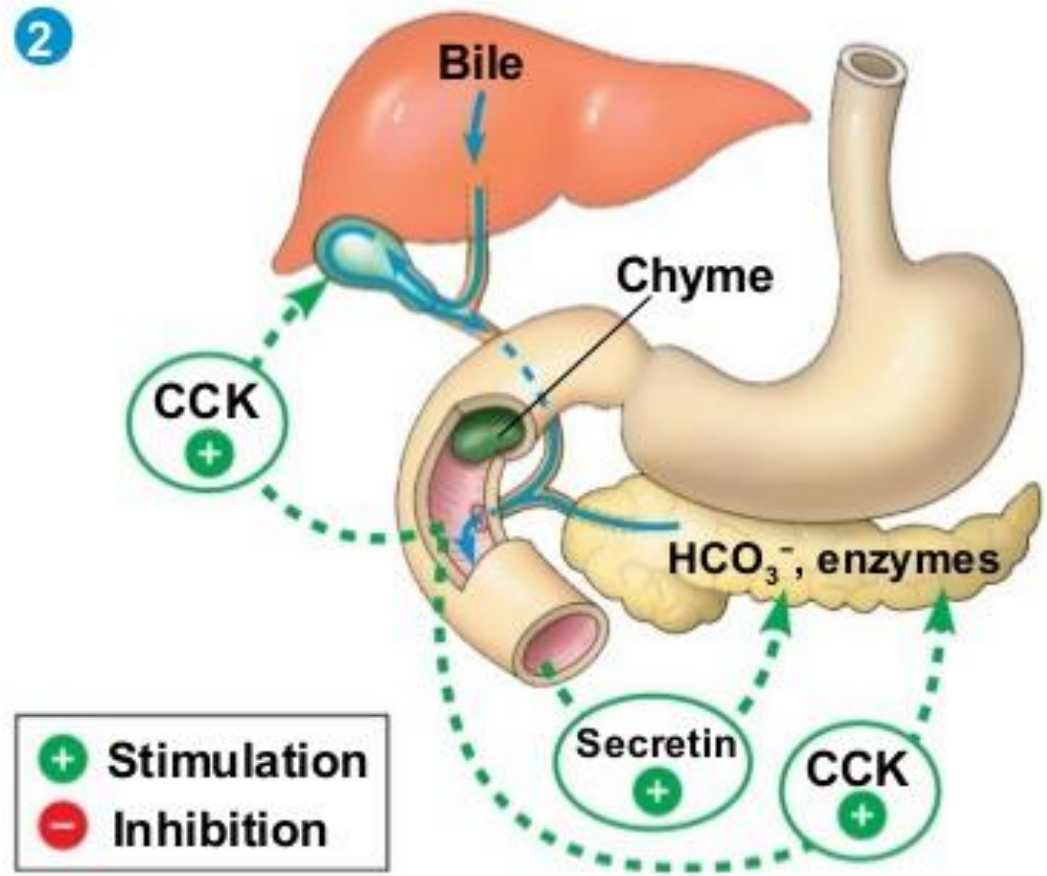

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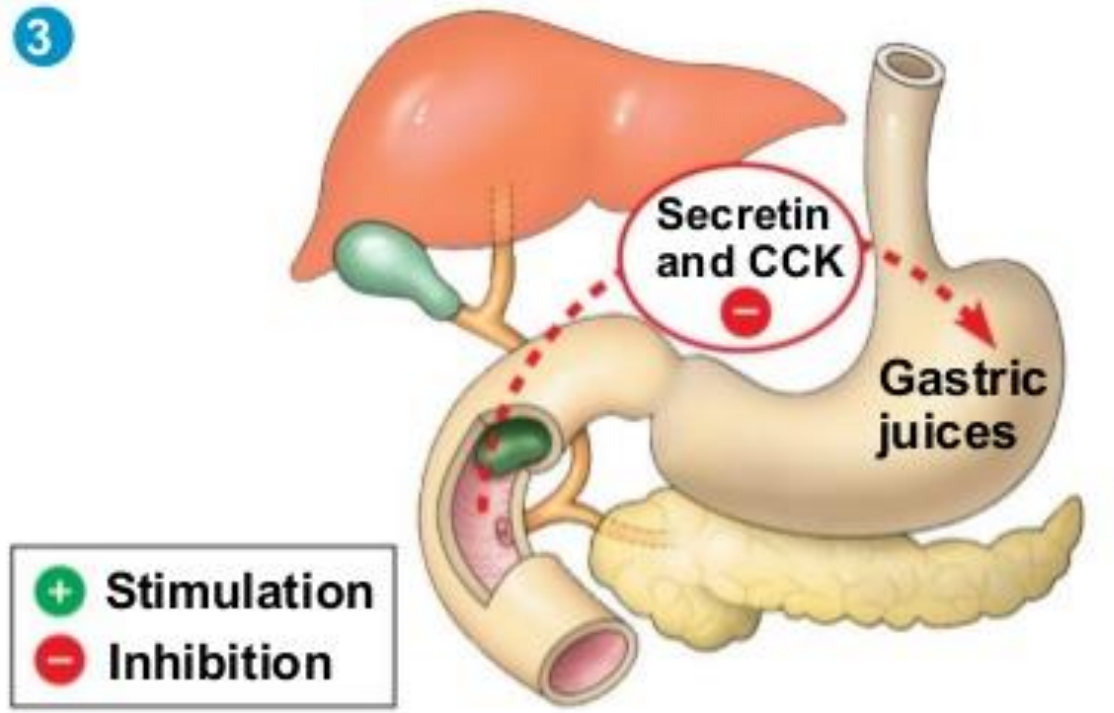
Figure 33.17c



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Homeostatic Regulation of Cellular Fuel

- After a meal is digested glucose is absorbed into the bloodstream
  - This in turn, raises blood glucose levels
- In between meals, blood glucose levels drop
  - Have you ever been “Hangry” before?
- The liver and pancreas work in concert to maintain stable levels of blood glucose

Homeostatic Regulation of Cellular Fuel

- ***Insulin*** is secreted when blood glucose levels are high
  - like right after eating
    - It stimulates the uptake of glucose by cells, especially liver and muscle cells, and adipose tissue
    - It lowers blood glucose levels

- ***Glucagon*** is secreted when blood glucose levels are low – in between eating
    - Glucagon targets the liver and adipose tissue
    - It stimulates the liver to break down glycogen to glucose
    - It raises blood glucose levels

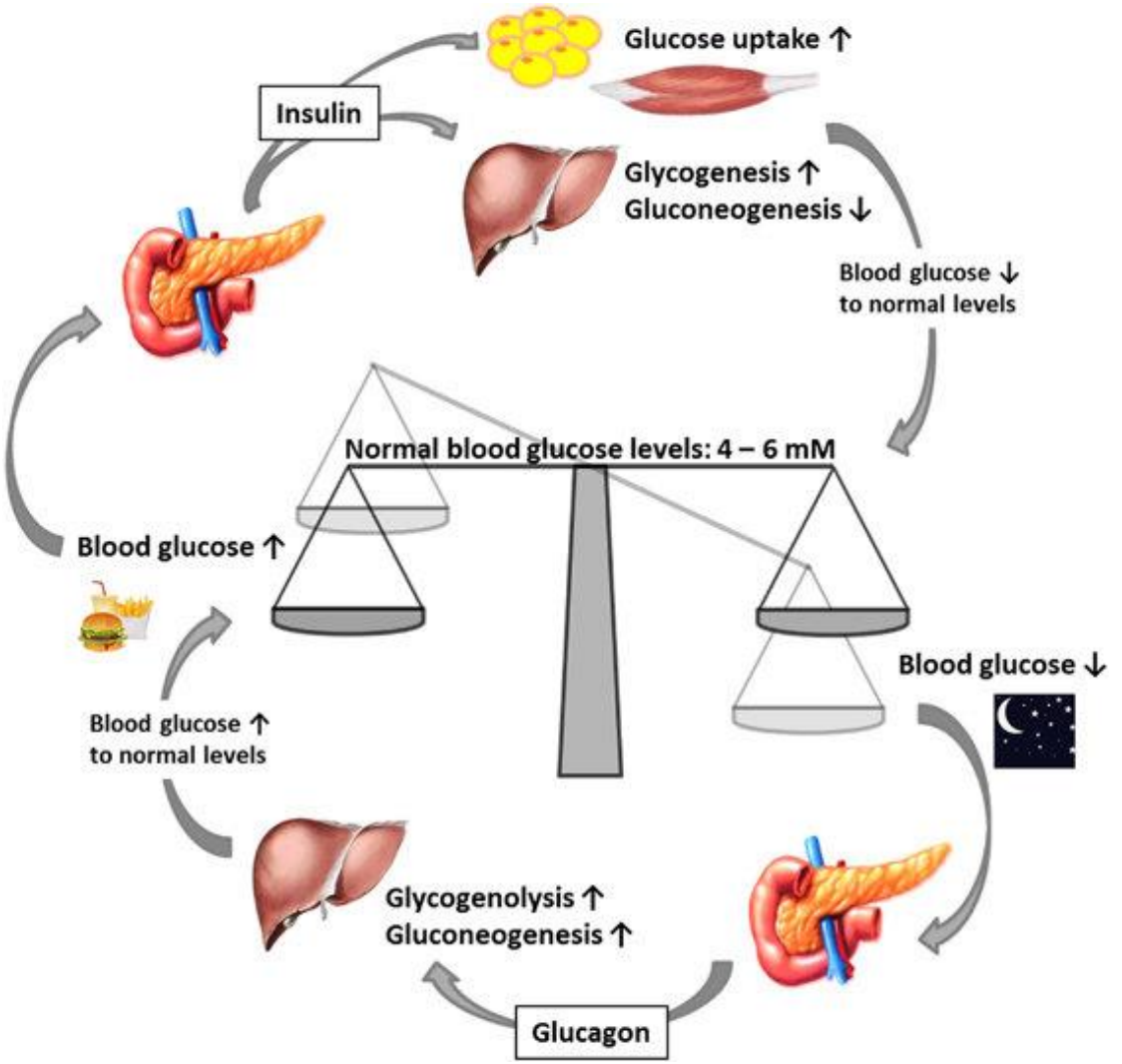
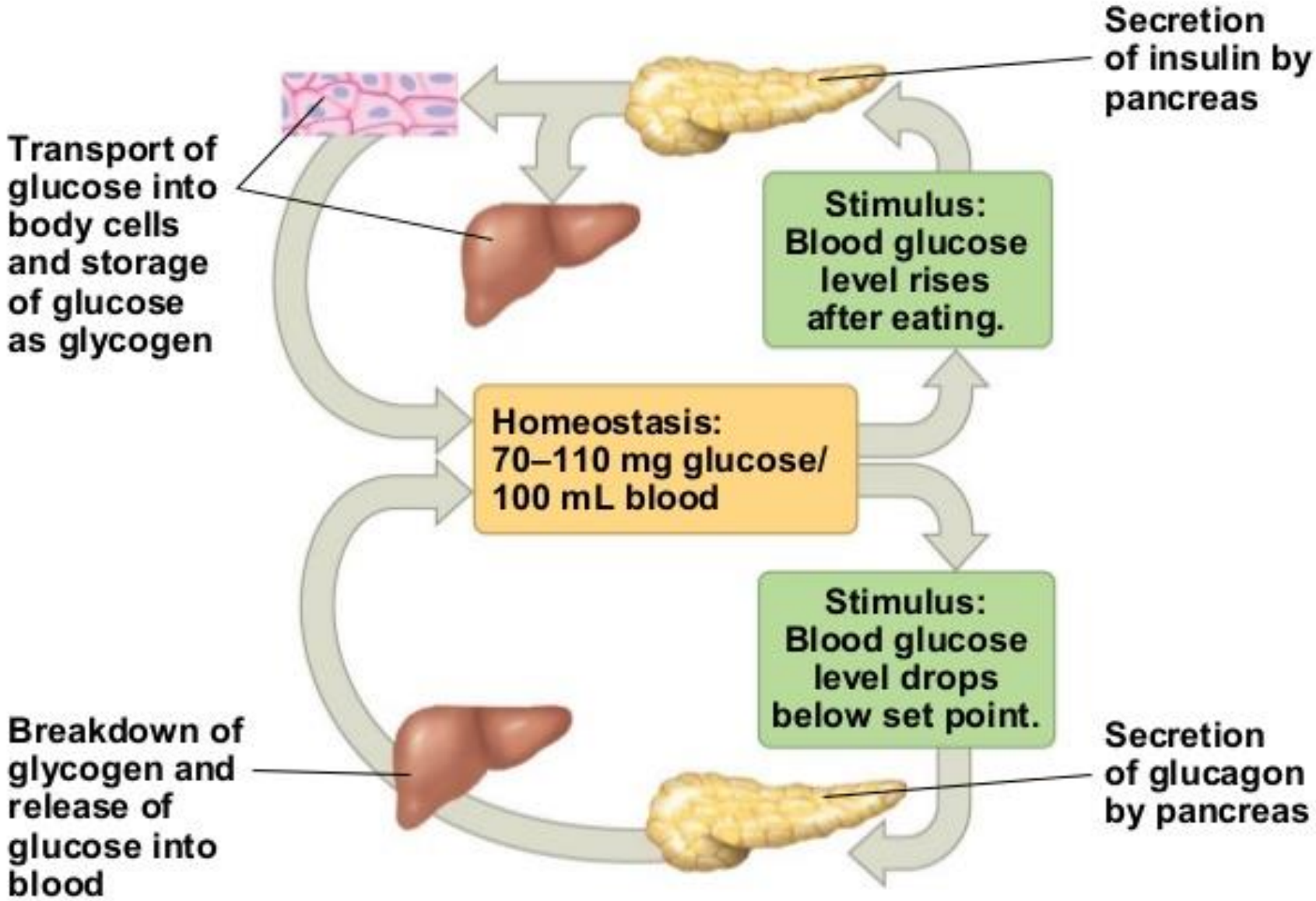


Figure 33.19



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Your Assignment:

- Do the Digestive System Review in preparation
- There will be 5 questions on the Digestive System on our Human Anatomy & Physiology Assessment!