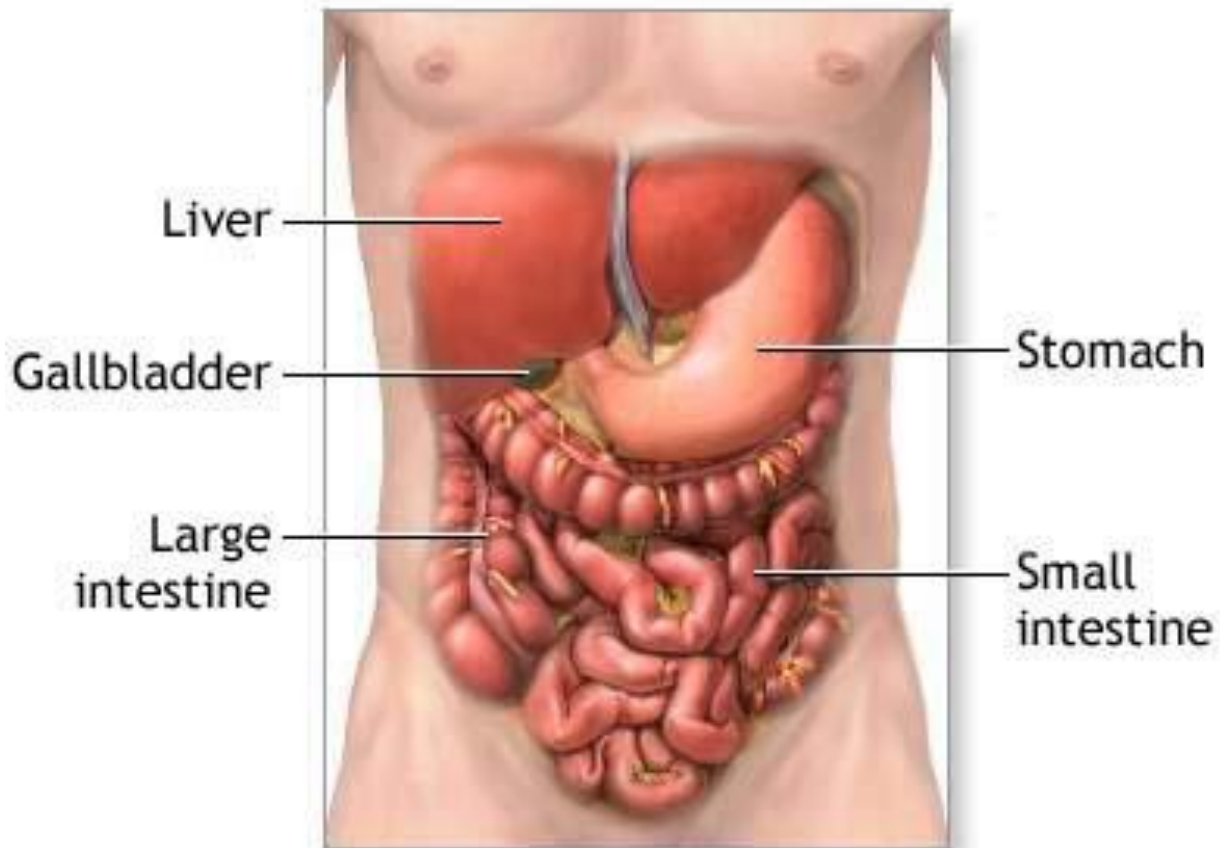


Biology 12

Ch. 11 Digestive System



Overview/Objectives

- **14.1- The digestive tract**

- General structure
- Two main types of digestion
- Path of food and functions of digestive organs
- What happens to indigestible material

- **14.2- Three accessory organs**

- Three main accessory organs that assist in the digestive process
- How each organ contributes to digestion

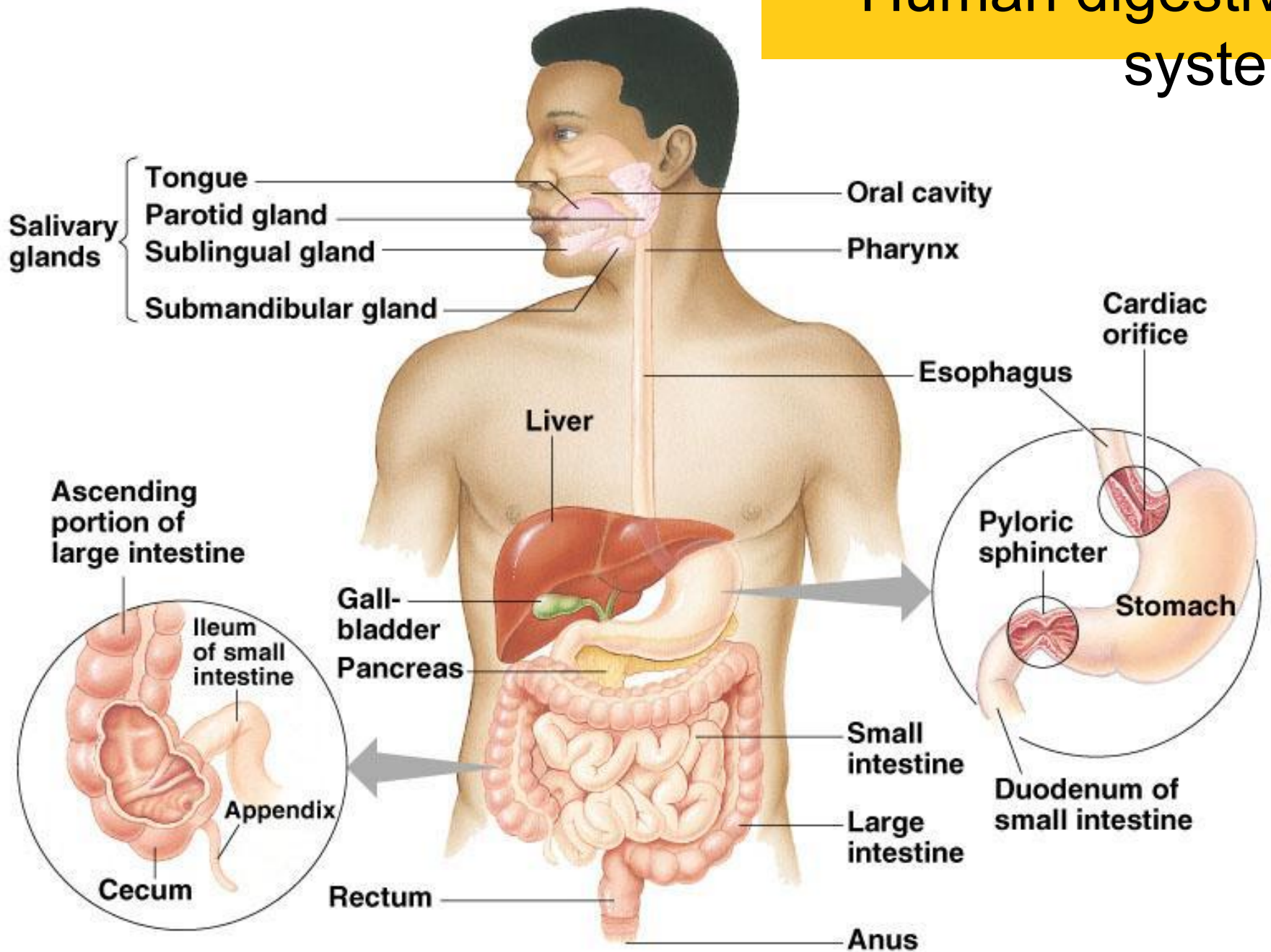
- **14.3- Digestive enzymes**

- Nutrient molecules absorbed in digestion
- Main digestive enzymes and their functions

- **14.4 Glucose Levels in the blood**

- Relationship between pancreas and liver

Human digestive system



GI (gastrointestinal) tract

14.1 The Digestive Tract

Functions of the Digestive System:

1. Ingest
2. Digest (break down to nutrients)
3. Absorb
4. Eliminate (indigestible remains)

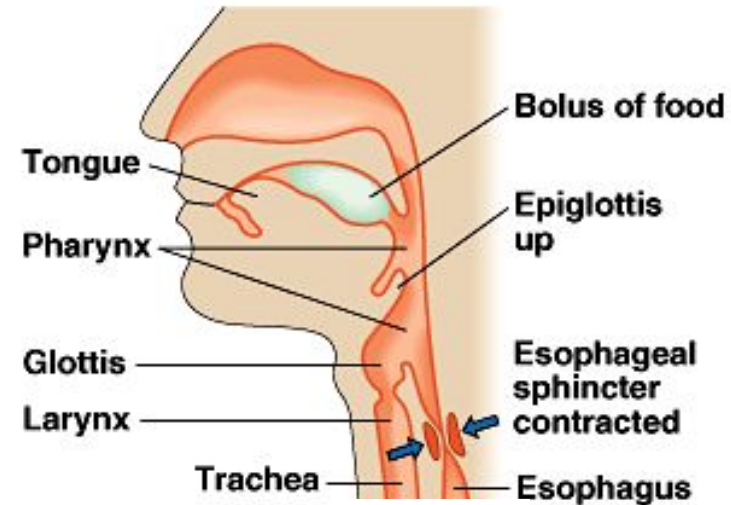
Digestion involves 2 main processes:

1. **Mechanical** digestion (chewing/mouth, churning/stomach)
2. **Chemical** digestion (enzymes further breakdown food)

Ingestion

1. The Mouth

- mechanical digestion
 - teeth
 - breaking up food
- chemical digestion
 - saliva
 - Salivary amylase
 - » enzyme digests starch
 - mucin
 - » slippery protein (mucus)
 - » protects soft lining of digestive system
 - » lubricates food for easier swallowing
 - buffers
 - » neutralizes acid to prevent tooth decay
 - anti-bacterial chemicals
 - » kill bacteria that enter mouth with food



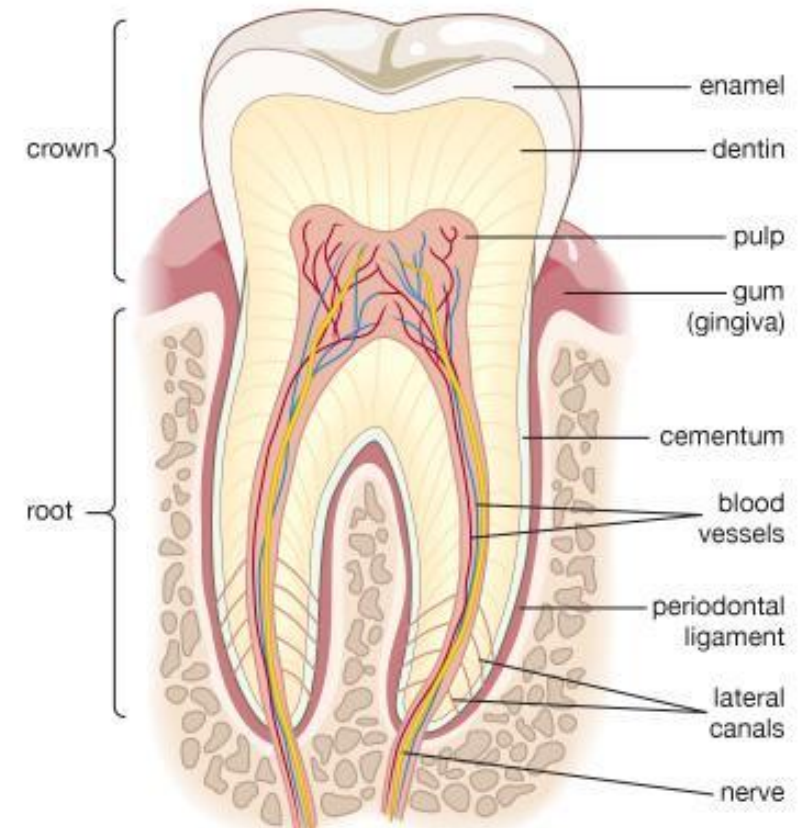
A Quick Look into Your Mouth

- **Chemical and mechanical digestion.**
 - **Lips & Cheek**= externally bound mouth
 - **Taste buds**= sensory receptors; send nerve impulses to the brain
 - **Tongue**= composed of skeletal muscle; mixes chewed food with saliva to create **bolus**
 - **Palate**= roof of mouth; separates nasal cavity from oral cavity. Two plates: 1. Anterior (hard) and 2. Posterior (soft)
 - **Salivary glands**= three pairs; produce saliva for mouth

A Quick Look into Your Teeth

Teeth □ mechanical breakdown

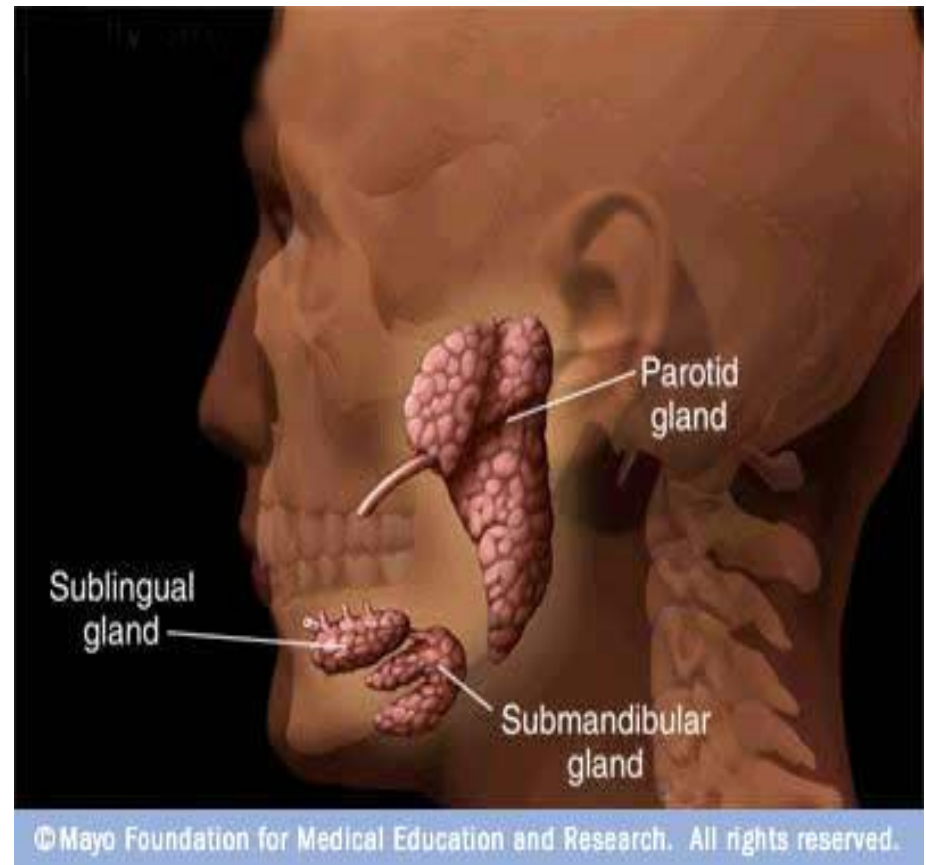
- Each tooth has 2 main divisions: **crown and root**
 - **Enamel:** hard outer calcium covering of the crown
 - **Inner pulp:** contains nerves and blood vessels
- **Dental caries (cavities):** occur when bacteria within mouth metabolizes sugar and give off acid □ teeth erode



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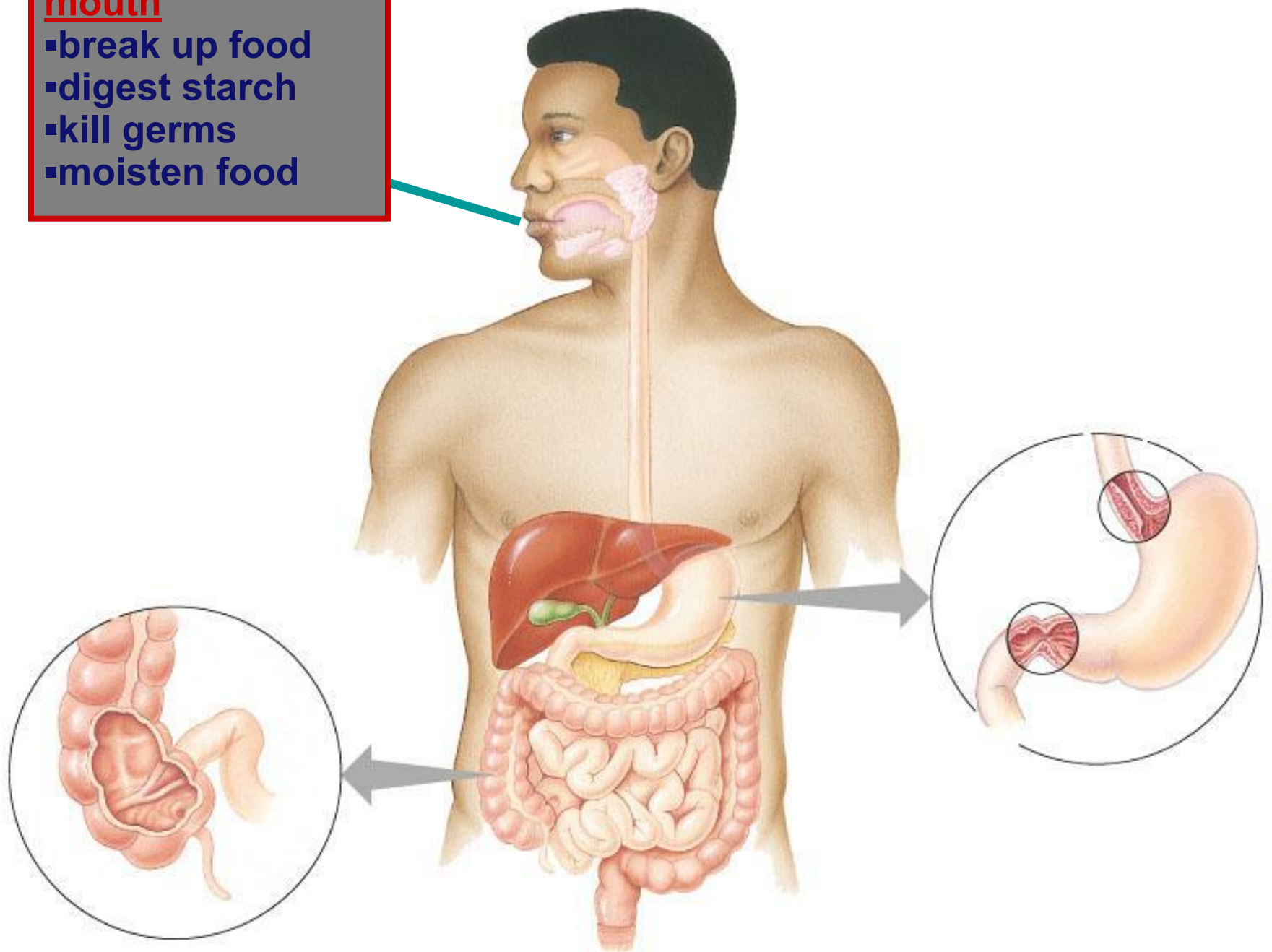
Digestive/Salivary Glands

- Groups of specialized **secretory** cells.
- Produce **saliva**

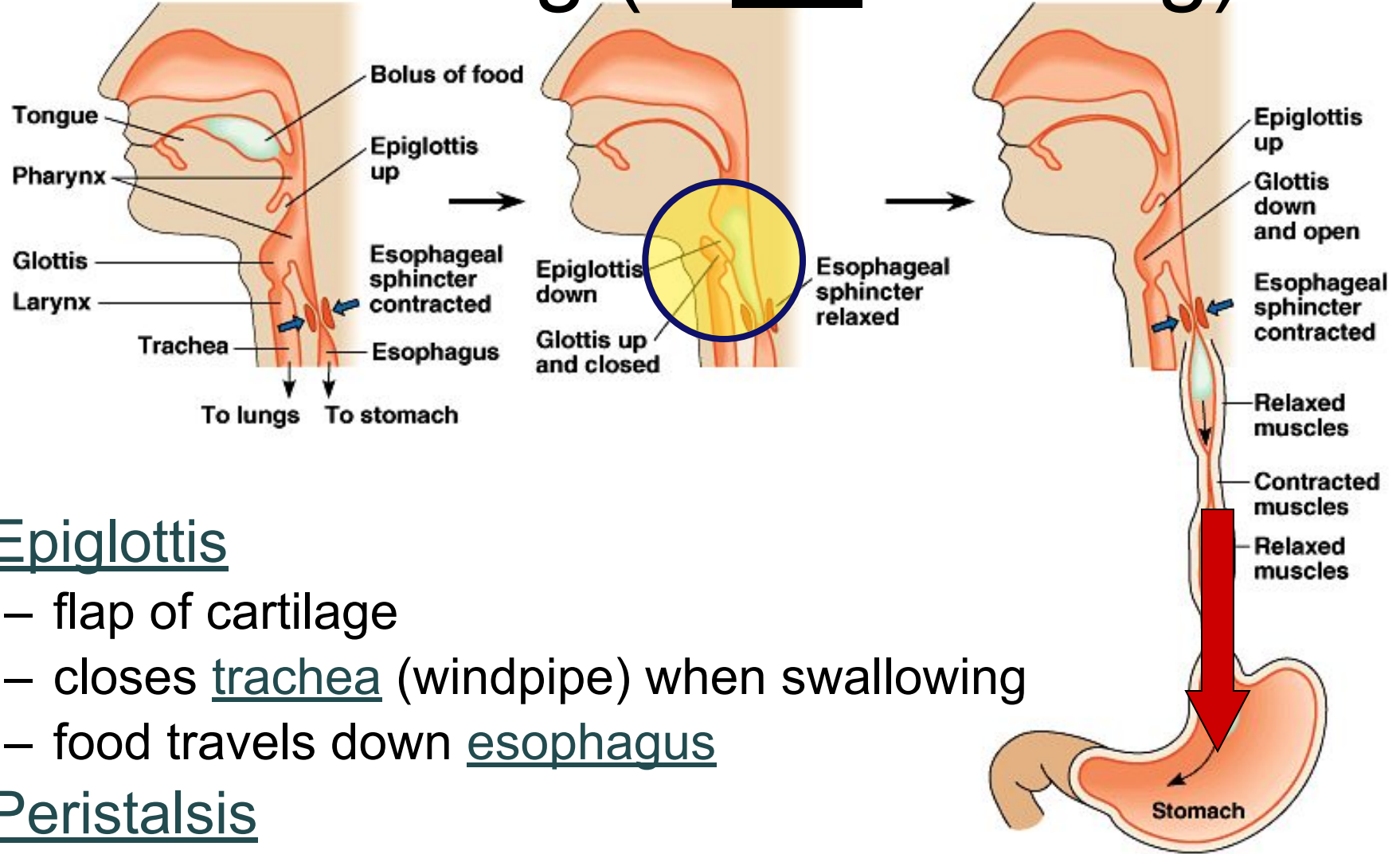


mouth

- break up food
- digest starch
- kill germs
- moisten food



Swallowing (& not choking)

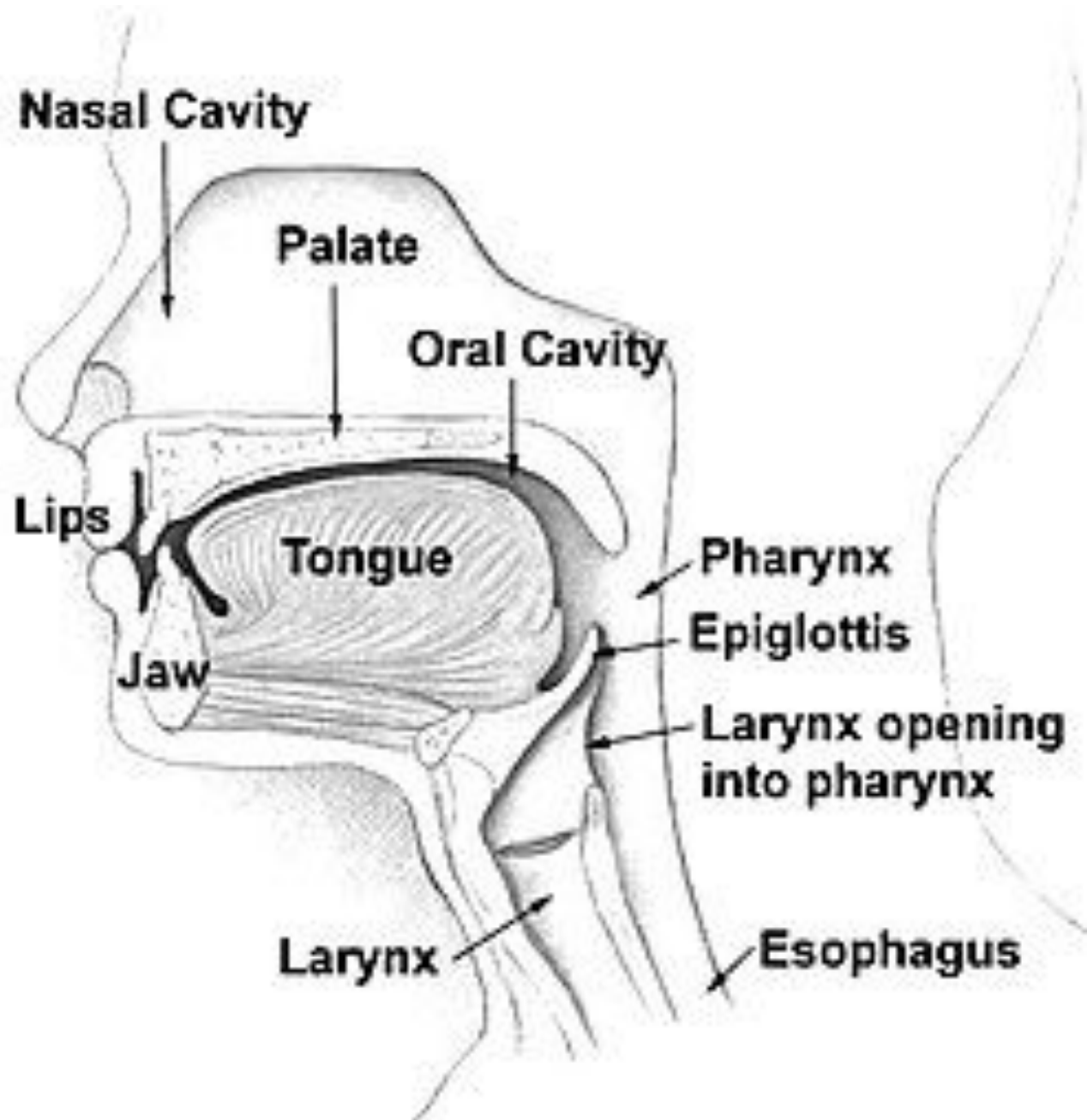


- Epiglottis

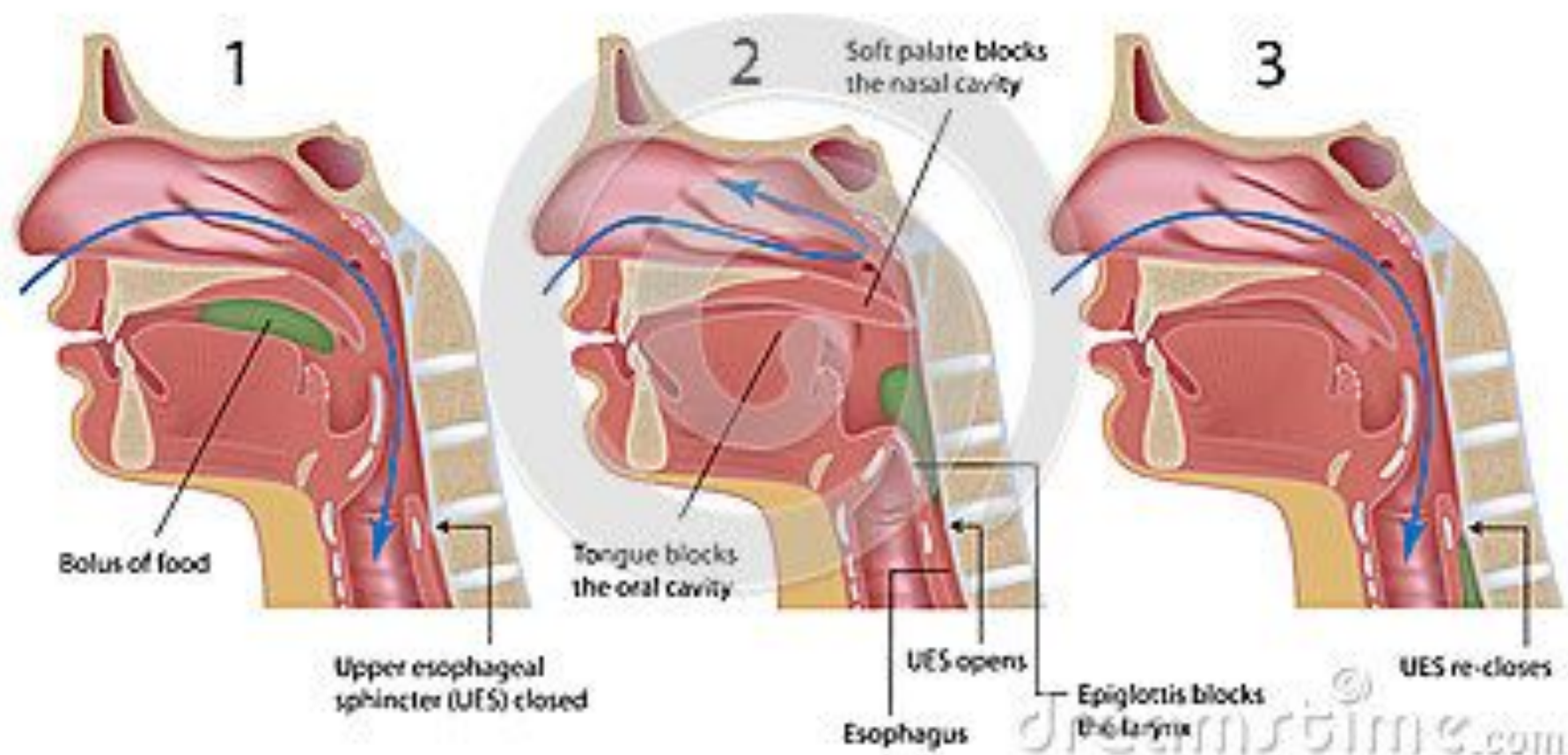
- flap of cartilage
- closes trachea (windpipe) when swallowing
- food travels down esophagus

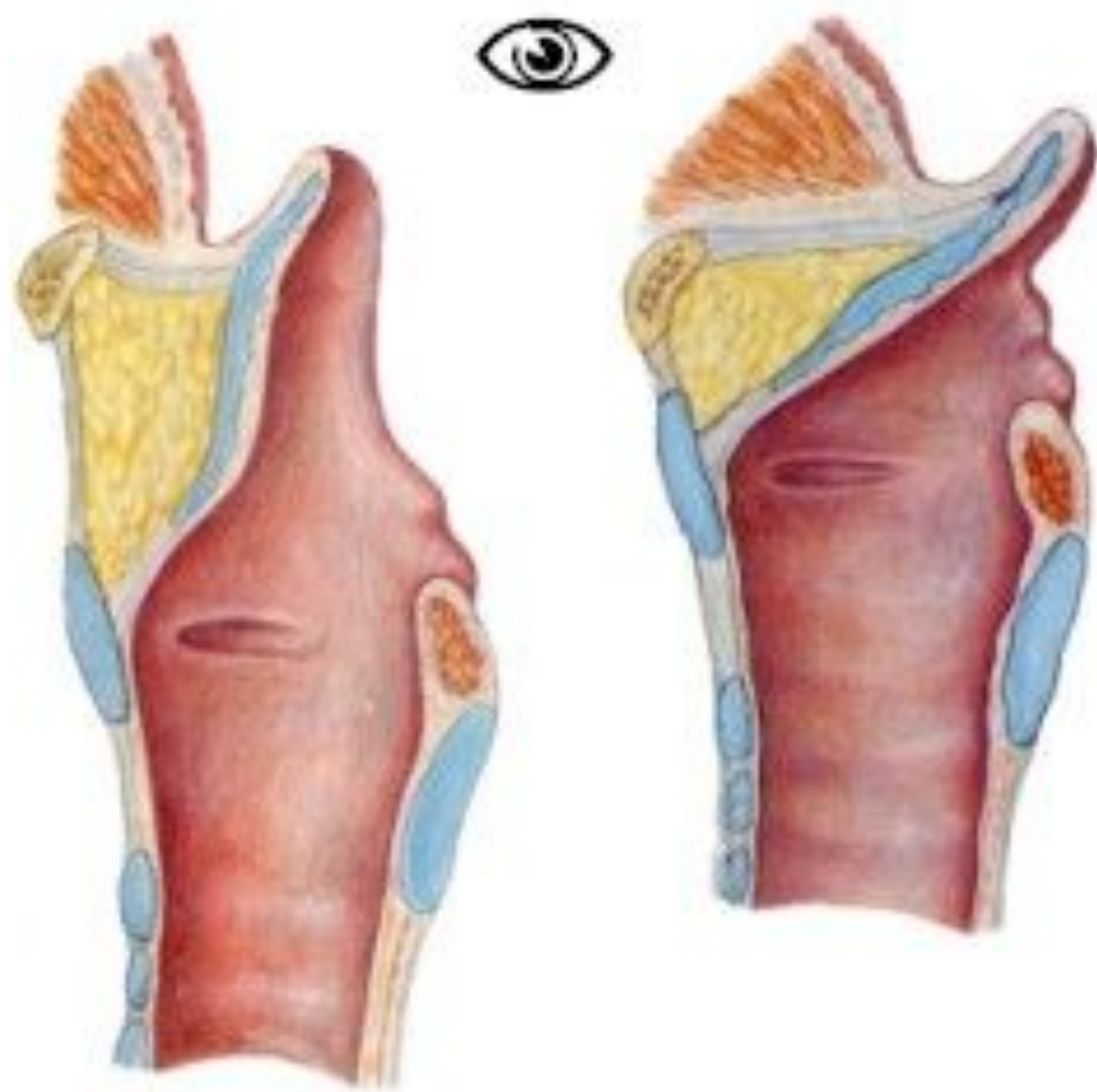
- Peristalsis

- involuntary muscle contractions to move food along



Swallowing



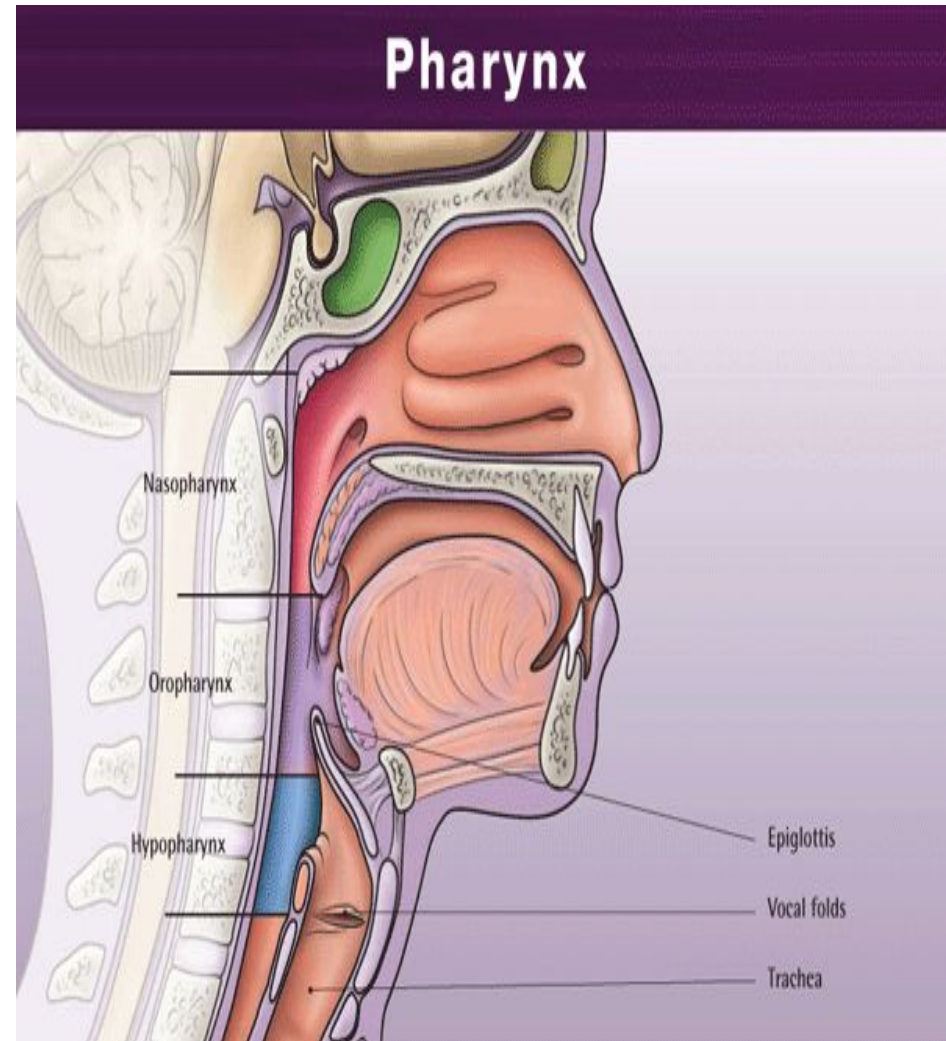


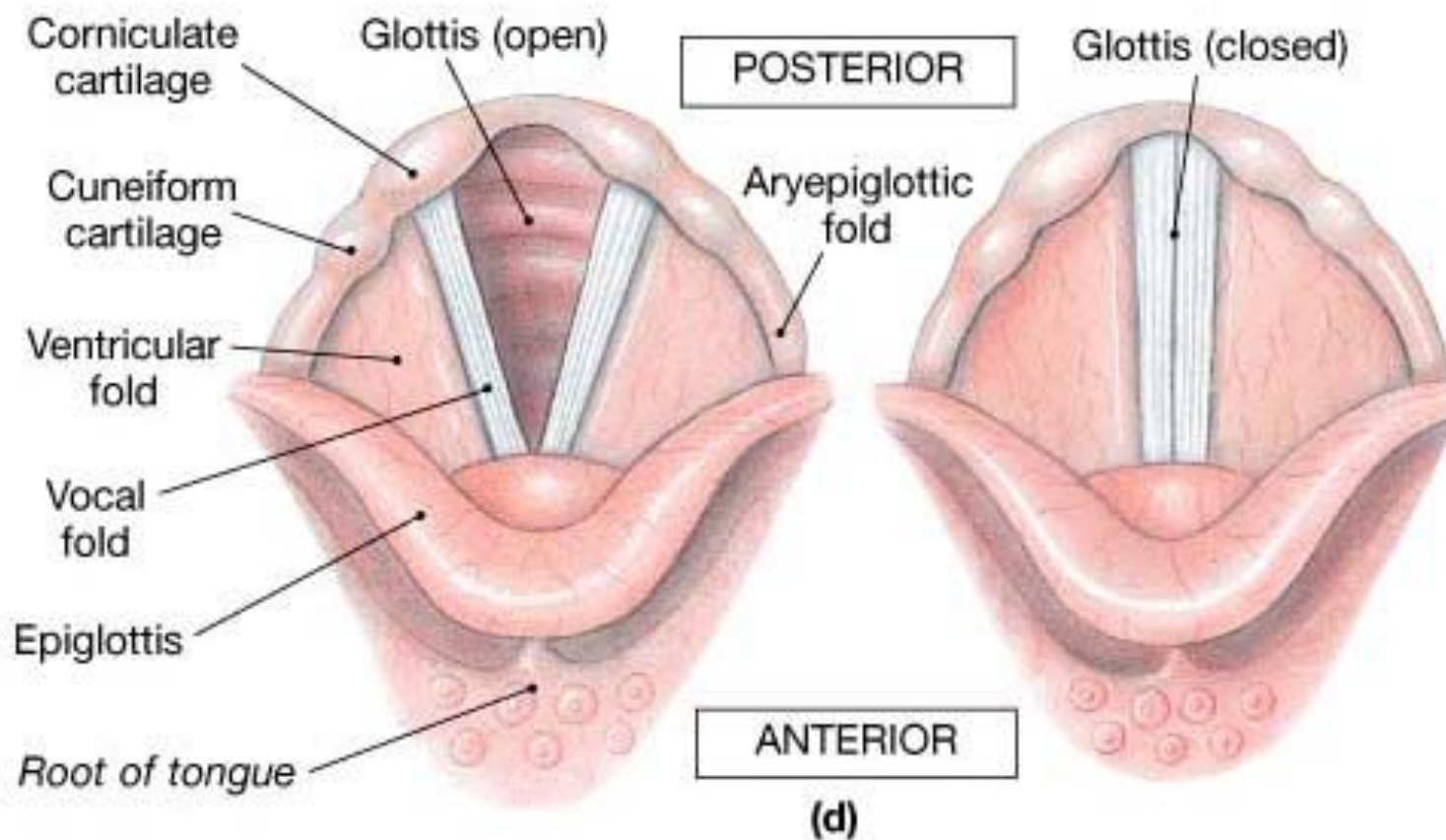
Which type of digestion is the following?

1. Chewing a saltine? - **Mechanical**
2. Saliva breaking the saltine down into molecules of glucose? - **Chemical**
3. Your tongue breaking pieces of a hamburger apart?
Mechanical
4. Pepsin (an enzyme) in your stomach breaking the hamburger into amino acids?
Chemical

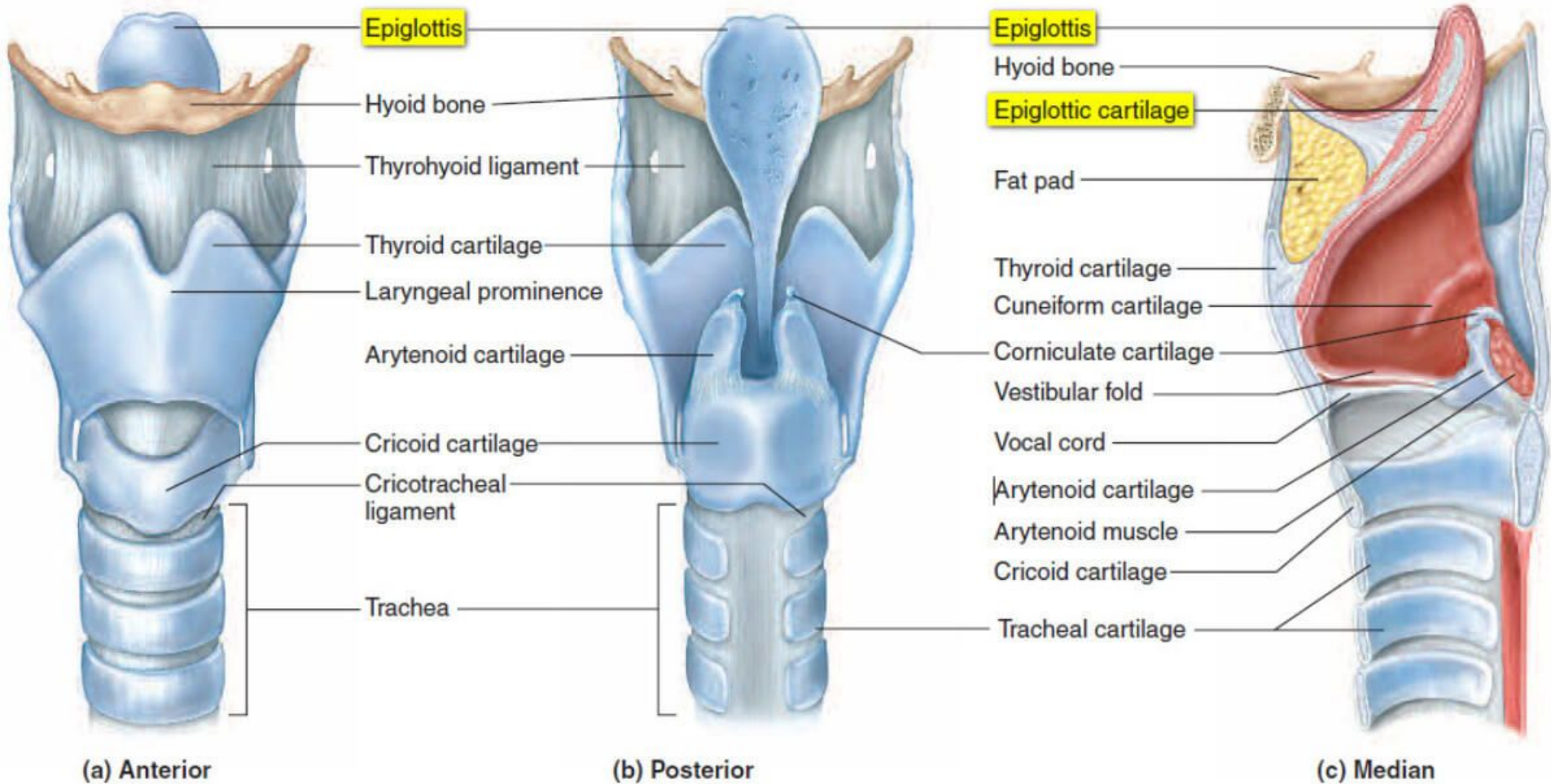
2. Pharynx

- Receives air from nasal cavity and food from mouth
- Where swallowing occurs (**reflex action**)
- Food is prevented going down the trachea by the **epiglottis**



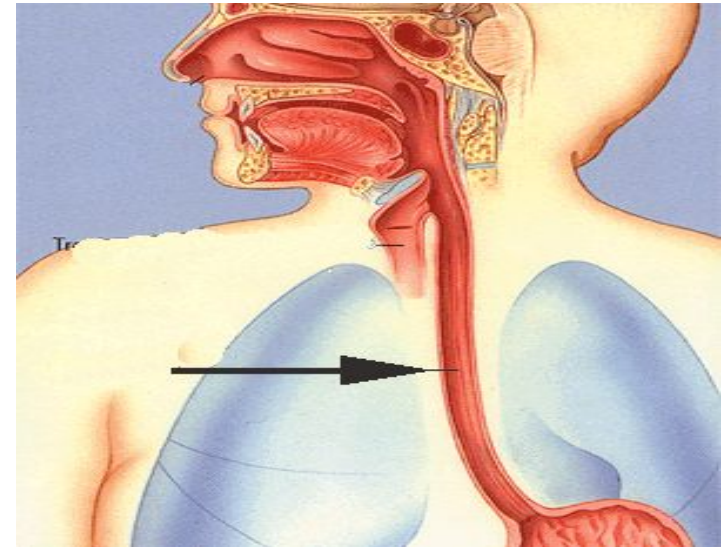


• **FIGURE 23-4 Anatomy of the Larynx.** (d) Diagrammatic superior view of the larynx with the glottis open and closed.



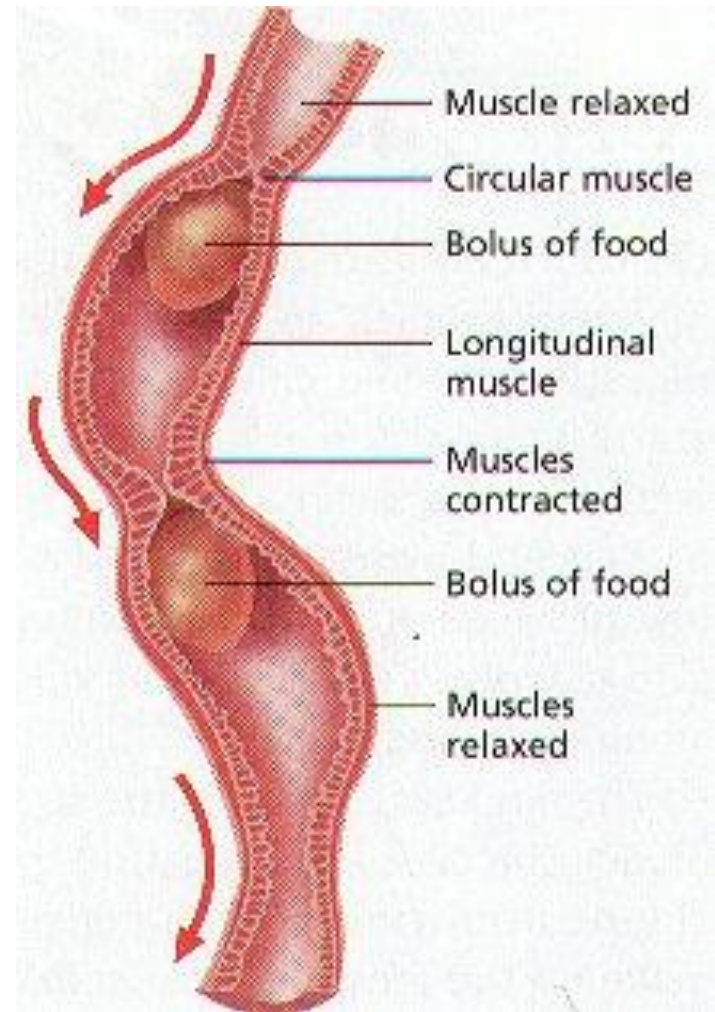
3. Esophagus

- Muscular tube, passes from pharynx to stomach
- Ordinarily collapsed, opens to receive bolus when swallowing occurs
- Function □ transport food bolus from mouth to stomach ***No chemical breakdown***

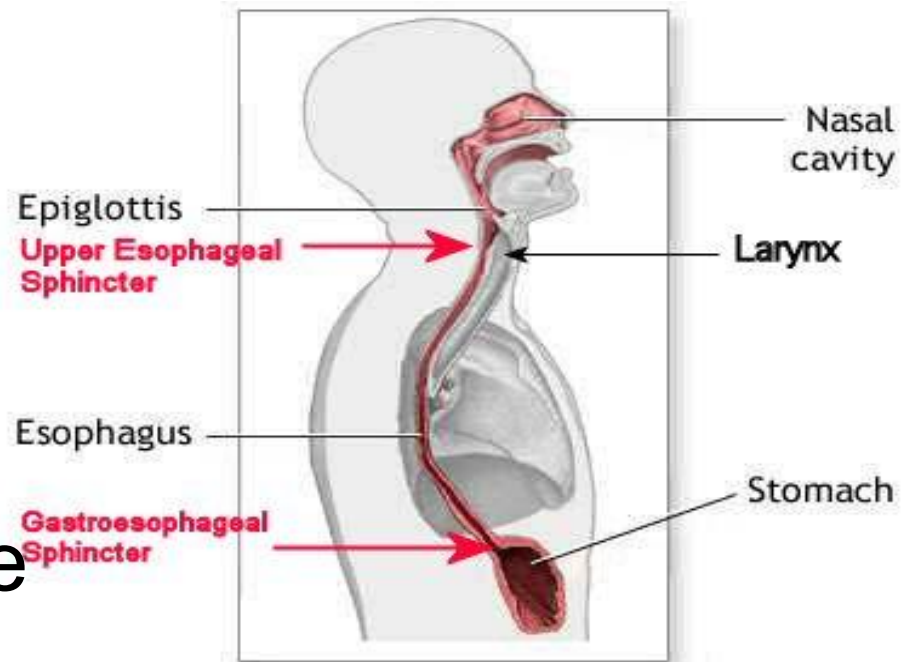


Peristalsis

- series of involuntary wave-like muscle contractions which move food along the digestive tract



Sphincters



- Muscles that encircle tubes and act as valves
- Relaxation of sphincter allows bolus to pass into stomach
- Contraction of sphincter prevents acid from stomach backing up into esophagus (**Heartburn**)

Taking the Heart Out of Heartburn

The esophagus has a ring of muscles at the top and bottom. If the bottom ring of muscles doesn't keep the lower part of the esophagus tightly closed between swallows, acid from the stomach can come back up into the esophagus. This creates a burning sensation called *heartburn*, but it has nothing to do with the heart. The pain a person may feel is in the area of the heart, but it would make more sense to call it esophagus-burn!





4. Stomach

- Food is temporarily stored here (about 4-6 hours).



- **Stomach** □ **Gastric juices** are secreted.



Stomach

- Has layers of muscle that line the inside (□ peristalsis).
- **Mechanically and chemically** breaks down food. (Ridges break down food physically)



Stomach

- Functions (in details)

1) food storage

- can stretch to fit
~2L food

2) disinfect food

- HCl = pH 2
–kills bacteria

mucus secreted by stomach cells protects stomach lining

Stomach


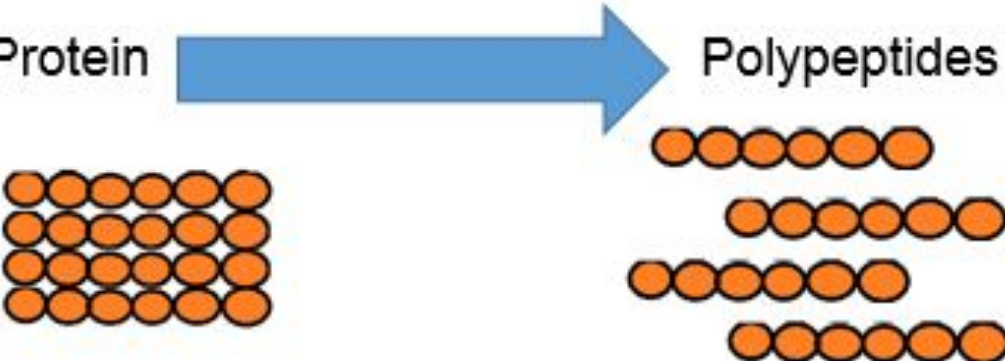




3) chemical digestion

- pepsin

- enzyme breaks
down proteins into
peptides



PROTEIN DIGESTION PROCESS

DIGESTION SITE	ENZYME	PROCESS
STOMACH	Pepsin	<p>Protein </p> <p>Polypeptides</p> 
DUODENUM	Trypsin (by Pancreas)	<p>Polypeptides </p> <p>Peptides</p> 
SMALL INTESTINE	Erepsin	<p>Peptides </p> <p>Amino Acids</p> 

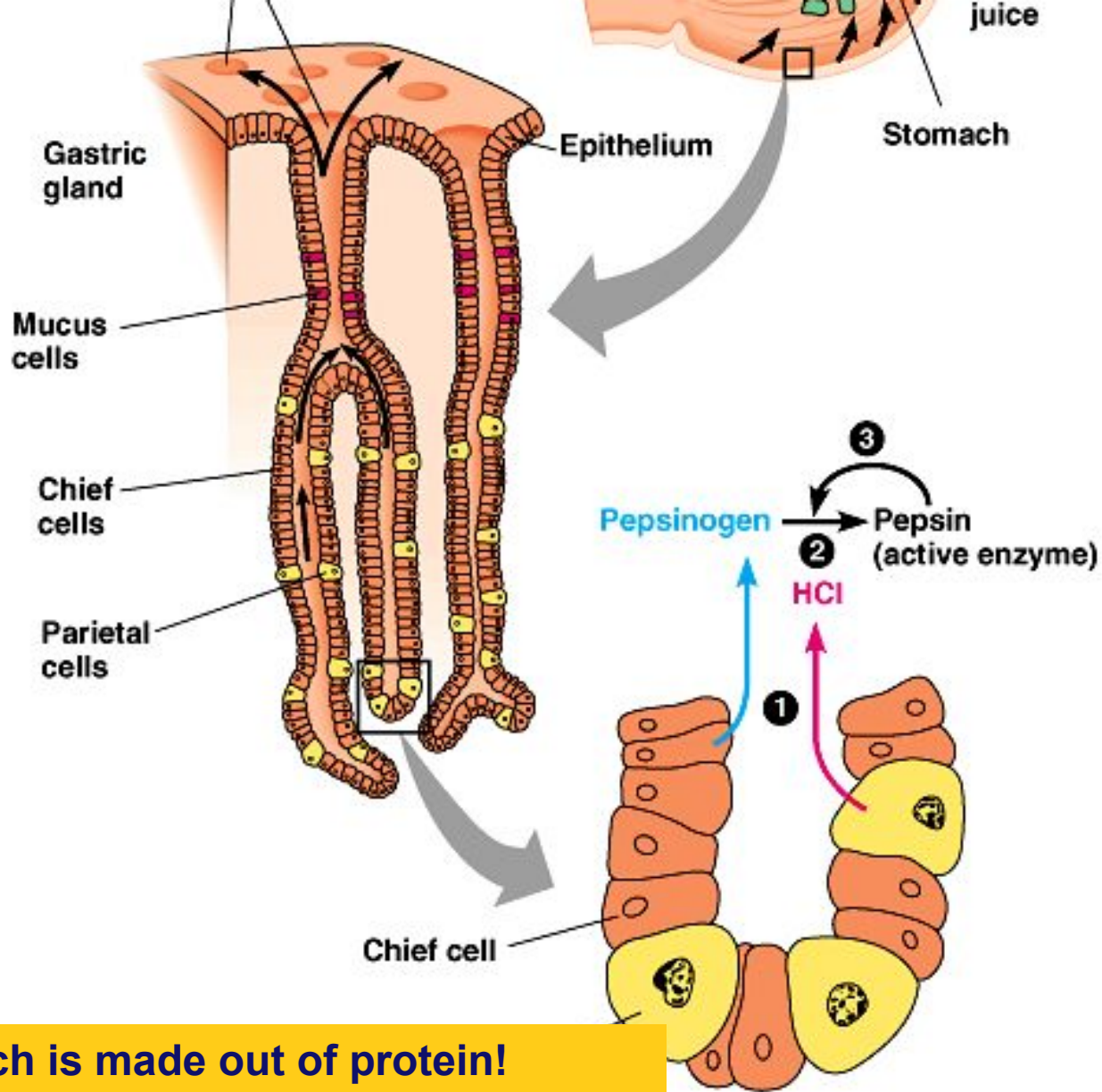
Stomach

But the stomach is made out of protein!

What stops the stomach from digesting itself?

mucus secreted by stomach cells protects stomach lining

- Pepsinogen and HCl
- ----- □ pepsin



**But the stomach is made out of protein!
What stops the stomach from digesting itself?**

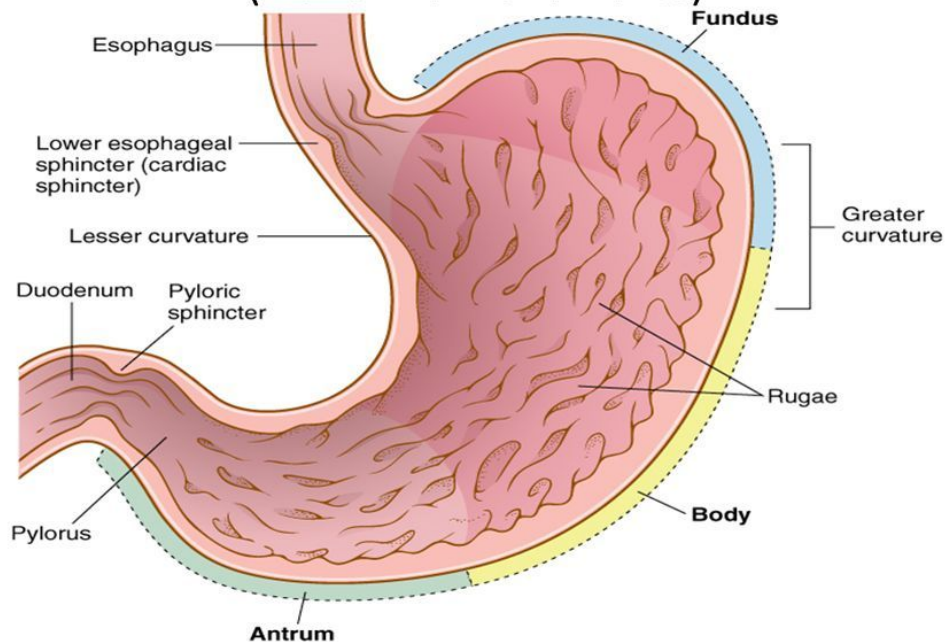
**mucus secreted by stomach cells protects
stomach lining**

Stomach

- Functions

4) physical digestion – stomach ridges

Parts of the Stomach
Food travels through the digestive tract by **peristalsis**
(wave like movements)



Physical digestion – stomach ridges

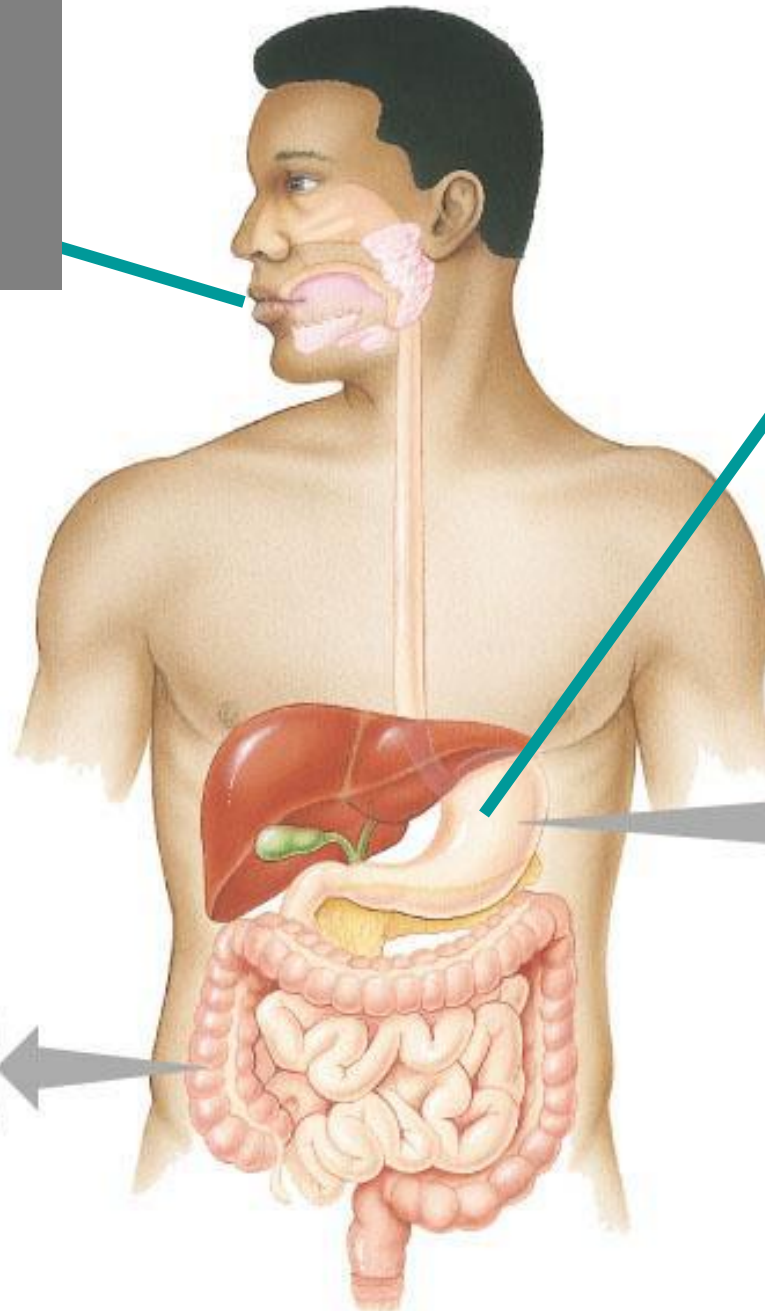


mouth

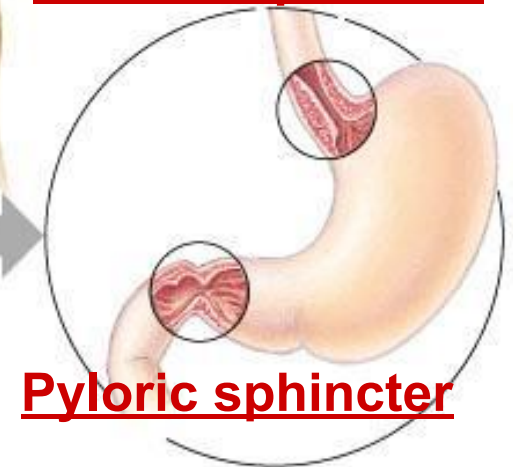
- break up food
- digest starch
- kill germs
- moisten food

stomach

- kills germs
- break up food
- digest proteins
- store food



Cardiac sphincter



Pyloric sphincter



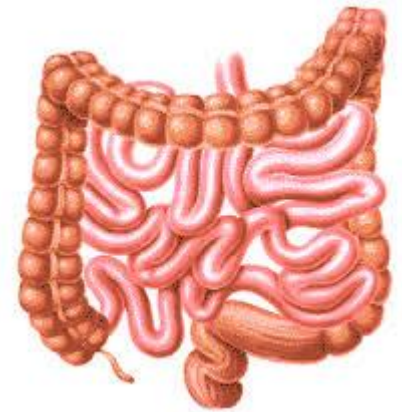
Gastric Juices (recap)

- Secreted by the stomach
- Acidic (pH 1.5-2.5) = **HCl**
- **Pepsin**- an enzyme that breaks down large proteins into amino acids
- Food is further broken down into a thin liquid called **chyme**



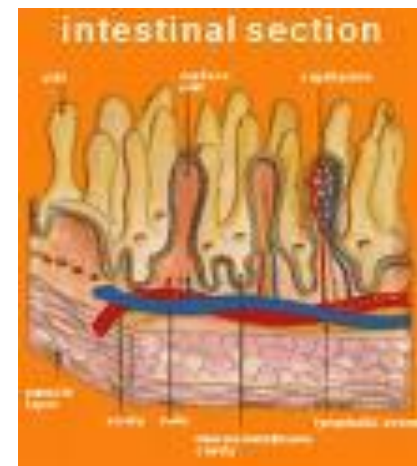
The Intestines

- After **chyme** exits the stomach through the **Pyloric sphincter**, it enters the longest section of the digestive system
- Two parts:
 1. Small Intestine=
2.5 cm in diameter, but 4-6 m long!
 2. Large Intestine=
6 cm in diameter and 1.5 m long



5. Small Intestine (S.I.) functions

- Most **chemical digestion** takes place here (main digestive organ)
- Simple **sugars** and amino acids (**proteins**) are absorbed into the inner lining.
- Lined with **villi** which increase surface area for absorption



Small Intestine

- **Functions:** 1) chemical digestion
 - major organ of digestion & absorption

Summary of Chemical Digestion (more later)

Mouth- begins to breakdown **carbohydrates**
(starch \square maltose)

Stomach- begins to breakdown **proteins**
(proteins \square peptides)

Small Intestine- completes breakdown of **carbohydrates, proteins and fats** into monomers (single units) that can be absorbed

Small Intestine

- **Functions**

2) absorption through lining (villi)

- over 6 meters!
- small intestine has huge surface area = 300m^2 (~size of tennis court)

3) peristalsis

- moves chyme through S.I.
- Takes 3-6 hours

Small Intestine

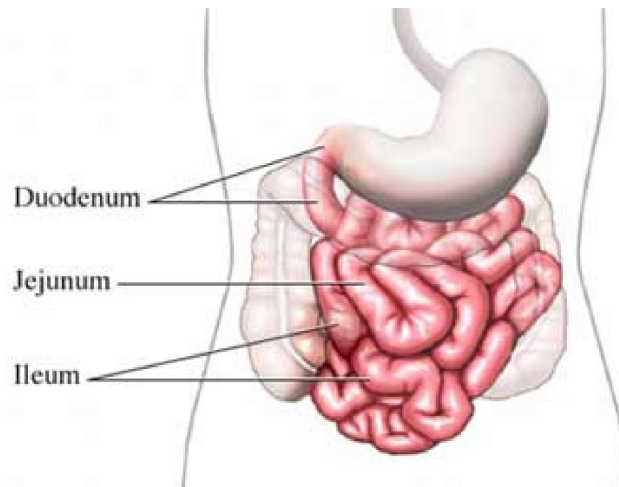
- **Structure**

3 sections:

1) duodenum = most digestion

2) jejunum = absorption of nutrients & water

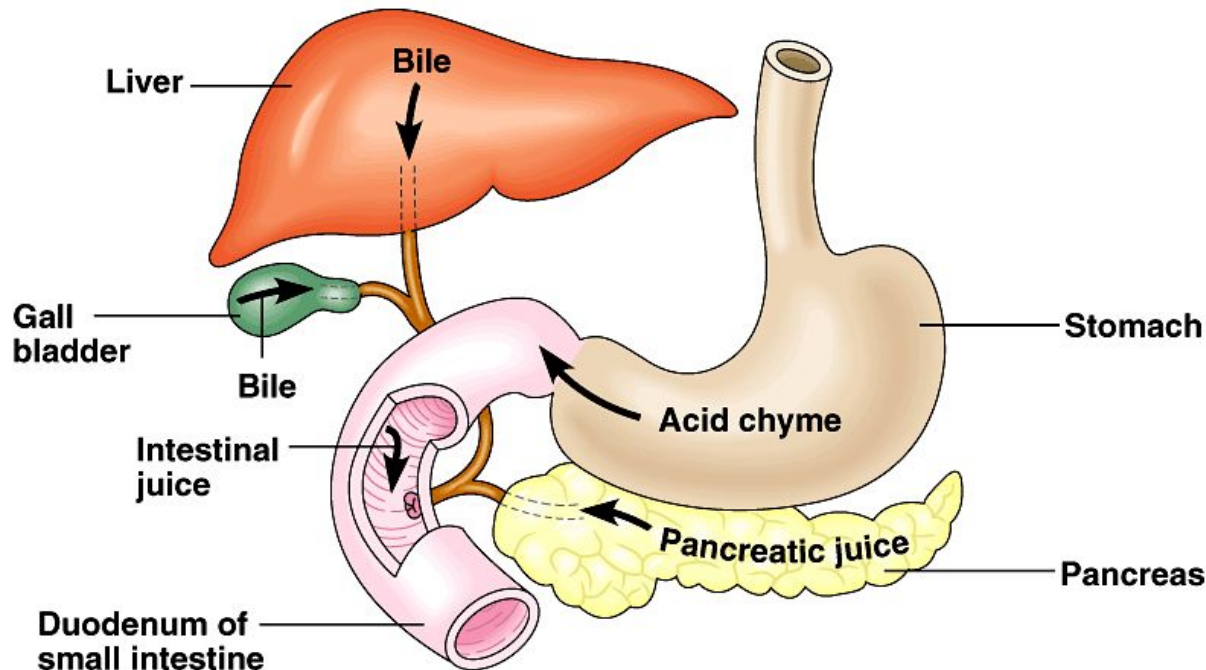
3) ileum = absorption of nutrients & water



Duodenum

- 1st **6 inches** section of small intestines
 - Receives acidic chyme from stomach
 - mixes with digestive juices from:

- pancreas
- liver
- gall bladder



Small Intestine- Digestive Juices

- Some enzymes are produced by the wall of the S.I.
- Other organs add fluids to the SI:
 - **Pancreas:** adds enzymes and a buffer to neutralize the HCl from the stomach and enzymes (Sodium Bicarbonate)
 - Changes pH from 3.5 □ 8.5

Small Intestine- Digestive Juices

– Liver: adds bile

- green fluid, breaks down fat
- produced in liver
- stored in **gall bladder**
- not an enzyme, but essential for fat digestion
- breaks large fat molecules into small droplets, increasing S.A. of fat molecule

Emulsification



Large oil drop



Small oil droplets

Absorption in the S.I.

(Jejunum and Ileum)

- Almost 90% of our daily fluid intake is absorbed in the small intestine.

Digestion **Absorption**

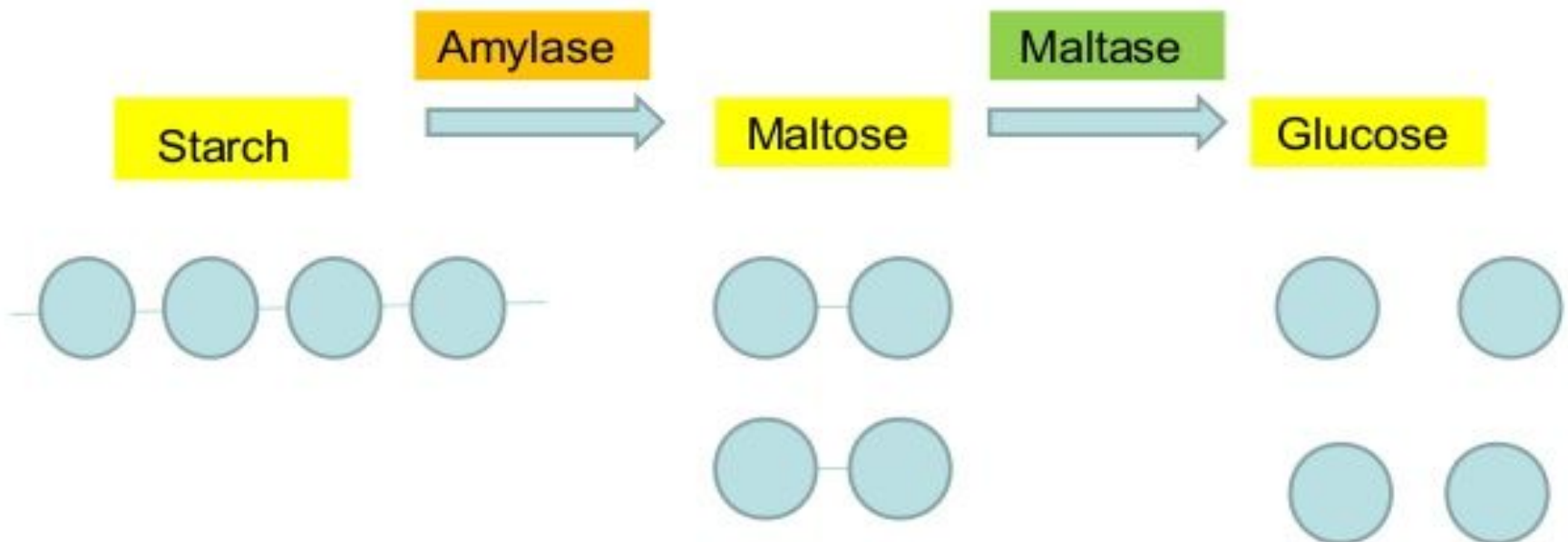
Carbohydrates

amylase, maltase

Starch **small (single) sugars**

Actions of Digestive Enzymes

- Glucose, the end product of carbohydrate digestion, is used for cellular respiration to release energy.



Absorption in the S.I.

(Jejunum and Ileum)


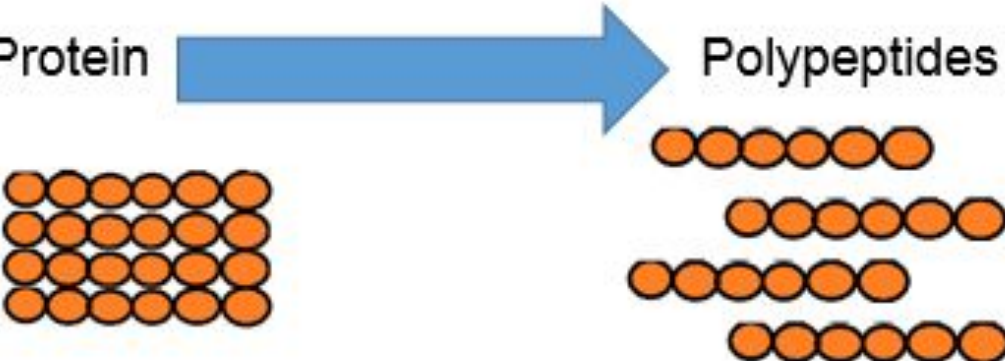




- Almost 90% of our daily fluid intake is absorbed in the small intestine.

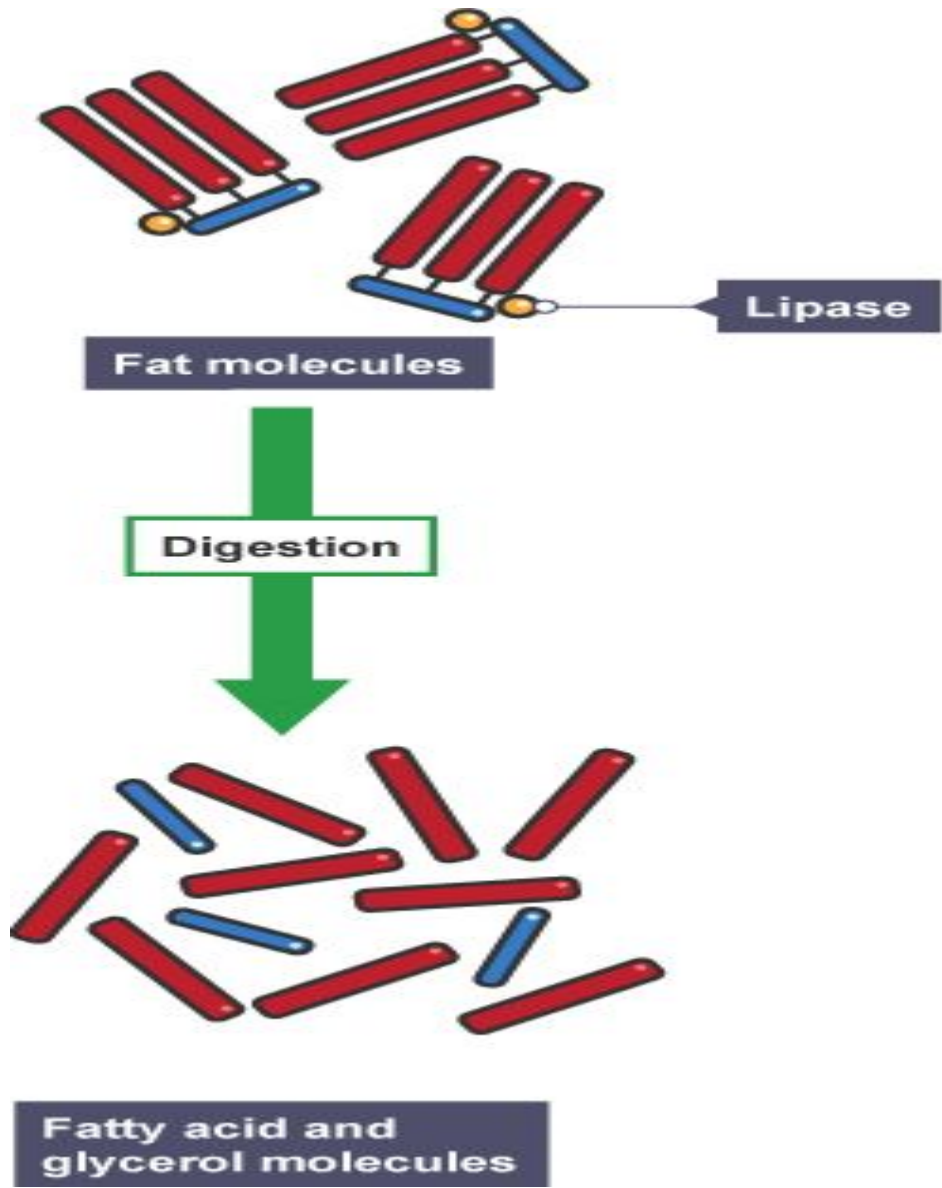
Digestion **Absorption**

pepsin, trypsin, peptidase

Protein **amino acids**

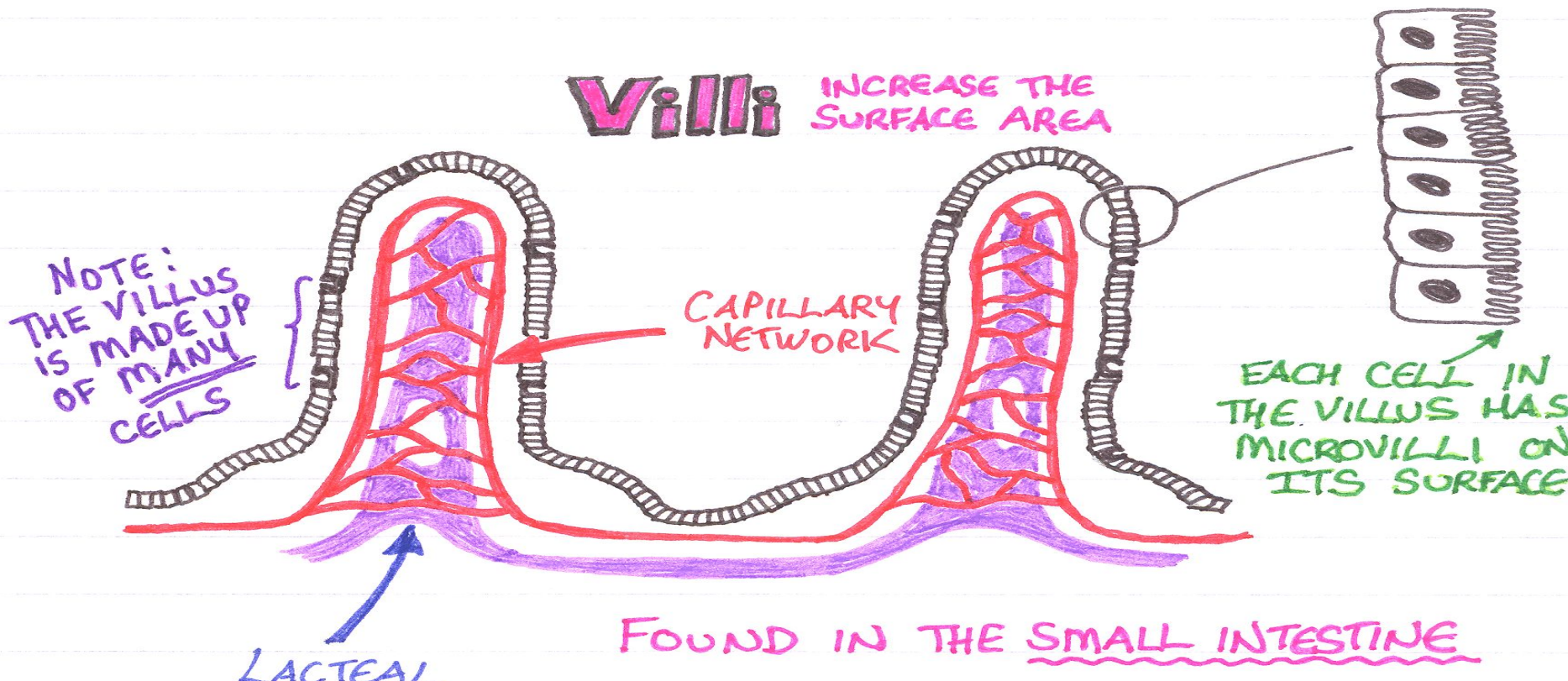
PROTEIN DIGESTION PROCESS

DIGESTION SITE	ENZYME	PROCESS
STOMACH	Pepsin	<p>Protein  Polypeptides</p> 
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SMALL INTESTINE	Erepsin	<p>Peptides  Amino Acids</p> 



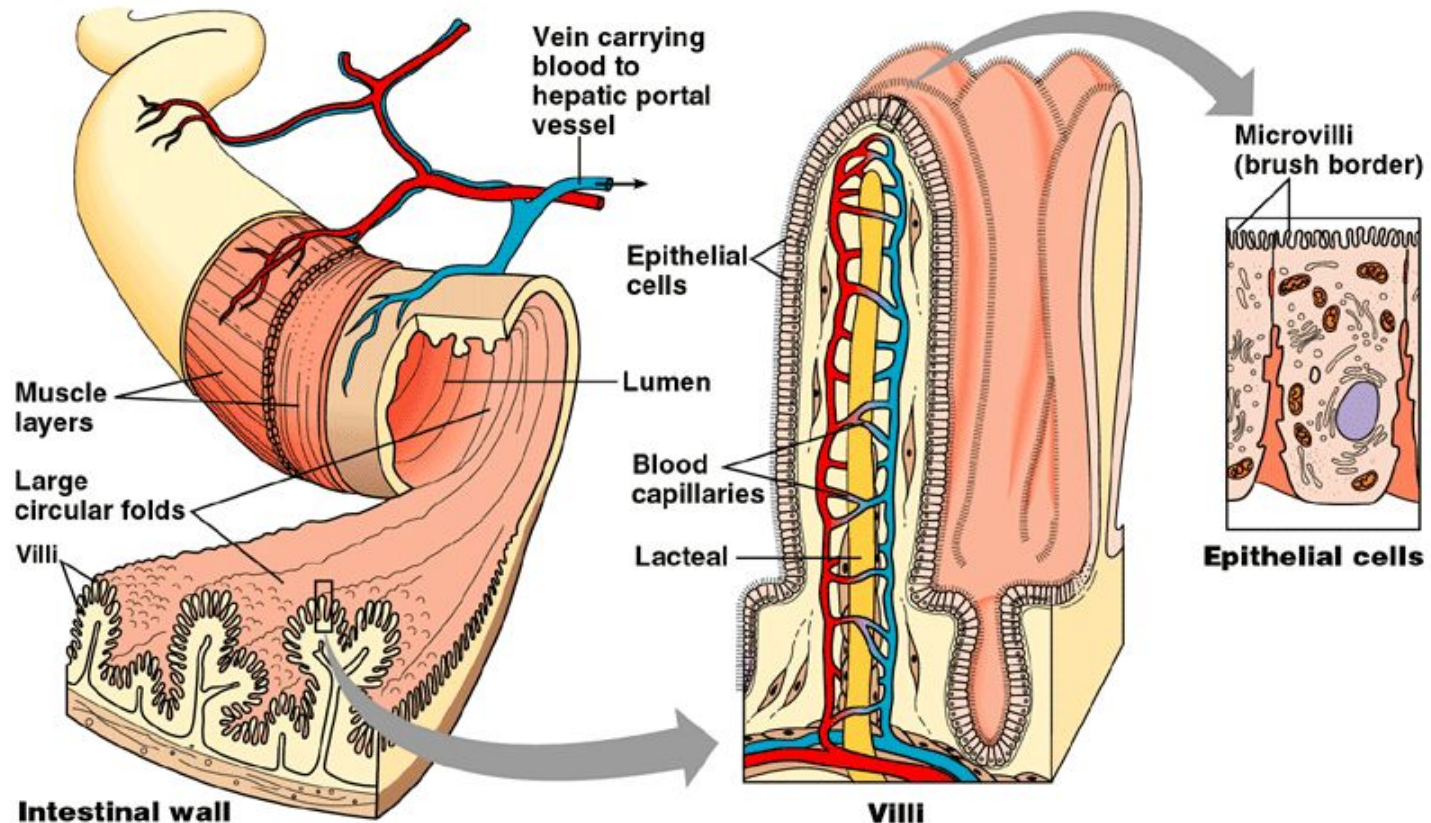
Absorption in the S.I. □

- By the end of the S.I. food molecules are small enough that they can be absorbed into cells (into blood capillary via villi)
- **Villi** - increase the surface area of the small intestines, thus providing better absorption of materials

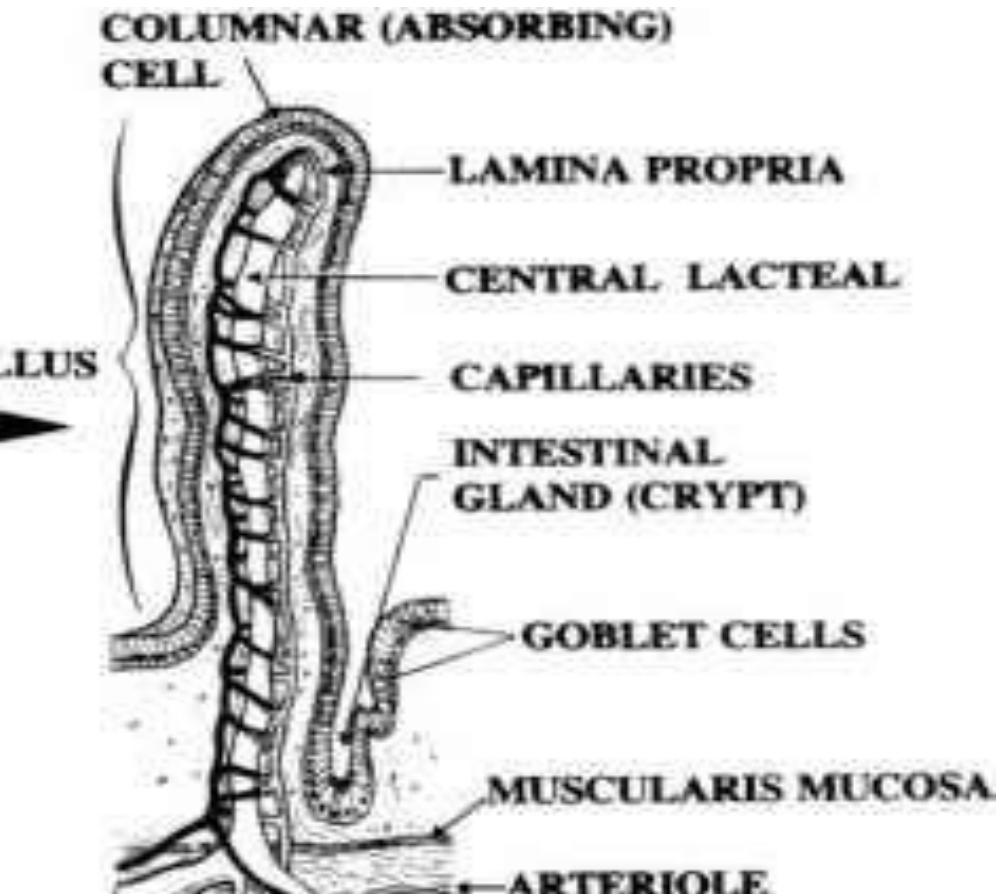


Absorption by Small Intestines

- Absorption through villi & microvilli
 - finger-like projections
 - increase surface area for absorption



Intestinal glands at the base of the villi (make maltase and peptidase) which finish digestion of carbohydrates and proteins



VILLI



The Digestive Enzymes

KNOW THIS CHART

Site	Enzyme	Role in Digestion
Mouth	Salivary amylase	Breaks down starches into disaccharides
Stomach	Pepsin	Breaks down proteins into large peptides
Small intestine (from pancreas)	Amylase	Continues the breakdown of starch
	Trypsin	Continues the breakdown of protein
	Lipase	Breaks down fat
Small intestine	Maltase, sucrase, lactase	Breaks down remaining disaccharides into monosaccharides
	Peptidase	Breaks down dipeptides into amino acids.



	(a) Carbohydrate digestion	(b) Protein digestion	(c) Nucleic acid digestion	(d) Fat digestion
Oral cavity, pharynx, esophagus	Polysaccharides (starch, glycogen) ↓ Salivary amylase Smaller polysaccharides, maltose			
Stomach		Proteins ↓ Pepsin Small polypeptides		
Lumen of small intestine	Polysaccharides ↓ Pancreatic amylases Maltose and other disaccharides	Polypeptides ↓ Trypsin, Chymotrypsin Smaller polypeptides ↓ Aminopeptidase, Carboxypeptidase Amino acids	DNA, RNA ↓ Nucleases Nucleotides	Fat globules ↓ Bile salts Fat droplets (emulsified) ↓ Lipase Glycerol, fatty acids, glycerides
Epithelium of small intestine (brush border)	↓ Disaccharidases Monosaccharides	Small peptides ↓ Dipeptidases Amino acids	↓ Nucleotidases Nucleosides ↓ Nucleosidases Nitrogenous bases, sugars, phosphates	

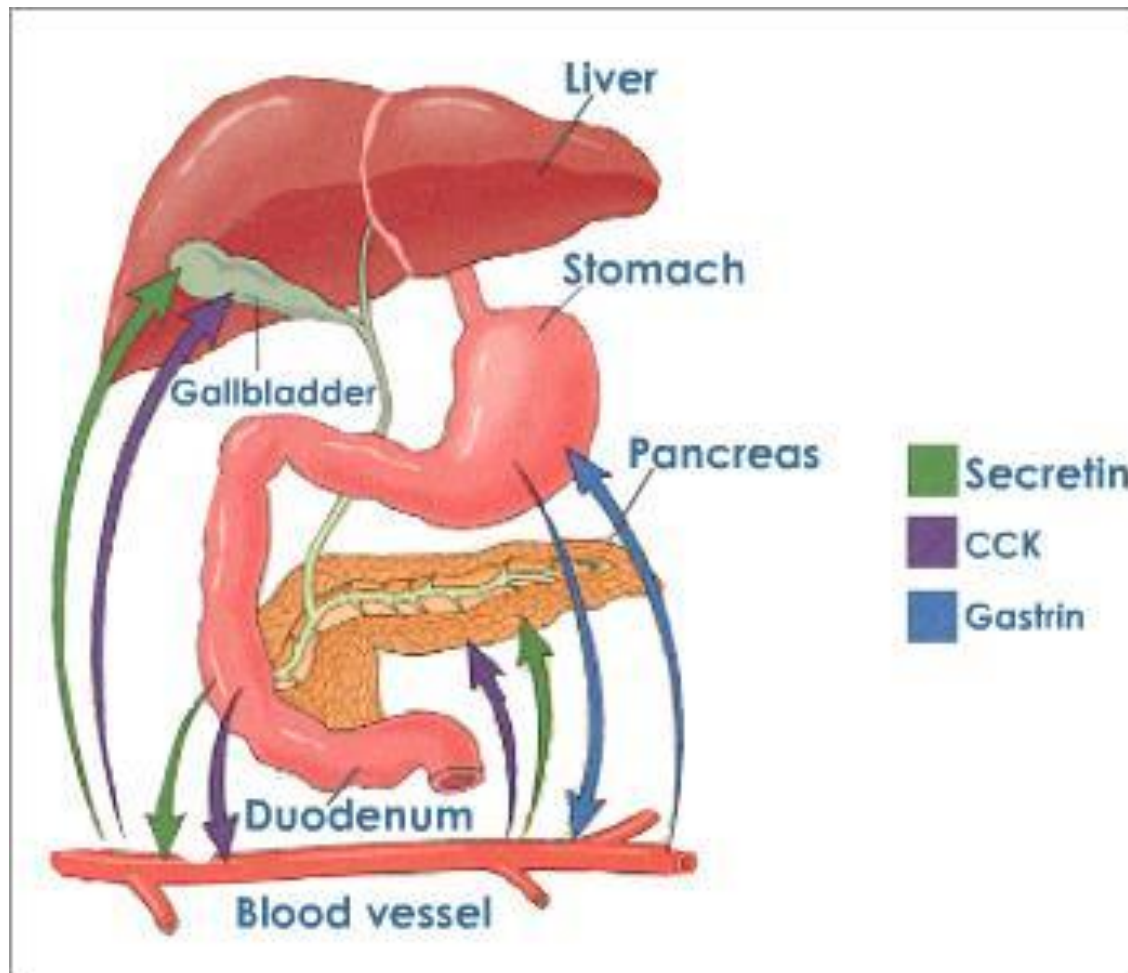
Hormones control digestion

Hormonal Control of Digestive Gland Secretions

Hormone: chemical secreted in one part of the body, controls the activity of other parts of the body

Hormone	Source	Effect	Controlled by
Gastrin	Lower part of stomach	Gastric glands to secrete pepsinogen (converts to pepsin)	Protein level in stomach
Secretin	Duodenum	Pancreas □ Enzyme Liver □ Bile	Chyme
CCK	Duodenum	Pancreas □ Enzyme Liver □ Bile	Fat and Protein level in Duodenum

Hormonal Control of Digestive Gland Secretions

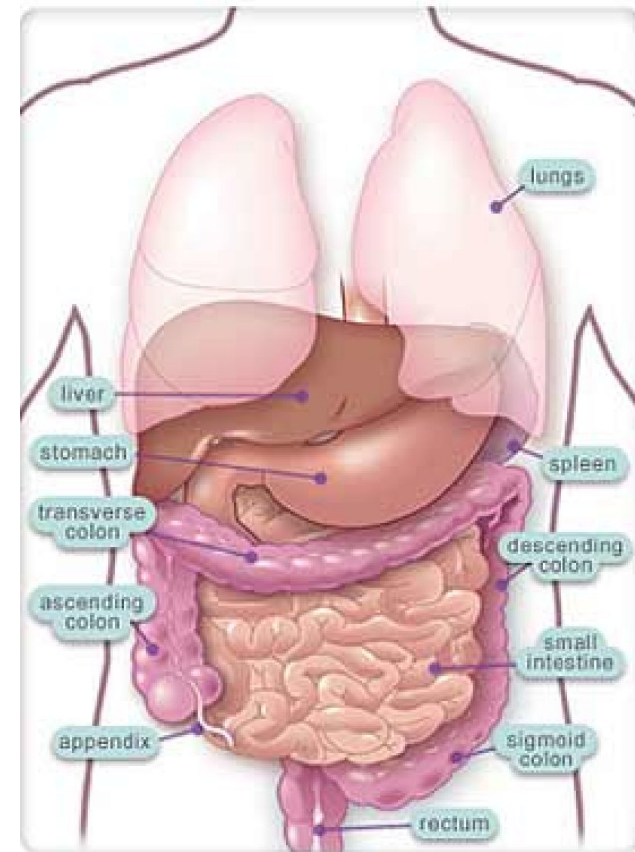


6. Large Intestines

- **Functions**

- 1) re-absorb water

- Absorb H₂O from undigested material (osmosis)
 - use ~9 liters of water every day in digestive juices
 - > 90% of water reabsorbed
 - not enough water absorbed
 - » diarrhea
 - too much water absorbed
 - » constipation



Large Intestine

- **Functions Continued**

2) absorb salt
some vitamins

- **Vitamins K and B**
(produced by
digestive bacteria
– more later) are
reabsorbed with
the water

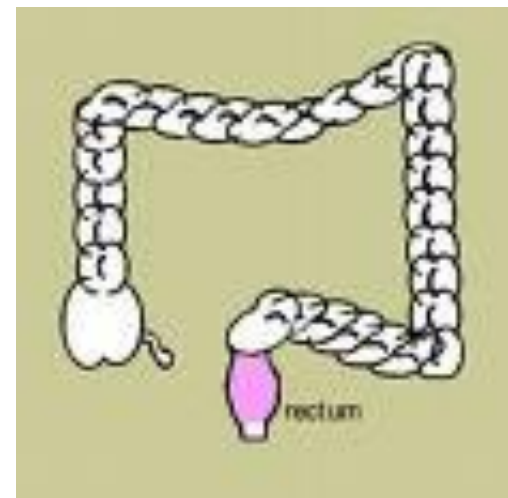


Large Intestine

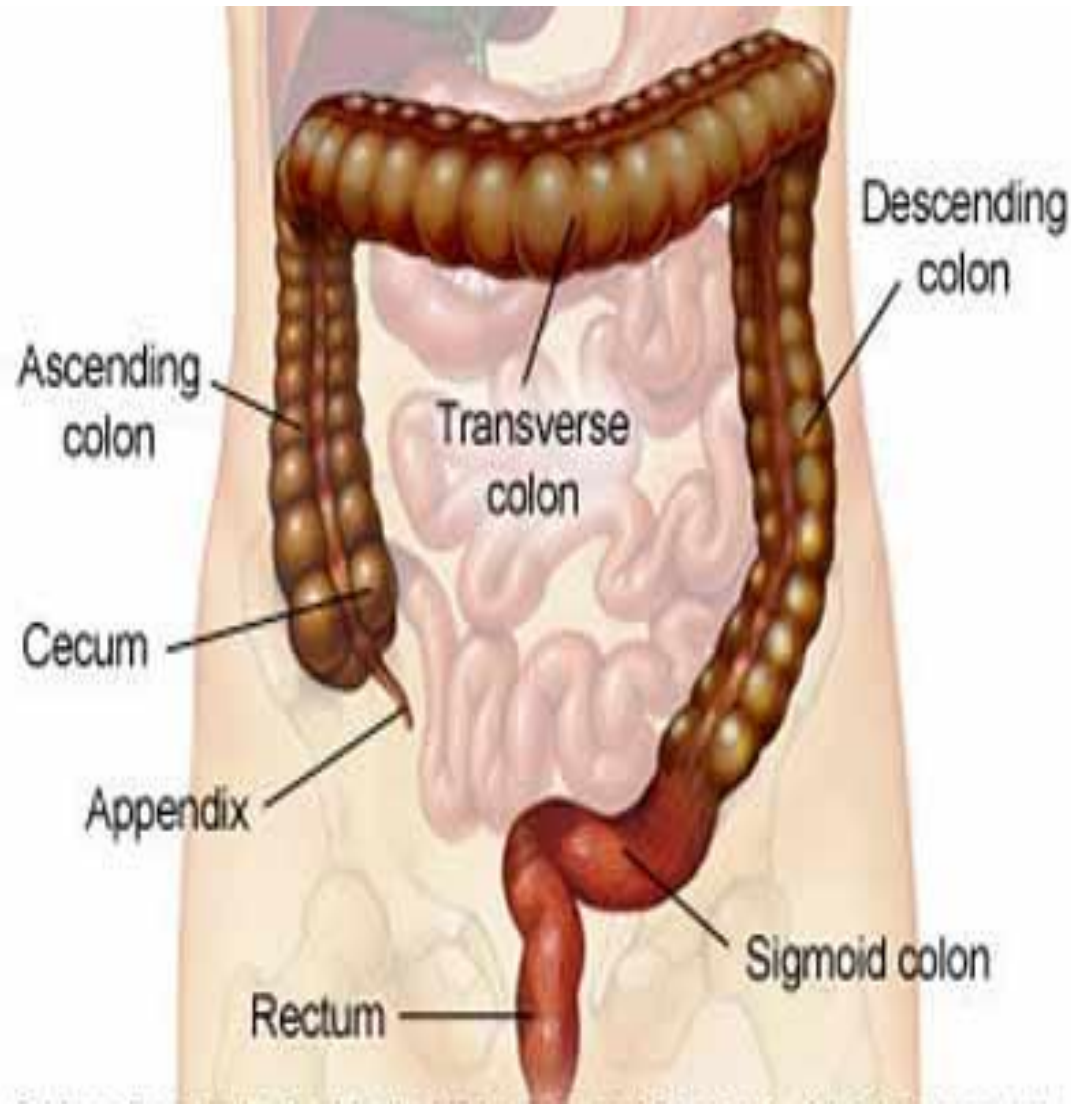
- **Functions Continued**

- **3) Store indigestible material until eliminated**

- **Solid materials**
(indigestible fibers) pass through the large intestine.
 - **Rectum**- solid wastes exit the body.



Parts of the Large Intestine





Structure of the Large Intestine

- Cecum

- Below junction with S.I.
- Contains **appendix** (may help fight infections)

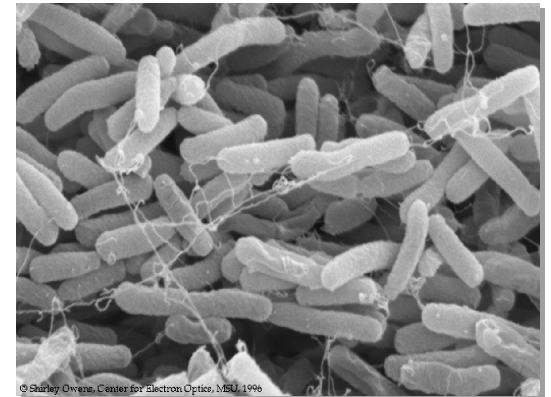


Structure of the Large Intestine

- Colon (3 parts)
 1. ascending colon
 2. transverse colon
 3. descending colon
- Rectum
 - Opens at **anus** where defecation occurs

You've got company!

- Living in the large intestine is a community of helpful bacteria
 - *Escherichia coli* (*E. coli*)
 - produce vitamins
 - vitamin K; B vitamins
 - generate gases
 - by-product of bacterial metabolism
 - methane, hydrogen sulfide

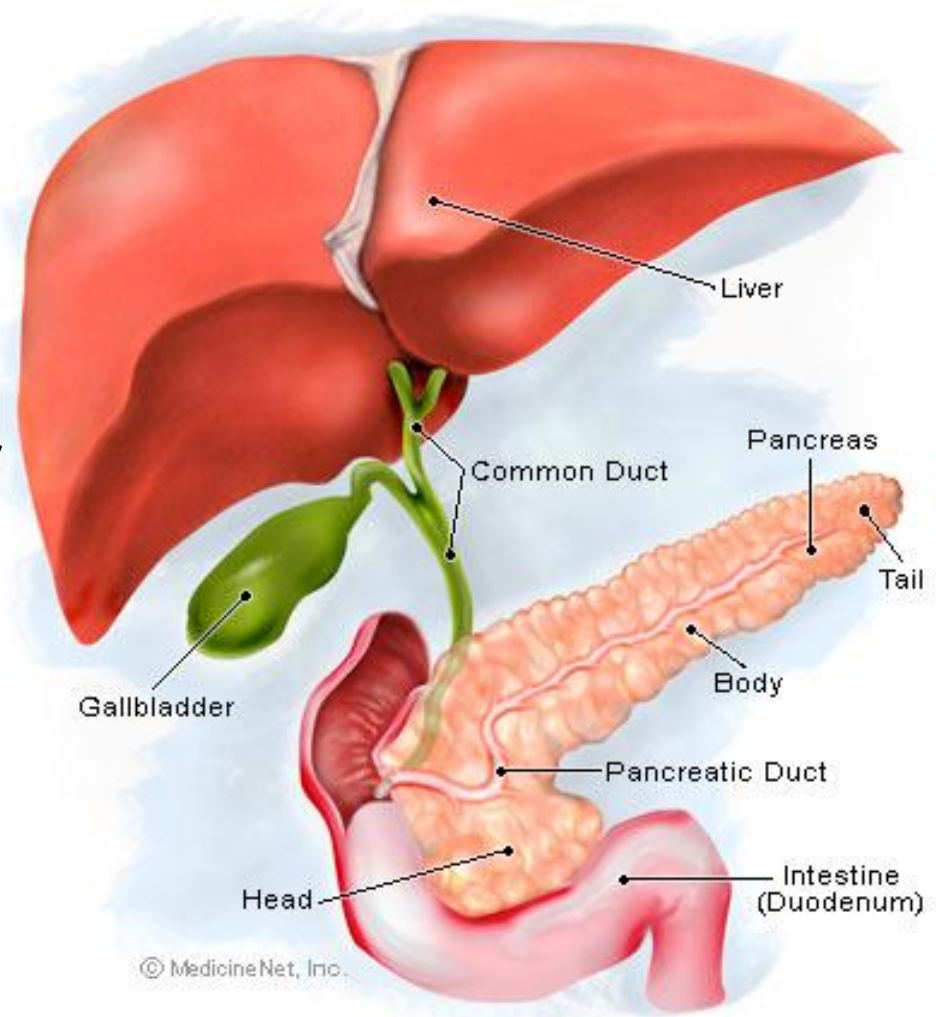


- <https://www.youtube.com/watch?v=1sISguPDlhY&t=4s>
- Bacteria in our gut (ted ed)

11.2

Three Accessory Organs

- 1) Pancreas
- 2) Liver
- 3) Gall Bladder



1) Pancreas

- Functions as both an endocrine (hormones) and exocrine (enzymes) gland
 - Endocrine = hormones
 - **Insulin** and **glucagon** to keep normal blood glucose levels (**more later**)

1) Pancreas

– Exocrine = enzymes (into duodenum)

- **Pancreatic juice** which contains:

- ❖ **Sodium bicarbonate** (NaHCO_3) and digestive enzymes

 - Note: sodium bicarbonate neutralizes chyme (changes pH from 3 □ 8.5)

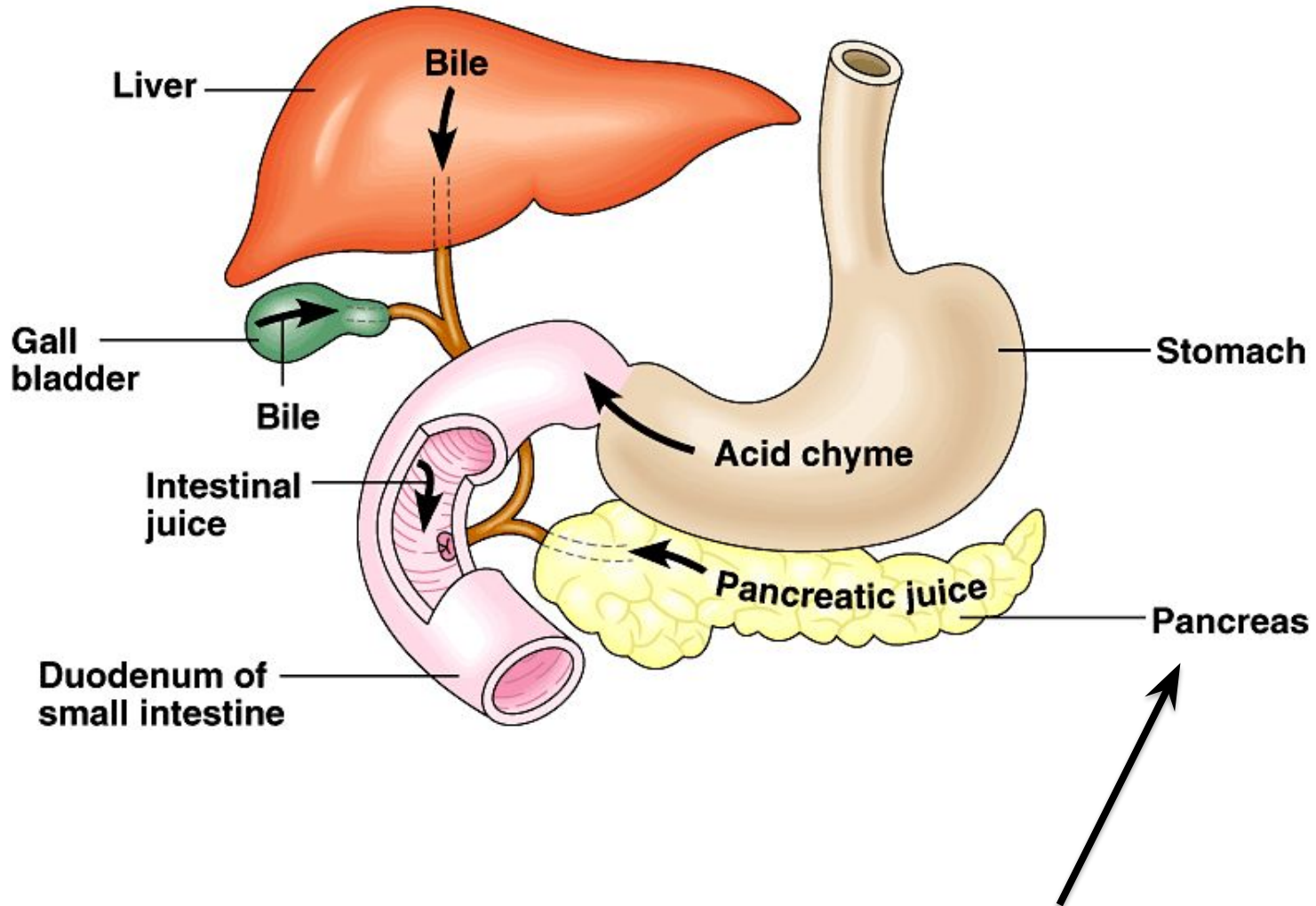
- ❖ **Pancreatic amylase** □ digests starch --
maltose

- ❖ **Trypsin** □ digests **peptides** □ **smaller peptides**

- ❖ **Lipase** □ digests fat □ **3 fatty acids & glycerol**

- ❖ **Nuclease** □ digests DNA, RNA – nucleotides
(ATGC)

Pancreas Continued

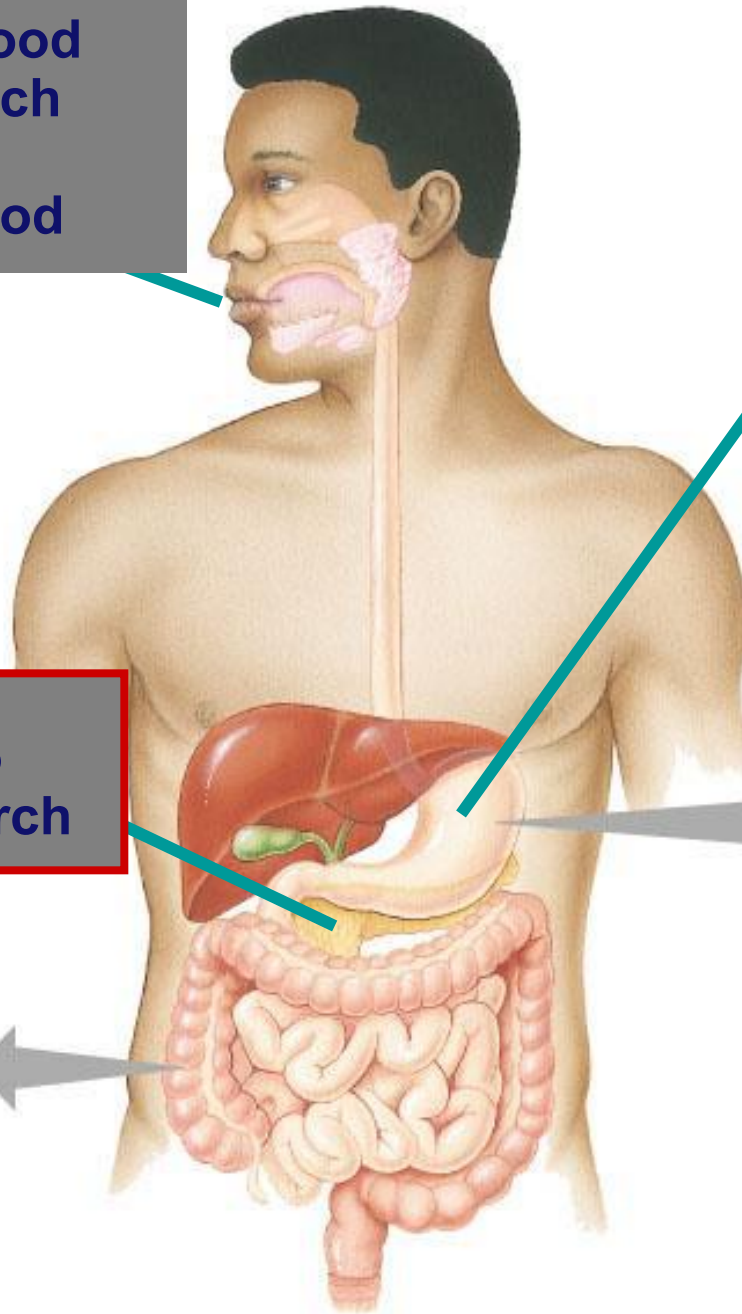


mouth

- break up food
- digest starch
- kill germs
- moisten food

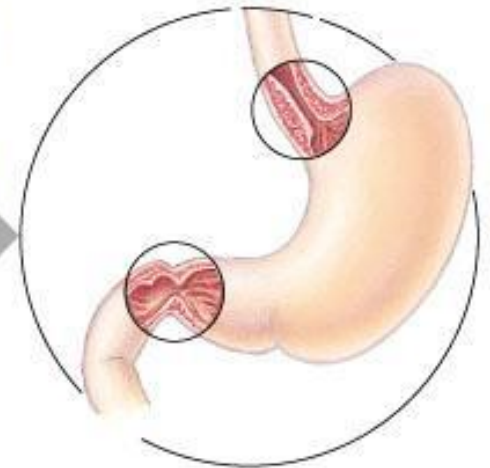
stomach

- kills germs
- break up food
- digest proteins
- store food



pancreas

- produces enzymes to digest proteins & starch





2) Liver

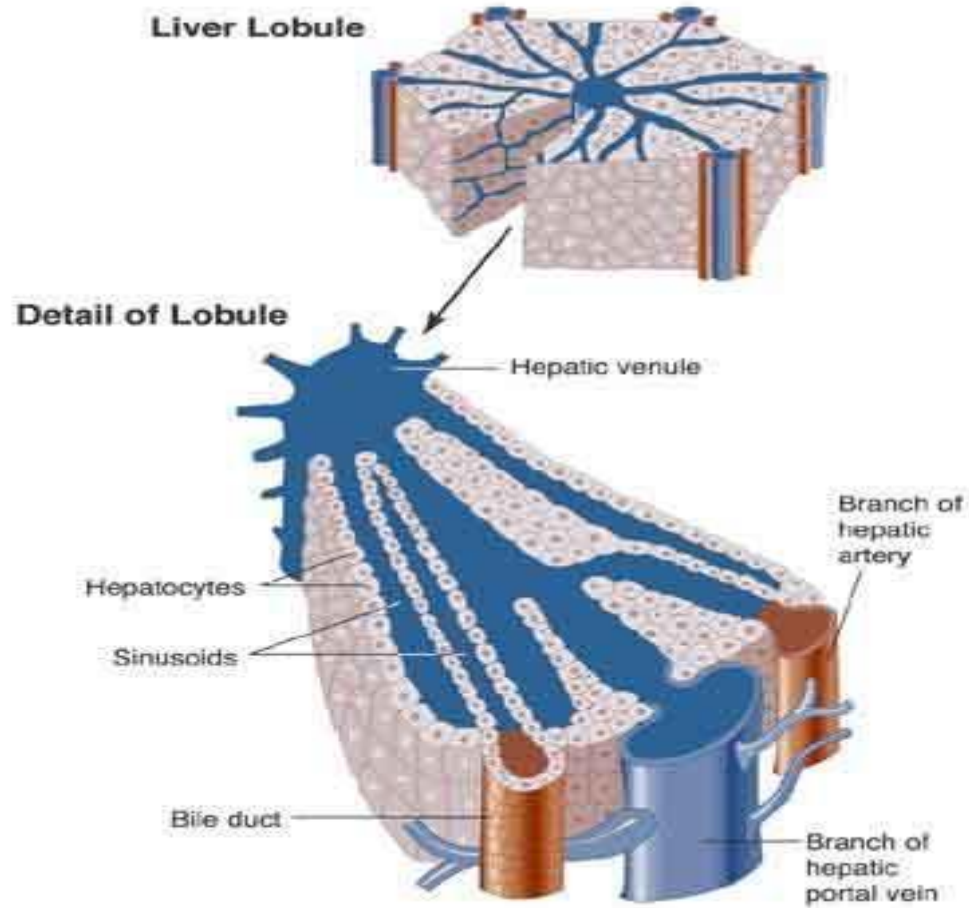
- The liver is the largest gland in the body

Structure:

- 100,000 lobules with triads between the lobules
- Triads contain:
 - **Bile Duct:** takes bile away from liver
 - **Hepatic Artery Branch:** brings oxygen rich blood to the liver
 - **Hepatic Portal Vein Branch:** transports nutrients from the intestines



Liver Structure: Hepatic Lobules



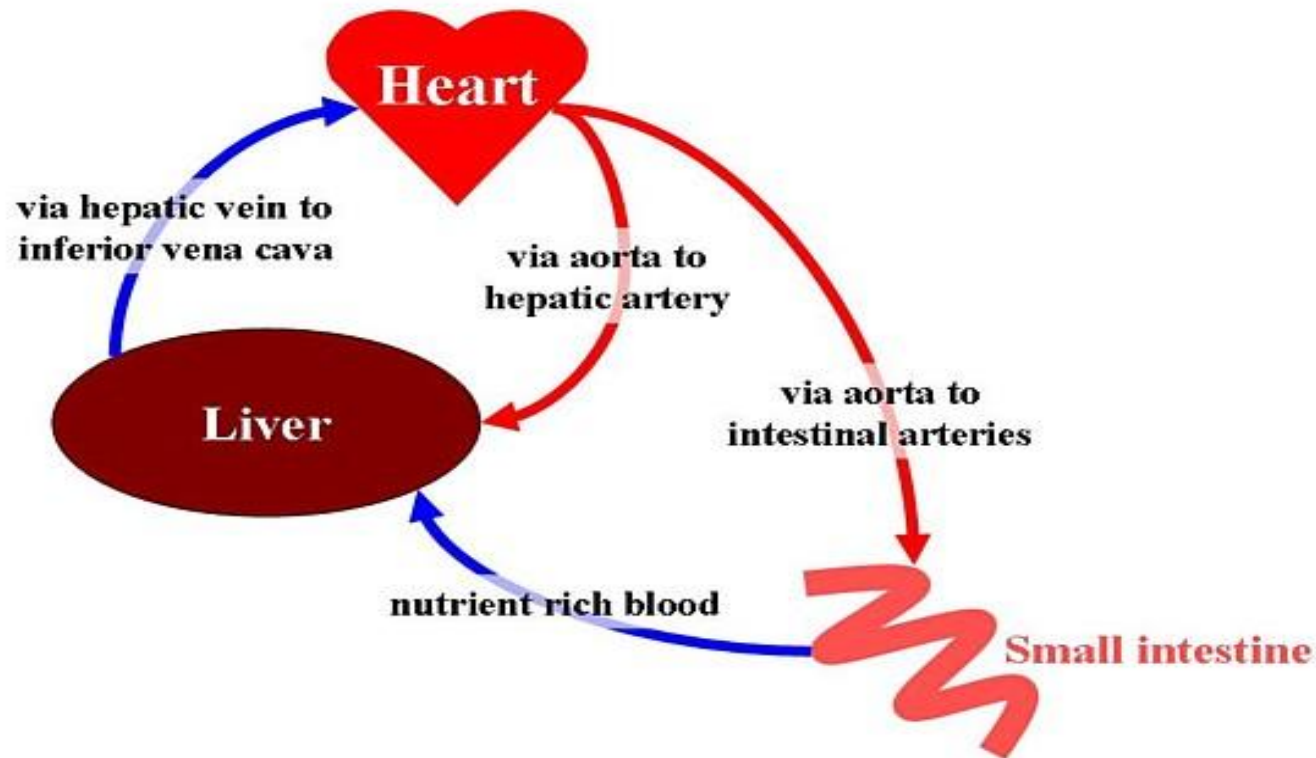
See also fig 14.10
p.268 of Inquiry into Life

Functions of the Liver

- 1) *Detoxifies blood*
- 2) *Stores iron and fat soluble vitamins (A,D,E,K)*
- 3) *Makes plasma proteins from amino acids*
- 4) Stores glucose as glycogen (breaks glycogen down to glucose when needed)
- 5) Produces urea from amino acid breakdown (goes to kidney for removal)
- 6) *Removes bilirubin (breakdown product of hemoglobin) from blood and excretes in bile*
- 7) Production of bile to emulsify fats

- <https://www.youtube.com/watch?v=wbh3SjzYdnQ>
- Ted ed Liver

Hepatic Portal System



The Hepatic Portal System

Liver Disorders

- **Jaundice**: yellowish eyes and skin due to too much bilirubin in blood (can result from hepatitis)
- **Hepatitis**: inflammation of the liver
- **Cirrhosis**: chronic disease of the liver (often seen in alcoholics)

The liver has amazing regenerative powers but not if it exceeds the rate of damage

mouth

- break up food
- digest starch
- kill germs
- moisten food

stomach

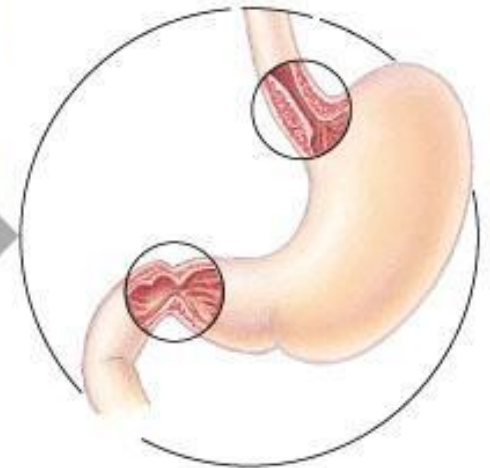
- kills germs
- break up food
- digest proteins
- store food

liver


- produces bile
- stored in gall bladder
- break up fats

pancreas

- produces enzymes to digest proteins & starch

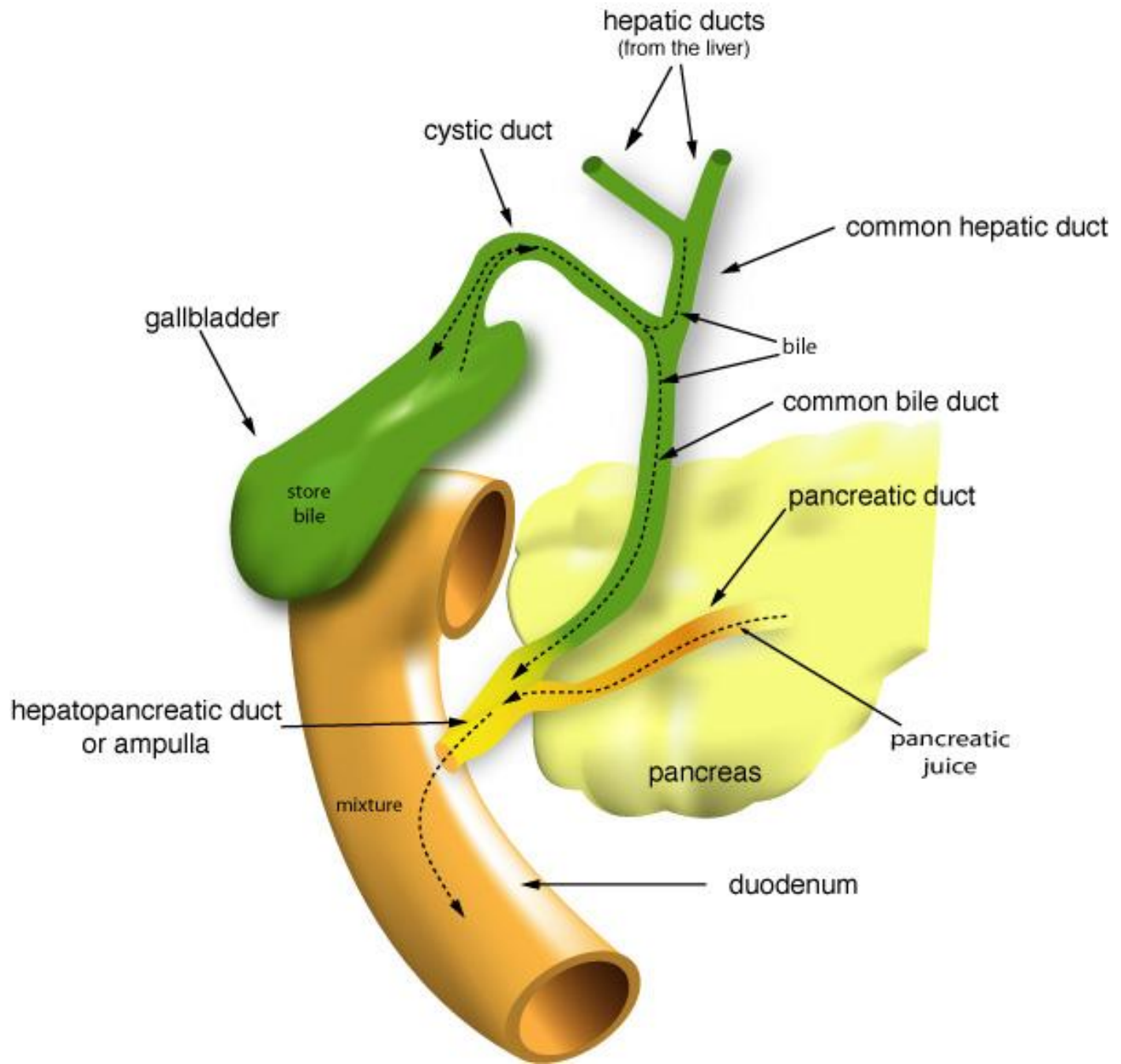


3) Gall bladder

- Pouch structure located near the liver which concentrates and stores excess bile
- *Water is reabsorbed by gall bladder to make bile thick (concentrated)*
- When needed, bile leaves gall bladder via common bile duct, to the duodenum
-  **Gall stones:** crystals in bile due to cholesterol content

BILE

- Bile emulsifies lipids (physically breaks apart FATS)
- Bile is a bitter, greenish-yellow alkaline fluid, stored in the gallbladder between meals and upon eating is discharged into the duodenum where it aids the process of digestion of fats.



Emulsification



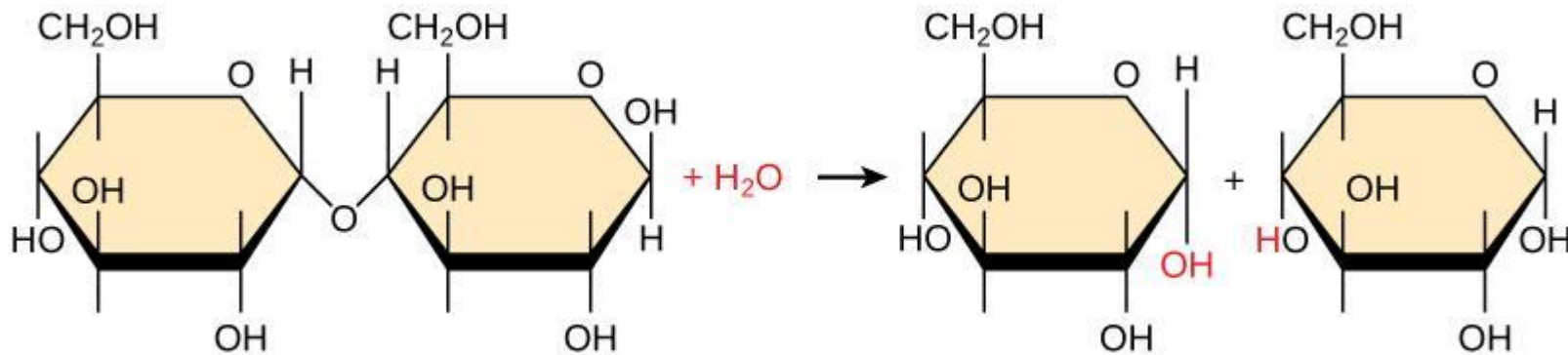
Large oil drop



Small oil droplets

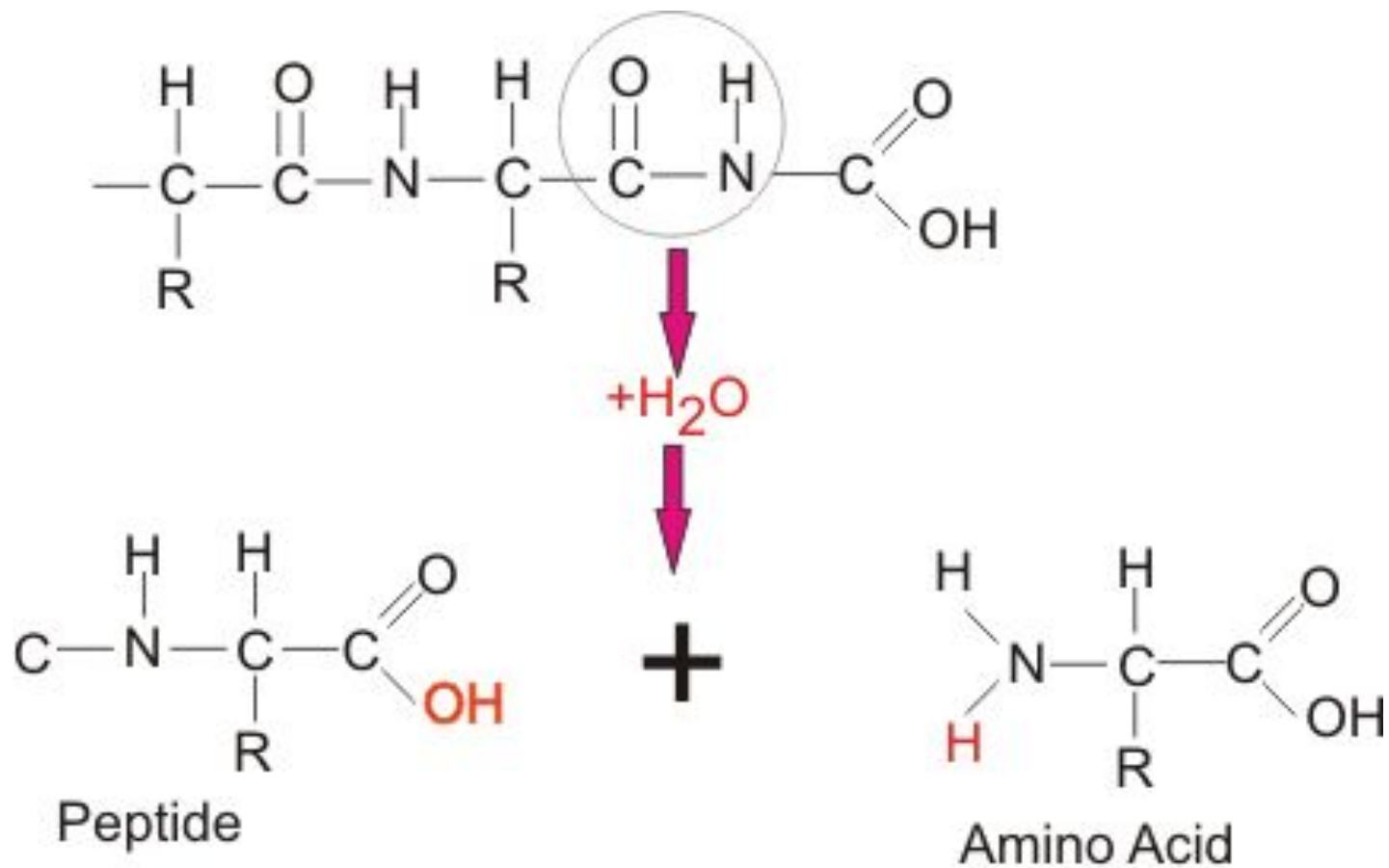
Digestive Enzymes

Digestive enzymes are **hydrolytic enzymes** that break down macromolecules by the introduction of water.



Like other enzymes, digestive enzymes are proteins that:

- have a particular shape that fits their substrate*
- function at an optimum temperature and pH*



Hydrolysis of Peptide Bond

Digestive Enzymes Produced by: Salivary Glands

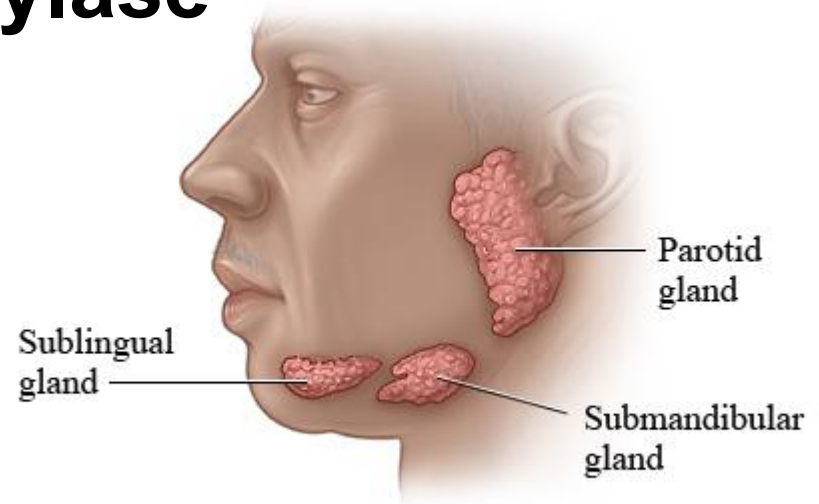
Enzyme: **Salivary Amylase**

Site of Action: Mouth

Optimum pH: Neutral

Digestion:

Starch + H₂O \square **Maltose**



Digestive Enzymes Produced by: Gastric Glands

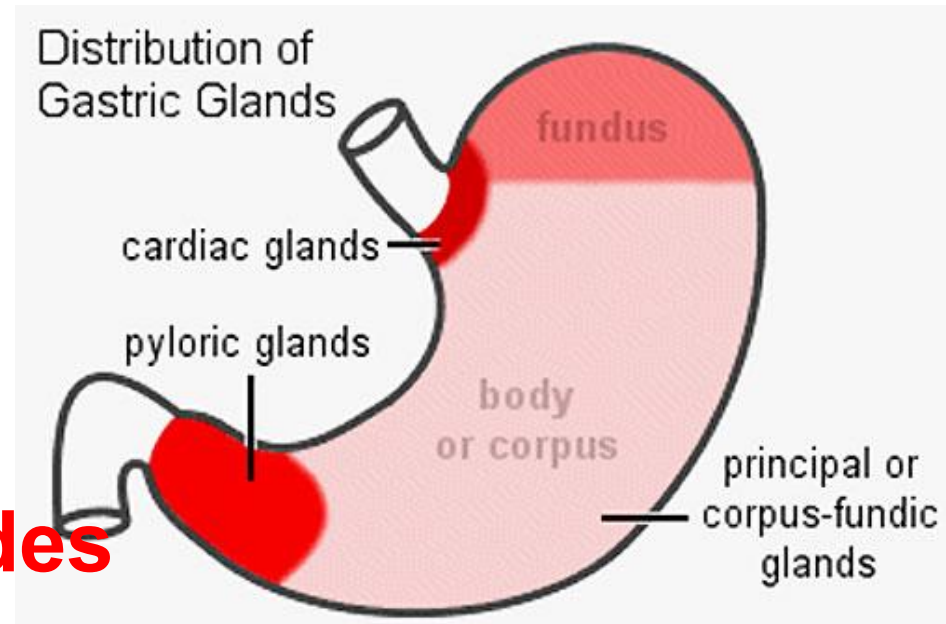
Enzyme: **Pepsin**

Site of Action: Stomach

Optimum pH: Acidic

Digestion:

**Protein + H₂O → Peptides
(5-7 amino acids)**



Digestive Enzymes Produced by: Pancreas (a)

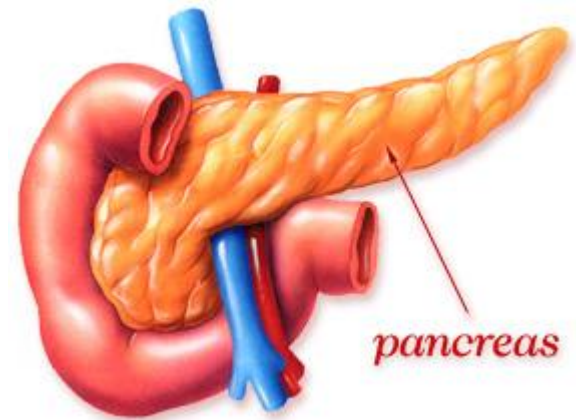
Enzyme: **Pancreatic Amylase**

Site of Action: Small Intestine

Optimum pH: Basic

Digestion:

Starch + H₂O \square **Maltose**



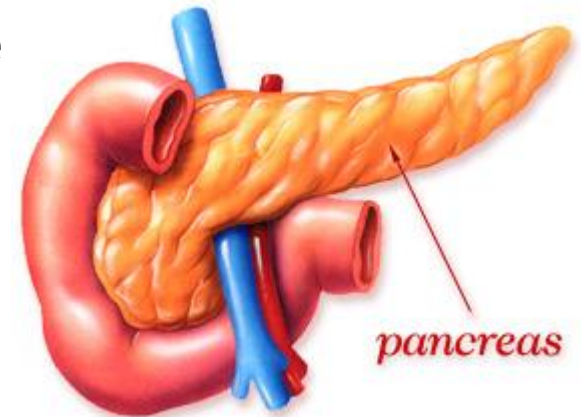
Digestive Enzymes Produced by: Pancreas (b)

Enzyme: **Trypsin**

Site of Action: small intestine

Optimum pH: basic

Digestion:



**Peptides (5-7 amino acids) + H₂O □
smaller Peptides (2-3 amino acids)**

Digestive Enzymes Produced by: Pancreas (c)

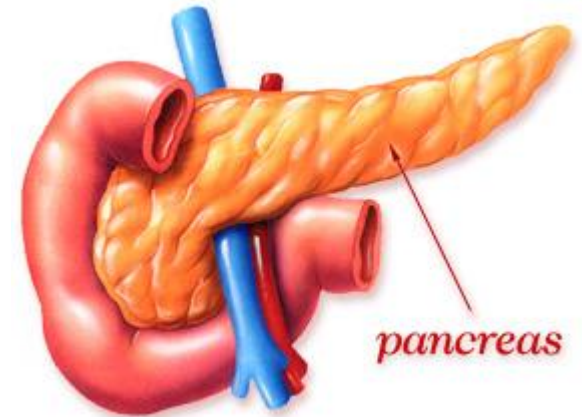
Enzyme: **Nuclease**

Site of Action: small intestine

Optimum pH: basic

Digestion:

RNA + DNA + H₂O \square **nucleotides**



Digestive Enzymes Produced by: Pancreas

Enzyme: **Lipase**

Site of Action: small intestine

Optimum pH: basic

Digestion:

Fat droplet + H₂O \square glycerol + fatty acid

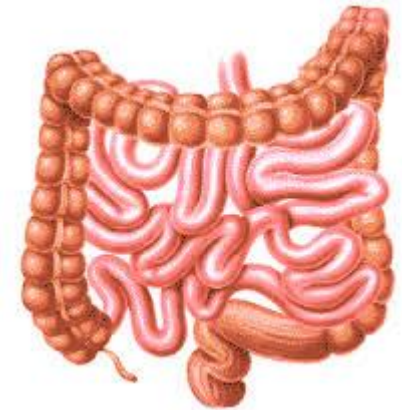
Digestive Enzymes Produced by: Small Intestine

Enzyme: **Maltase**

Site of Action: small intestine

Optimum pH: basic

Digestion:



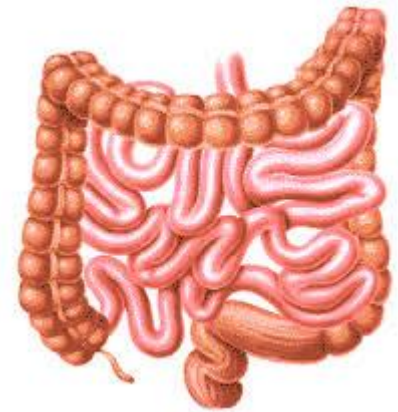
Digestive Enzymes Produced by: Small Intestine

Enzyme: **Peptidases**

Site of Action: small intestine

Optimum pH: basic

Digestion:



**Smaller Peptides (2-3 amino acids) +
 H_2O \square amino acids**

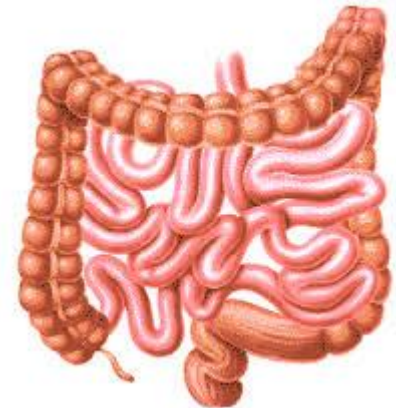
Digestive Enzymes Produced by: Small Intestine

Enzyme: **Nucleosidases**

Site of Action: small intestine

Optimum pH: basic

Digestion:



Nucleotide + H₂O **base + sugar +
phosphate**

The Digestive Enzymes

KNOW THIS CHART

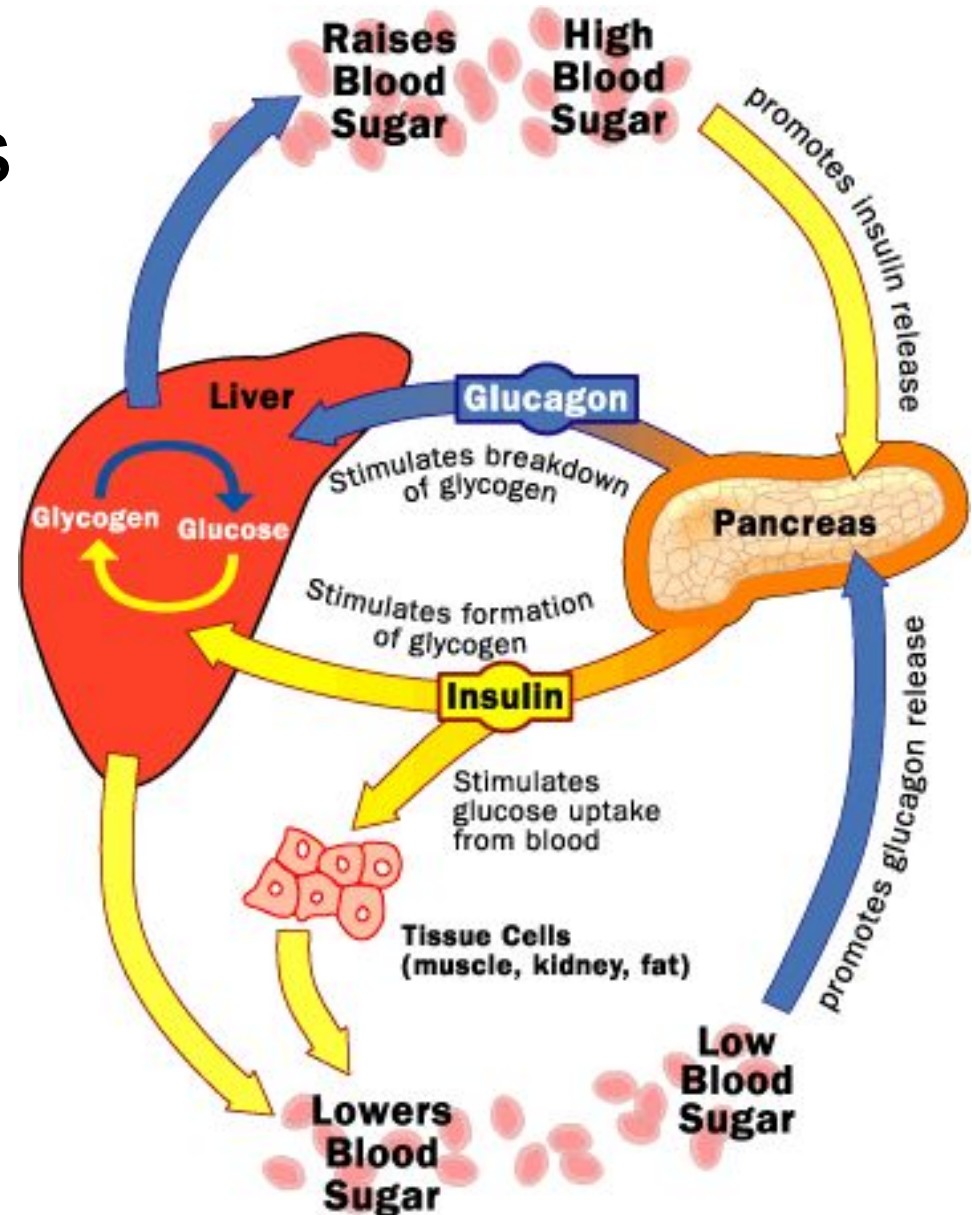
Site	Enzyme	Role in Digestion
Mouth	Salivary amylase	Breaks down starches into disaccharides
Stomach	Pepsin	Breaks down proteins into large peptides
Small intestine (from pancreas)	Amylase	Continues the breakdown of starch
	Trypsin	Continues the breakdown of protein
	Lipase	Breaks down fat
Small intestine	Maltase, sucrase, lactase	Breaks down remaining disaccharides into monosaccharides
	Peptidase	Breaks down dipeptides into amino acids.



	(a) Carbohydrate digestion	(b) Protein digestion	(c) Nucleic acid digestion	(d) Fat digestion
Oral cavity, pharynx, esophagus	Polysaccharides (starch, glycogen) ↓ Salivary amylase Smaller polysaccharides, maltose			
Stomach		Proteins ↓ Pepsin Small polypeptides		
Lumen of small intestine	Polysaccharides ↓ Pancreatic amylases Maltose and other disaccharides	Polypeptides ↓ Trypsin, Chymotrypsin Smaller polypeptides ↓ Aminopeptidase, Carboxypeptidase Amino acids	DNA, RNA ↓ Nucleases Nucleotides	Fat globules ↓ Bile salts Fat droplets (emulsified) ↓ Lipase Glycerol, fatty acids, glycerides
Epithelium of small intestine (brush border)	↓ Disaccharidases Monosaccharides	Small peptides ↓ Dipeptidases Amino acids	↓ Nucleotidases Nucleosides ↓ Nucleosidases Nitrogenous bases, sugars, phosphates	

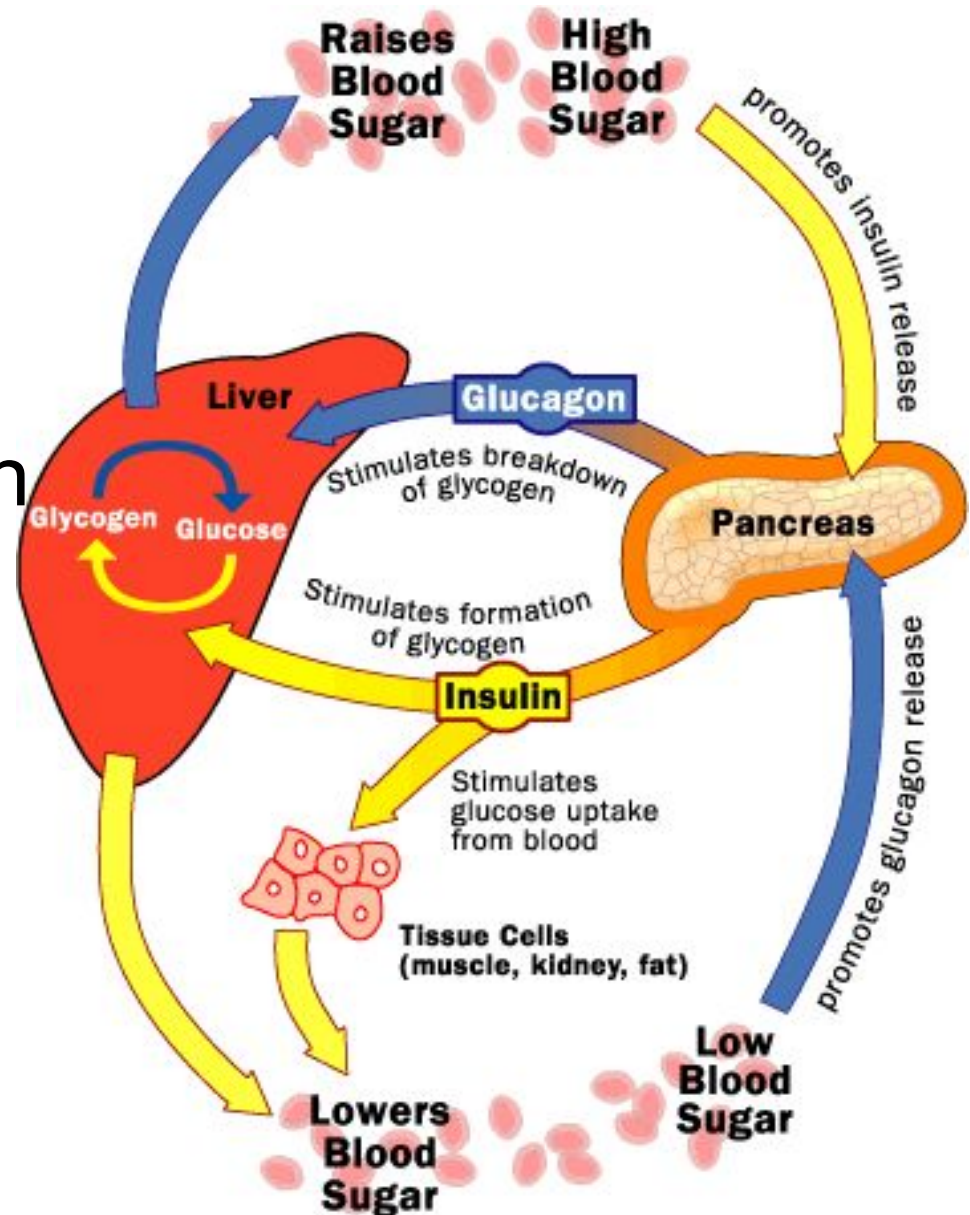
14.4 Glucose Levels in the Blood

Insulin- responds to high blood glucose, causes liver to form glycogen from glucose



14.4 Glucose Levels in the Blood

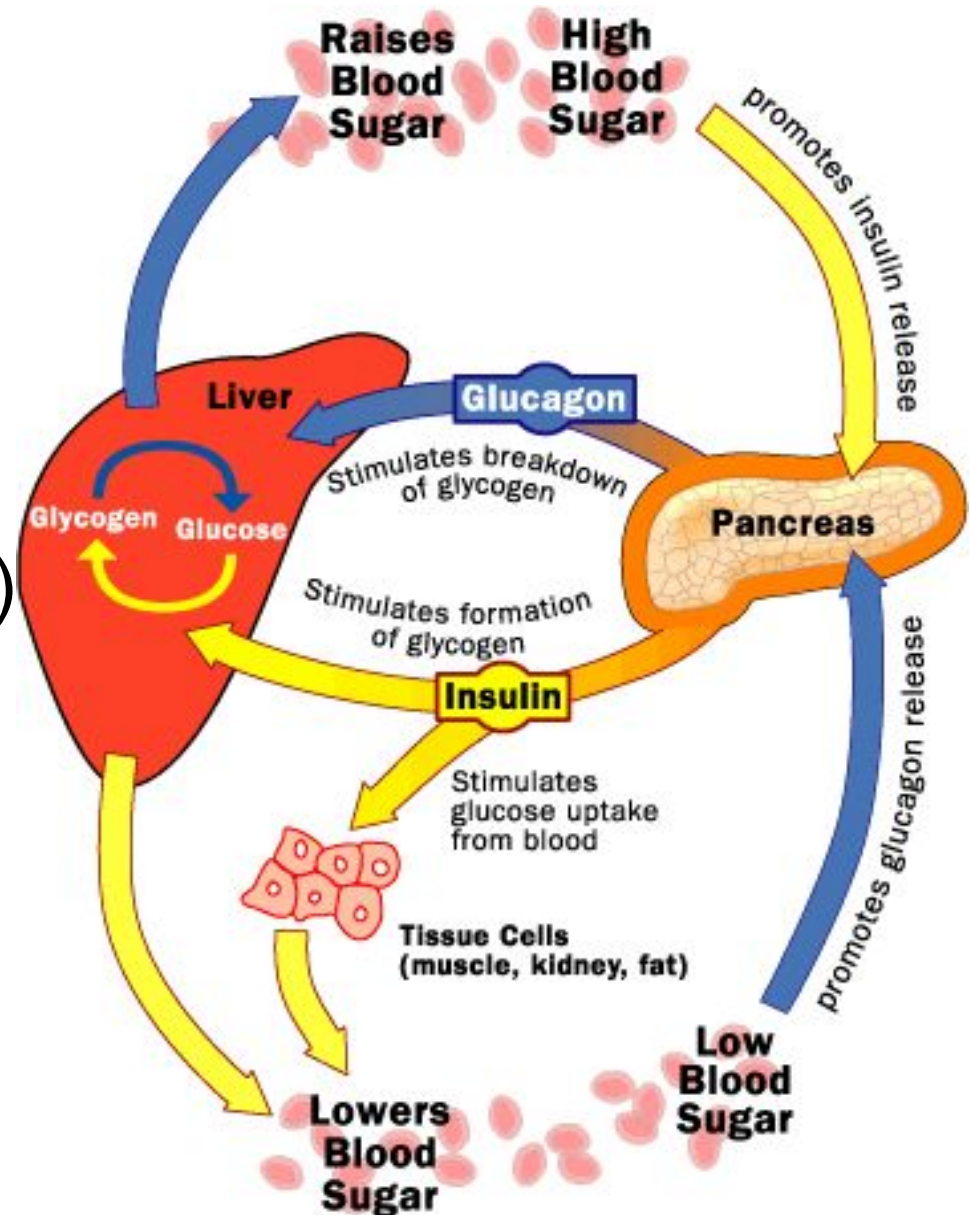
Glucagon – responds to low glucose levels, causes liver to breakdown glycogen to glucose



14.4 Glucose Levels in the Blood

Diabetes:

- **Type I:** (Juvenile) pancreas doesn't make insulin; cells can't take in glucose
- **Type II:** (Adult onset) cells no longer respond to insulin



Let's go to the Video!

<https://www.youtube.com/watch?v=b20VRR9C37Q>

Human Digestive System

<http://www.boreme.com/posting.php?id=29587#.VAaKYfldU71>

Travelling through the digestive system