DIGESTION

http://ca.youtube.com/watch?v=Uzl6M1YlU3w

Interesting Facts

- We eat about **500kg** of food per year.

- We make approximately **1.7 liters** of saliva every day.

- Every day **11.5 liters** of digested food, liquids and digestive juices flow through the digestive system, but only **100 mL** is lost in feces.

- Digestive problems cost Americans **$50 billion** each year in both direct costs and absence from work.

- By age 50, many people will produce only **15%** of the Hydrochloric Acid (stomach acid) they released at age 25.

- Most of us pass somewhere between **200 and 2,000 ml** of gas per day (average, about 600 ml) in roughly **13-14** passages.

•***How big is your stomach ?***

An adult's stomach holds about **1 liter of food**. A child's stomach holds a little bit less. Your stomach gets bigger the more you eat. A large adult can eat and drink **up to 4 liters** of food and liquid at one meal!

•***How long are the intestines ?***

The small intestine is more than three times as long as the whole body ! In an adult, this is about **21 feet long**. The large intestine is another 5 feet long. The whole tube from the mouth to the anus is about **30 feet long**. Wow !

•As a group, vegetarians produce **more gas** than meat-eaters because the intestinal enzymes can't digest the cellulose in vegetables' cell walls

Prescribed Learning Outcomes page 202-213

I1. **Identify and give a function for each of the following:**
Mouth, Tongue, Teeth, Salivary glands, Pharynx, Epiglottis, Esophagus, Cardiac Sphincter, Stomach, Pyloric sphincter, Duodenum, Liver, Gall bladder, Pancreas, Small intestine, Appendix, Large intestine (colon), Rectum, Anus.

I2. **Relate the following digestive enzymes to their glandular sources and describe the digestive reaction they promote:**
salivary amylase, pancreatic amylase, proteases (pepsin, trypsin), lipase, peptidase, maltase, nucleases.

I3. **Describe swallowing and peristalsis.**

I4. **Identify the components and describe the digestive actions of gastic, pancreatic, and intestinal juices.**

I5. **Identify the source gland for and describe the function of insulin**

I6. **Explain the role of bile in the emulsification of fats.**

I7. **List six major functions of the liver.**

I9. **Examine the small intestine and describe how it is specialized for digestion and absorption.**

I10. **Describe the functions of E. coli in the colon.**

VOCABULARY

_____ Absorption
_____ Acid chyme
_____ Albumin
_____ Alkaline
_____ Amylase
_____ Anal sphincter
_____ Appendix
_____ Bicarbonate ions
_____ Bile
_____ Bilirubin
_____ Biliverdin
_____ Bolus
_____ Cardiac sphincter
_____ Chemical digestion
_____ Cholecystokinin (CCK)
_____ Chyme
_____ Cirrhosis
_____ Deaminate
_____ Defecation
_____ Disaccharide
_____ Duodenum
_____ E. Coli
_____ Emulsifier
_____ Endocrine gland
_____ Epiglottis
_____ Esophagus
_____ Exocrine gland
_____ Fatty acids
_____ Gall bladder
_____ Gastric juice
_____ Gastrin
_____ Glucagon
_____ Glycerol
_____ Glycogen
_____ HCl
_____ Hemoglobin
_____ Ileo-caecal valve
_____ Insulin
_____ Islets of Langerhans
_____ Lacteals
_____ Large intestine (colon)
_____ Lipase
_____ Maltase
_____ Maltose
_____ Mechanical Digestion
_____ Mitochondria
_____ Nuclease
_____ Pancreas
_____ Pancreatic amylase
_____ Pancreatic juice
_____ Pepsin
_____ Pepsinogen
_____ Peptidase
_____ Peptides
_____ Peristalsis
_____ Pharynx
_____ Protease
_____ Pyloric sphincter
_____ Rectum
_____ Saliva
_____ Salivary amylase
_____ Salivary glands
_____ Secretin
_____ Sodium bicarbonate
_____ Sphincter
_____ Starch
_____ Stomach
_____ Trypsin
_____ Urea
_____ Villi

DEFINITIONS

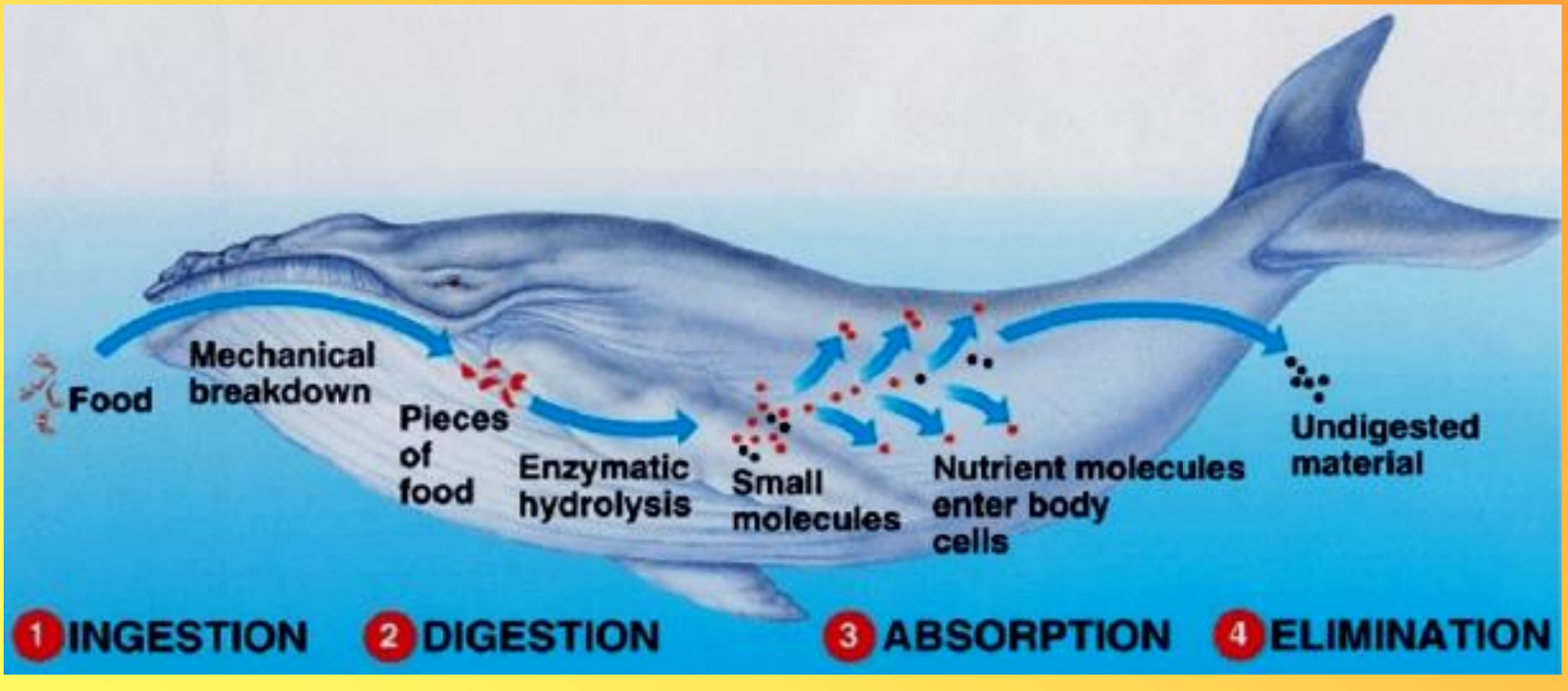
Anatomy is the study of structures.

Physiology is the study of functions.

Functions of the Digestive System

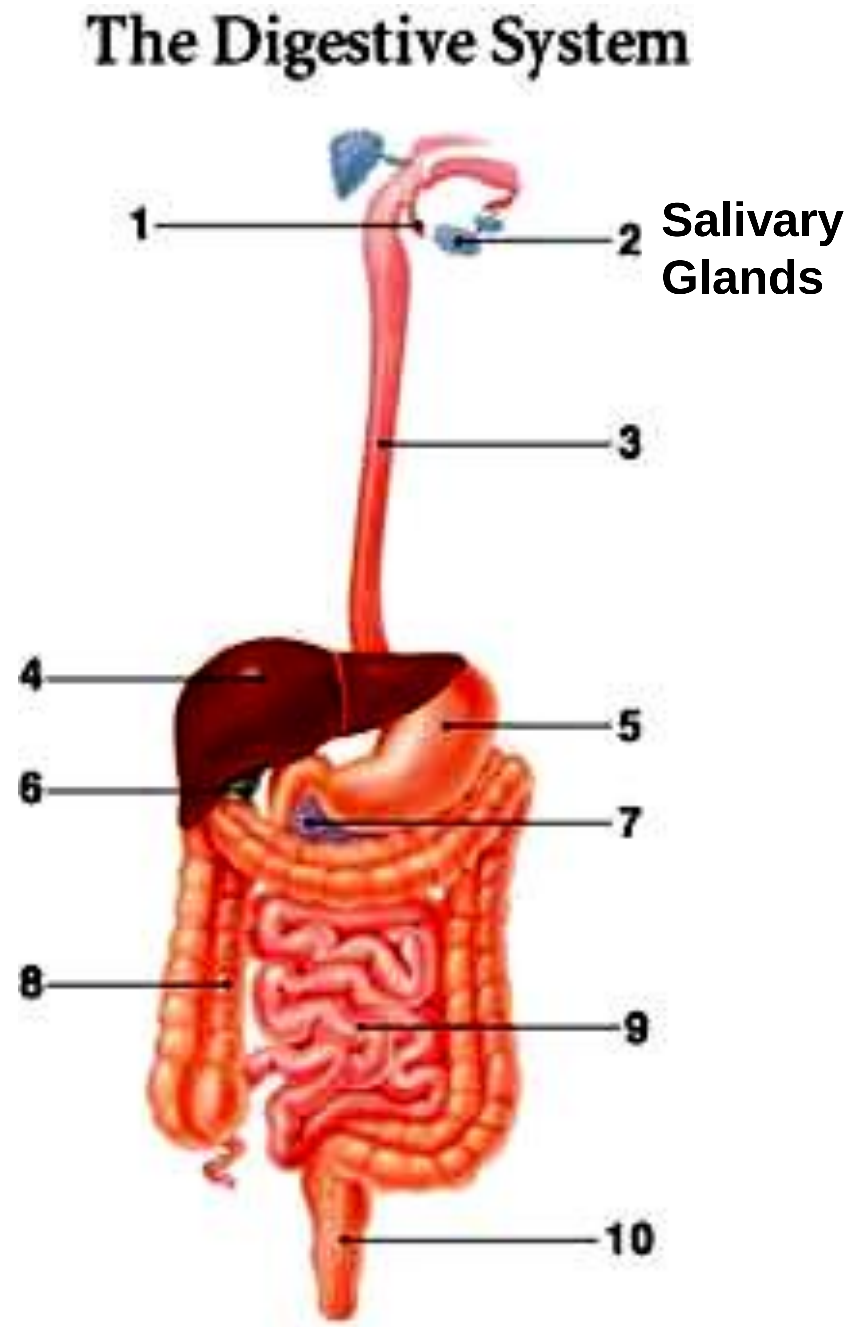
- **Ingest** (eat) our food
- **Secretes** (enzymes, bile, HCl) to assist in digestion
- **Digest** (breaks down) food
- **Absorbs** our food
  - Used to make **energy**
  - Used to help us **grow and repair** ourselves
- **Eliminates** our food (rids us of undigestable waste)

Steps of Digestion

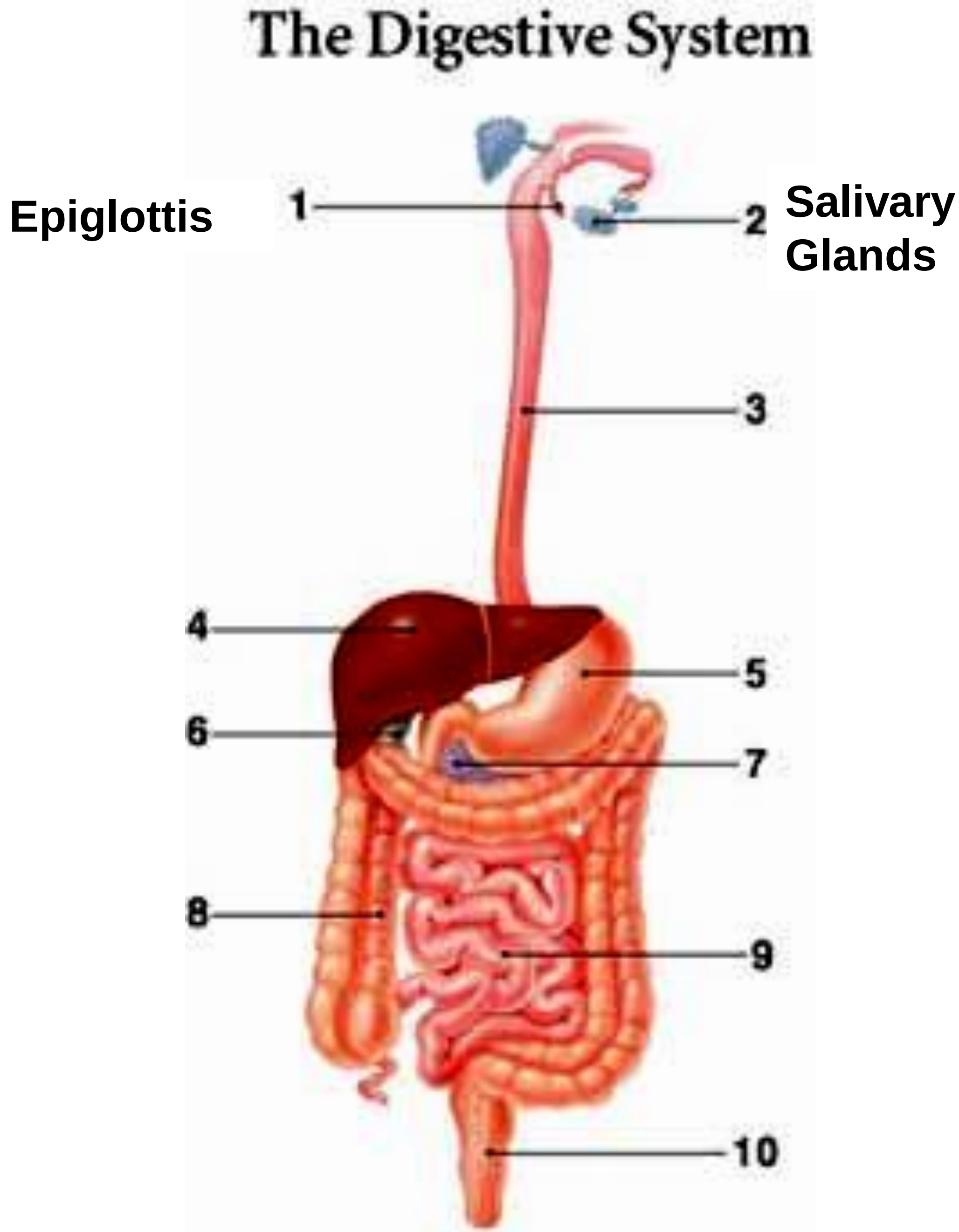


HUMAN

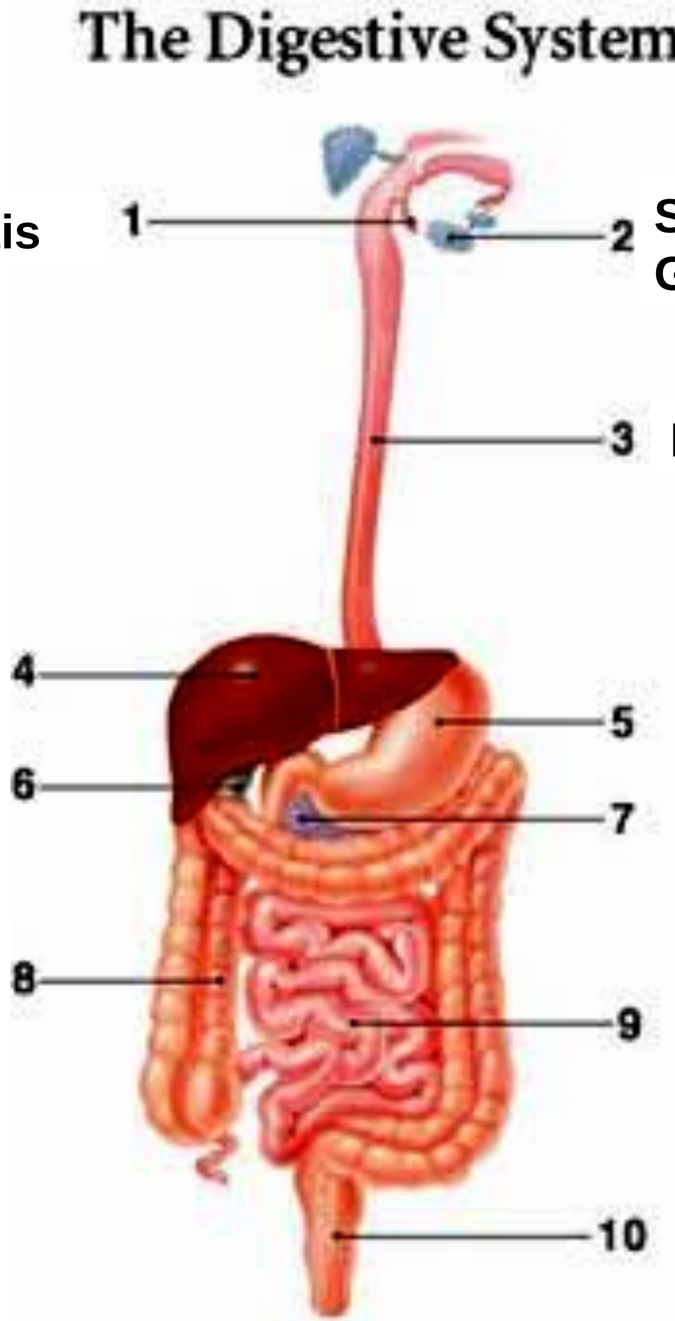
DIGESTION



HUMAN DIGESTION



HUMAN DIGESTION

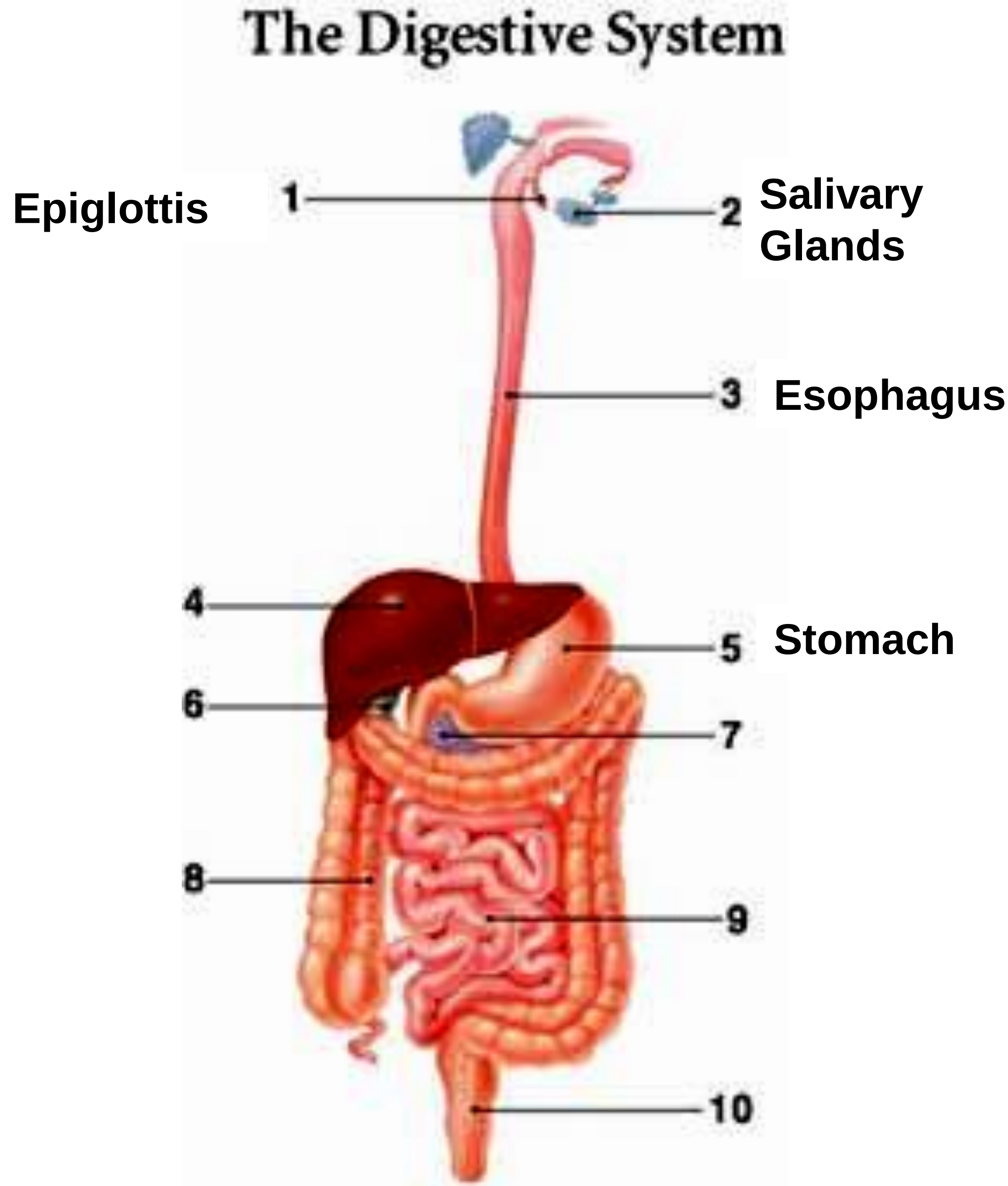


Epiglottis

Salivary Glands

Esophagus

HUMAN DIGESTION



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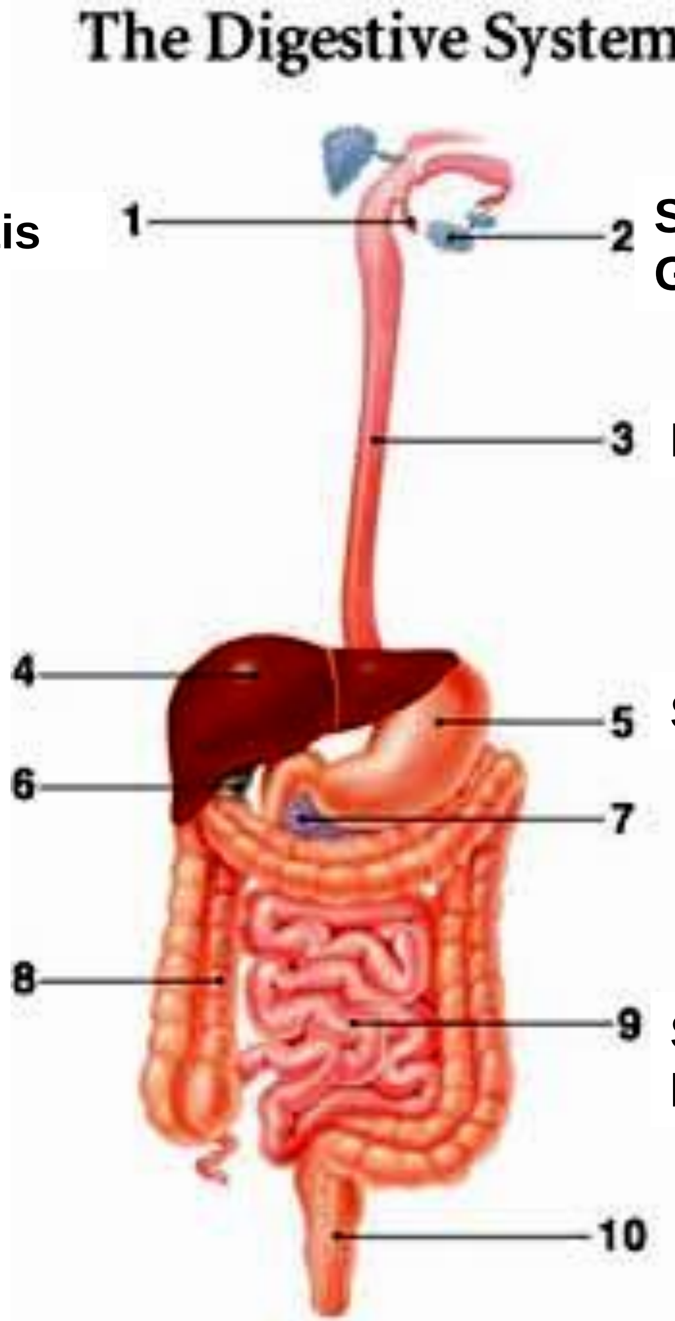


Epiglottis

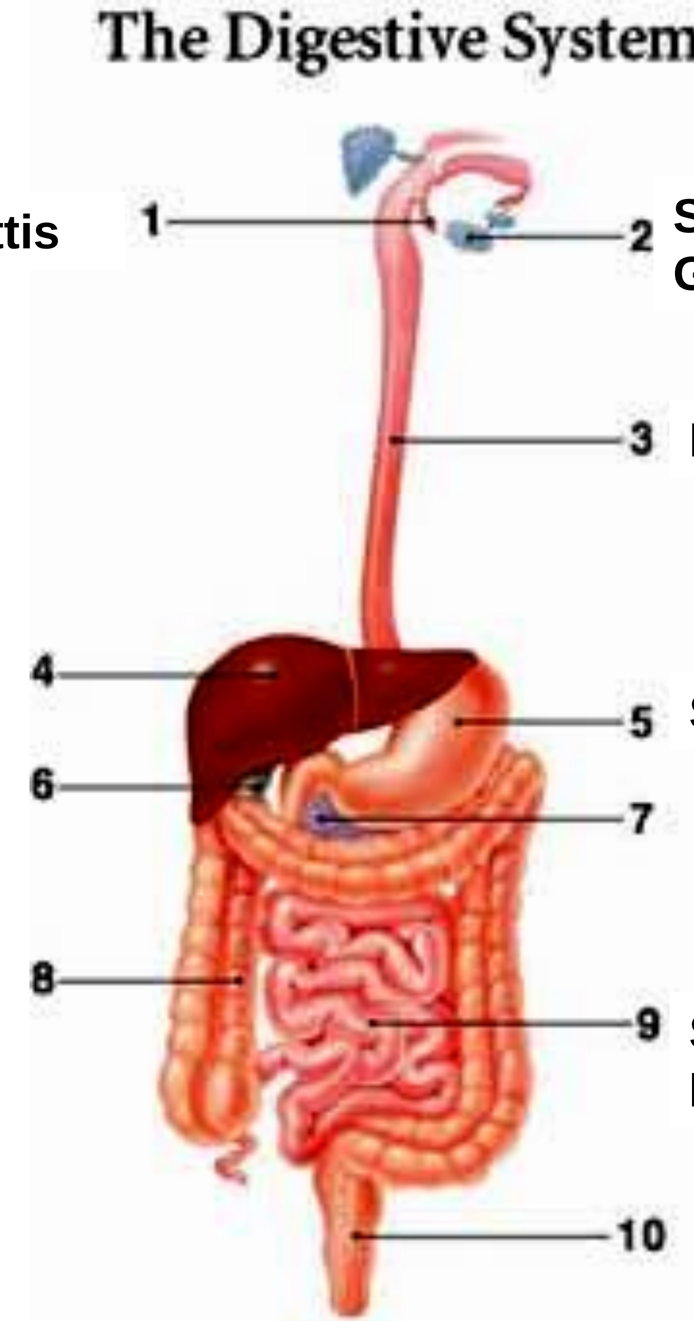
Salivary Glands

Esophagus

Stomach

Small Intestine

HUMAN DIGESTION



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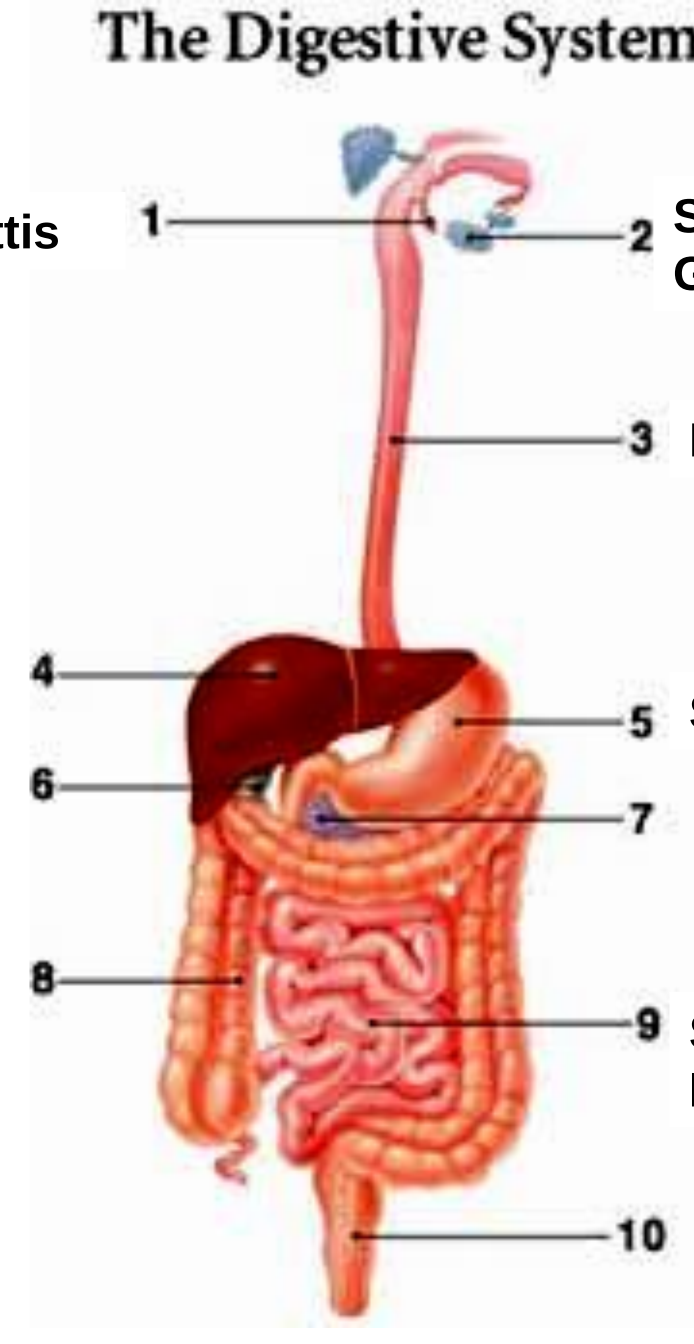

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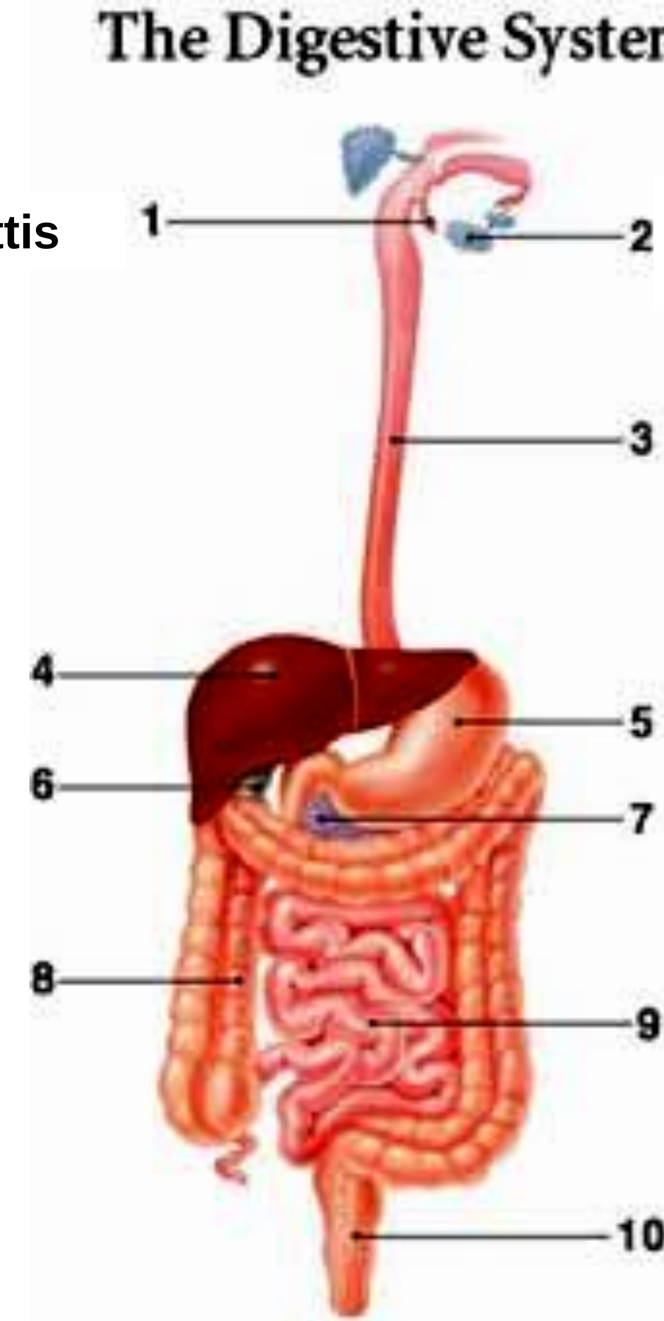


Epiglottis

Salivary Glands

Esophagus

Liver

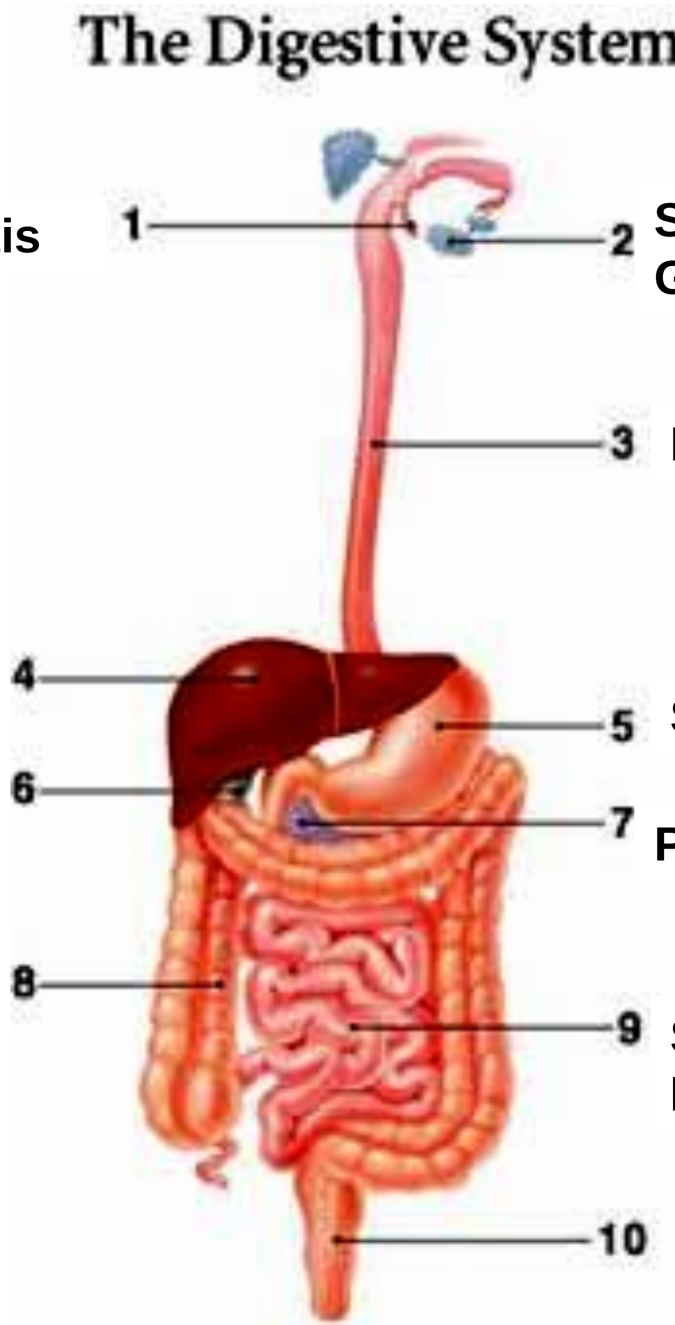
Stomach

Gall bladder

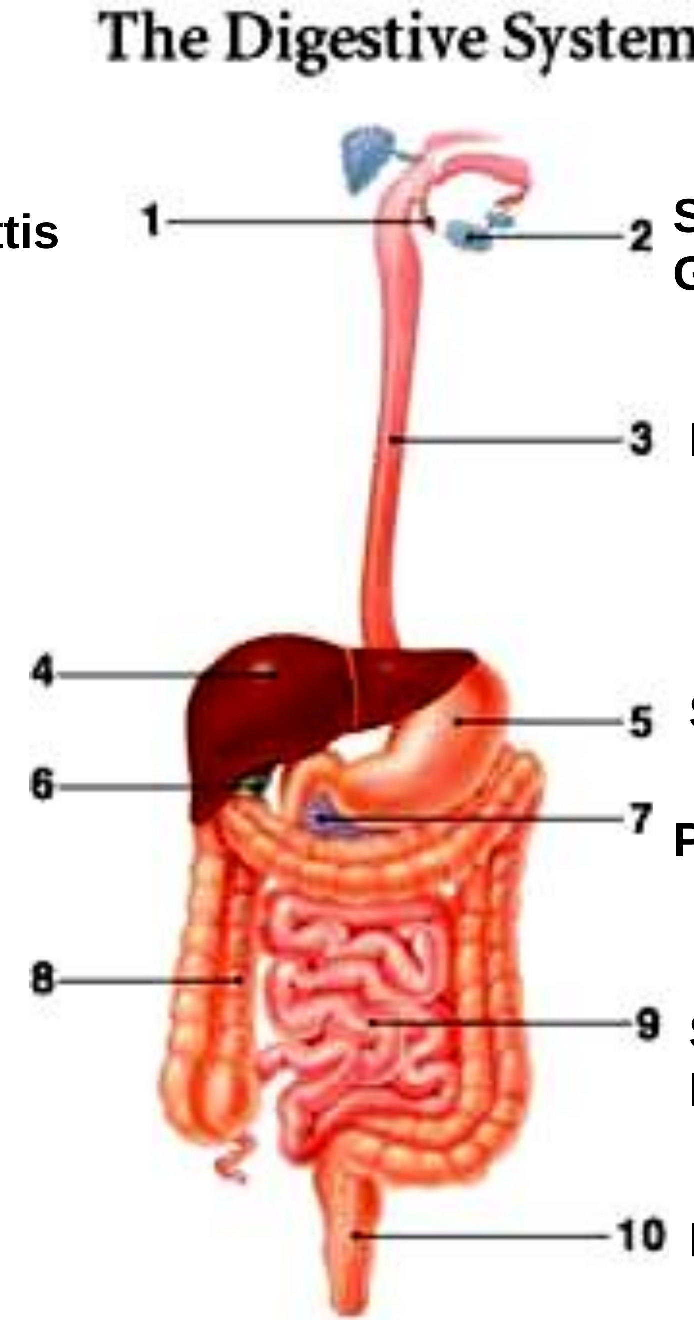
Large Intestine

Small Intestine

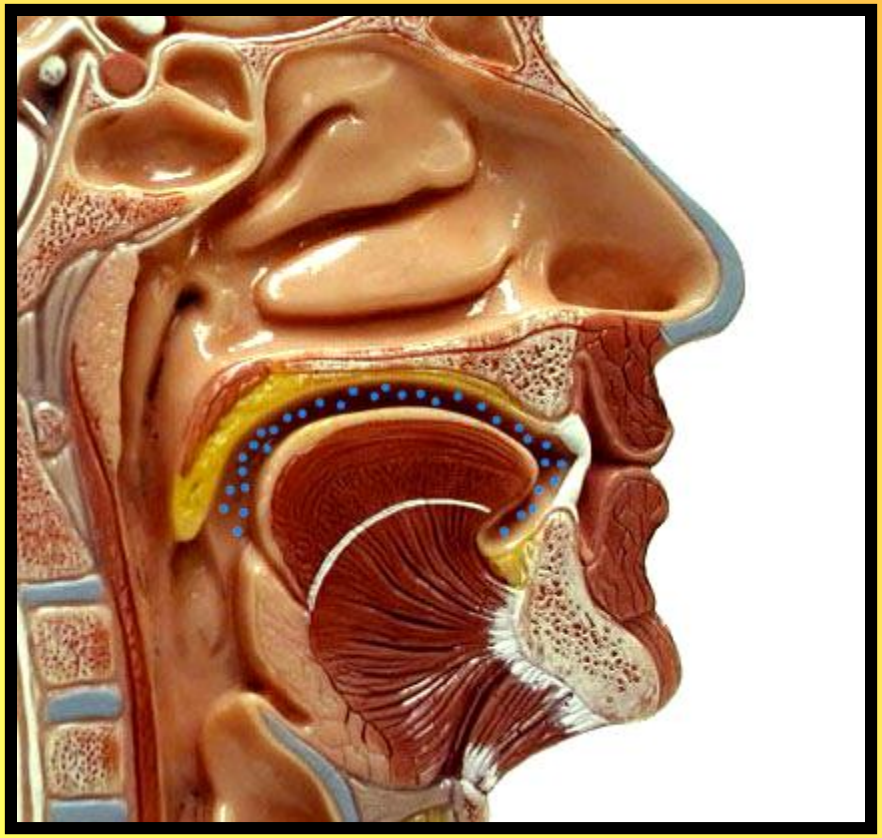
HUMAN DIGESTION



HUMAN DIGESTION



THE MOUTH: functions

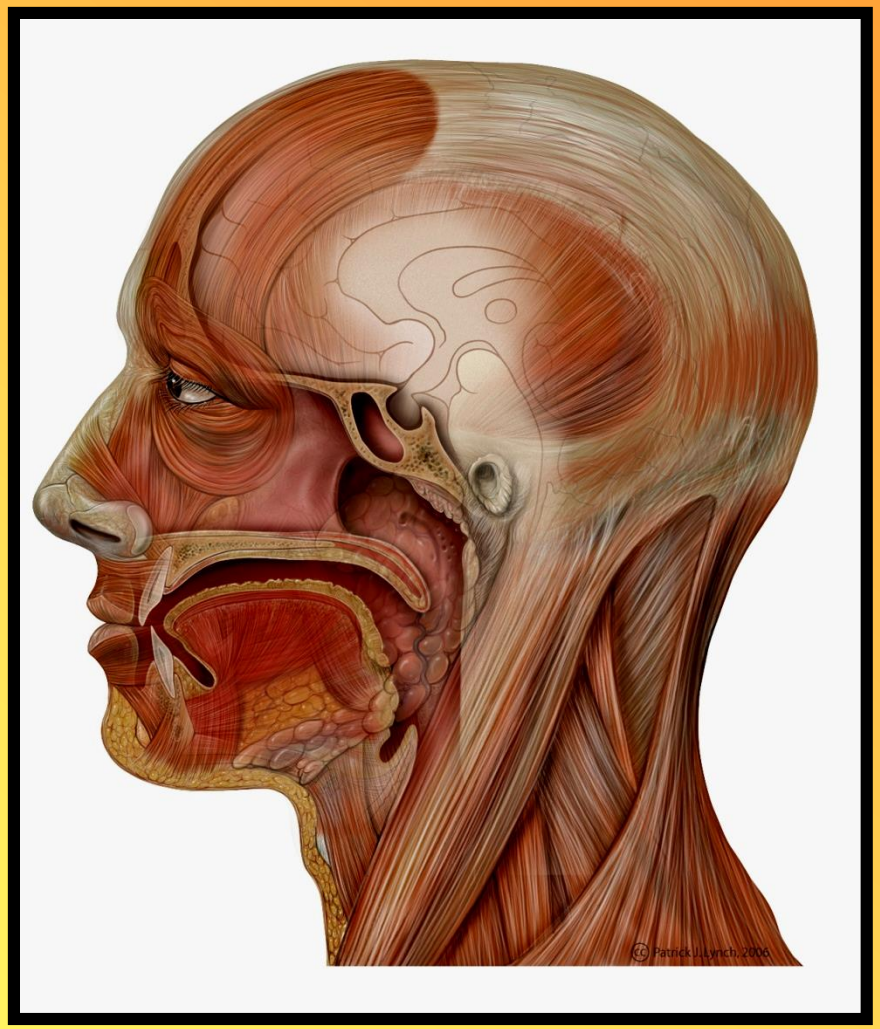


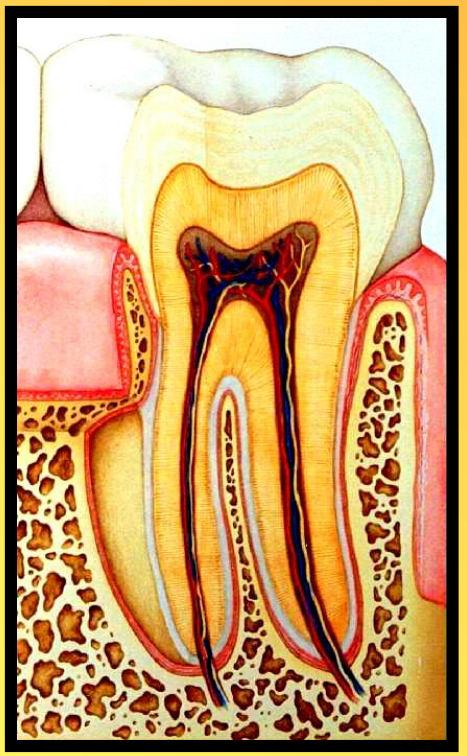
1. **Ingestion**

2. To begin **digestion**:
   a) mechanical
   b) chemical

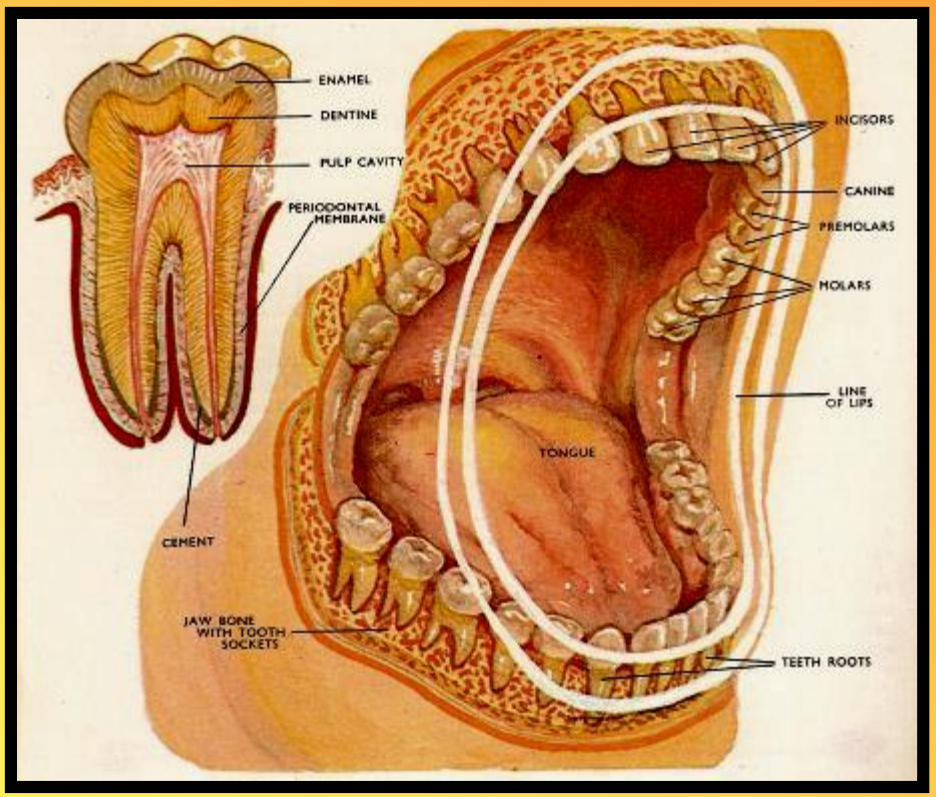
THE MOUTH: structures

- **Teeth**
- **Salivary Glands**
- **Tongue**





THE MOUTH: structures



- **Teeth**
- **Takes in the food**
- **Begins mechanical digestion by breaking the food in to smaller pieces.**


"Bean"

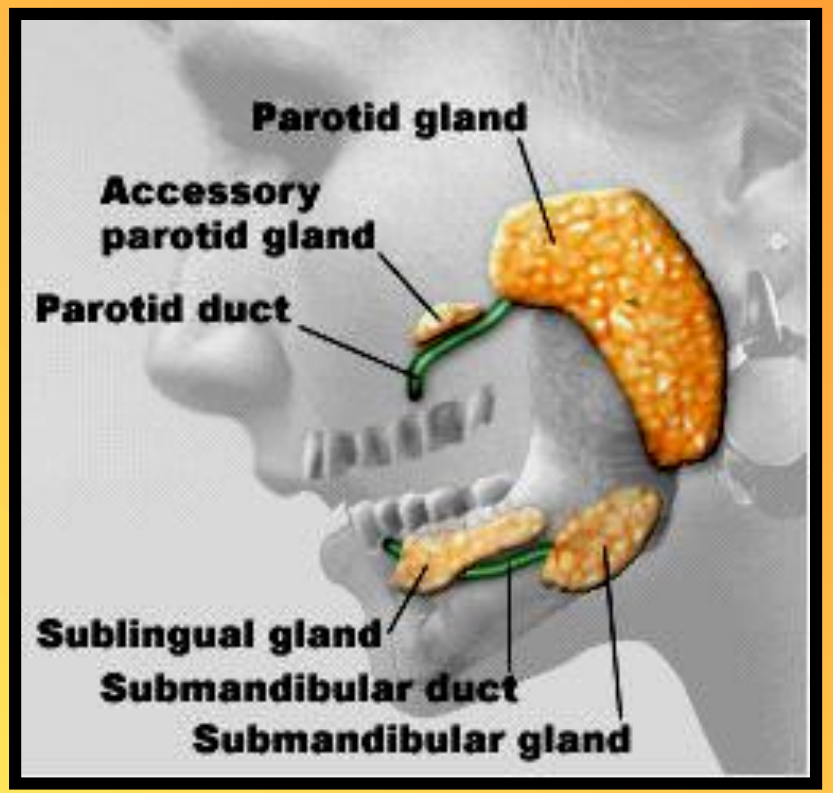

Distal
Mesial
Occlusal
Lingual
Labial


YOU ANIMAL!

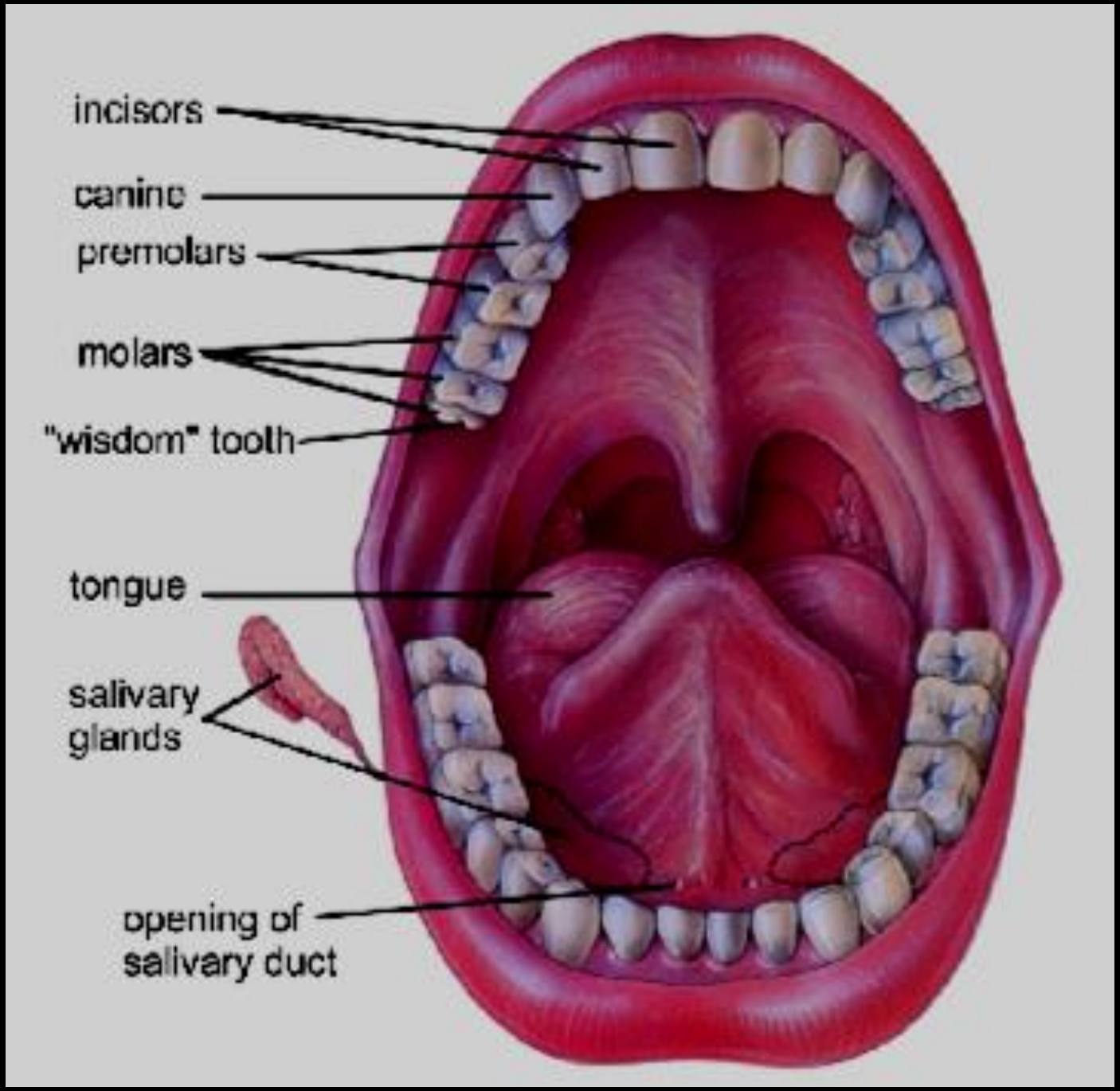
THE MOUTH: structures

- **Salivary Glands:** ducted glands that produce saliva, which:

1) **Liquifies** food
2) Contains **amylase** and begins **chemical digestion**
3) **Lubricates** and softens the **BOLUS** of food.
4) Enzymes in saliva **kill bacteria**



Cooked Starch —**SALIVARY AMYLASE**→ maltose


incisors
canine
premolars
molars
"wisdom" tooth
tongue
salivary glands
opening of salivary duct

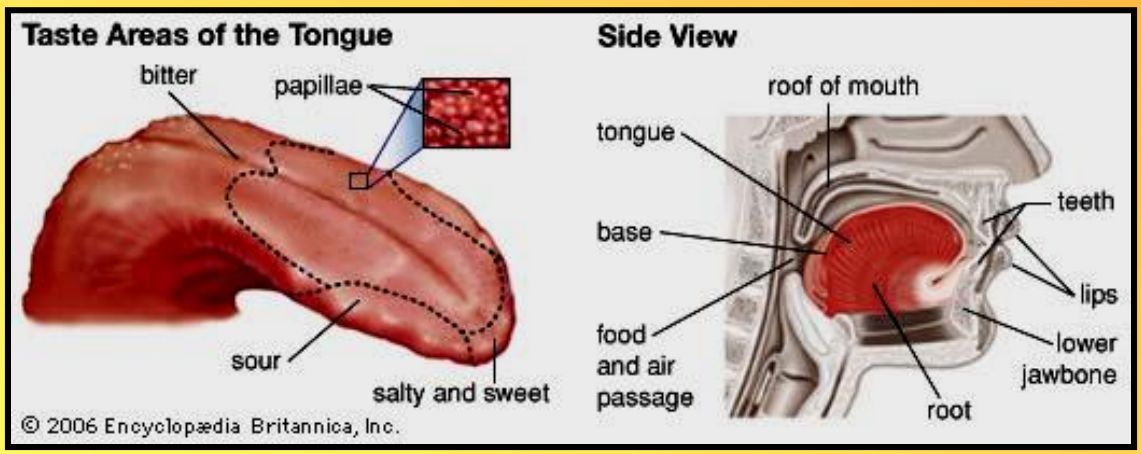
THE MOUTH: structures

- **Tongue: 3 functions**

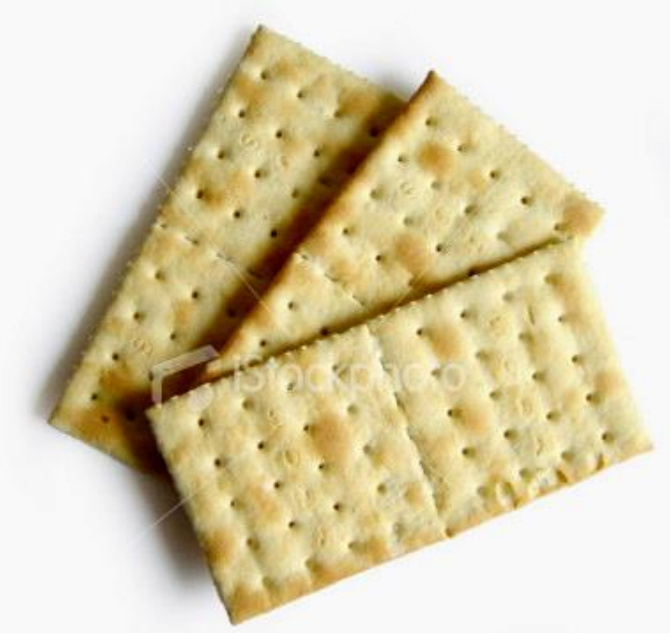
1. Contains taste buds, at the back of the tongue. This protects us against poisons as they most often taste bitter.

2. Moves the food around in the mouth and towards the teeth to mix the food and the saliva.

3. Pushes the BOLUS of the food to the back of the throat to the 'swallow reflex center'.



LET'S CHEW!



PHARYNX

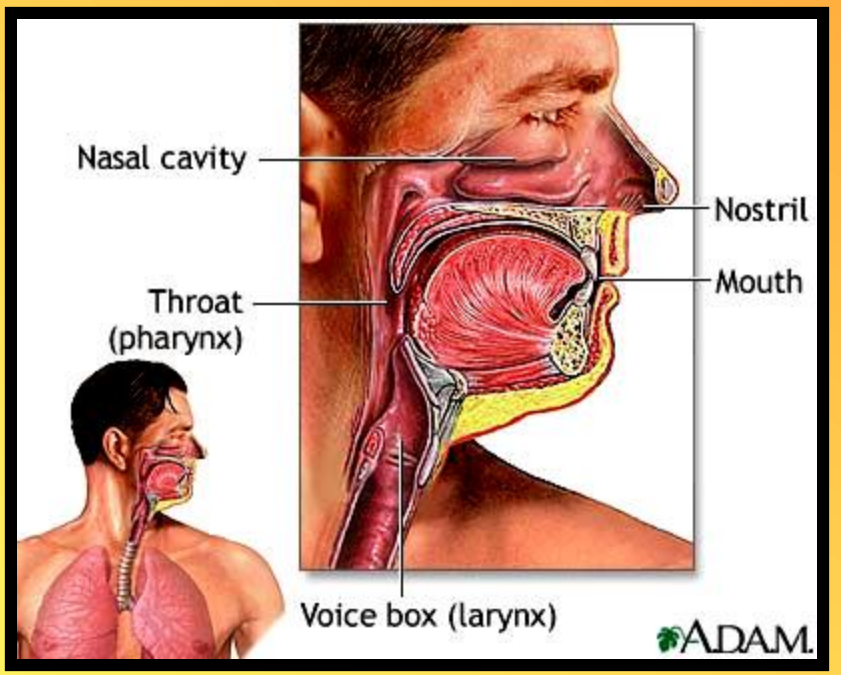
Structure: the **back of the throat**. Opens to the respiratory and digestive systems.

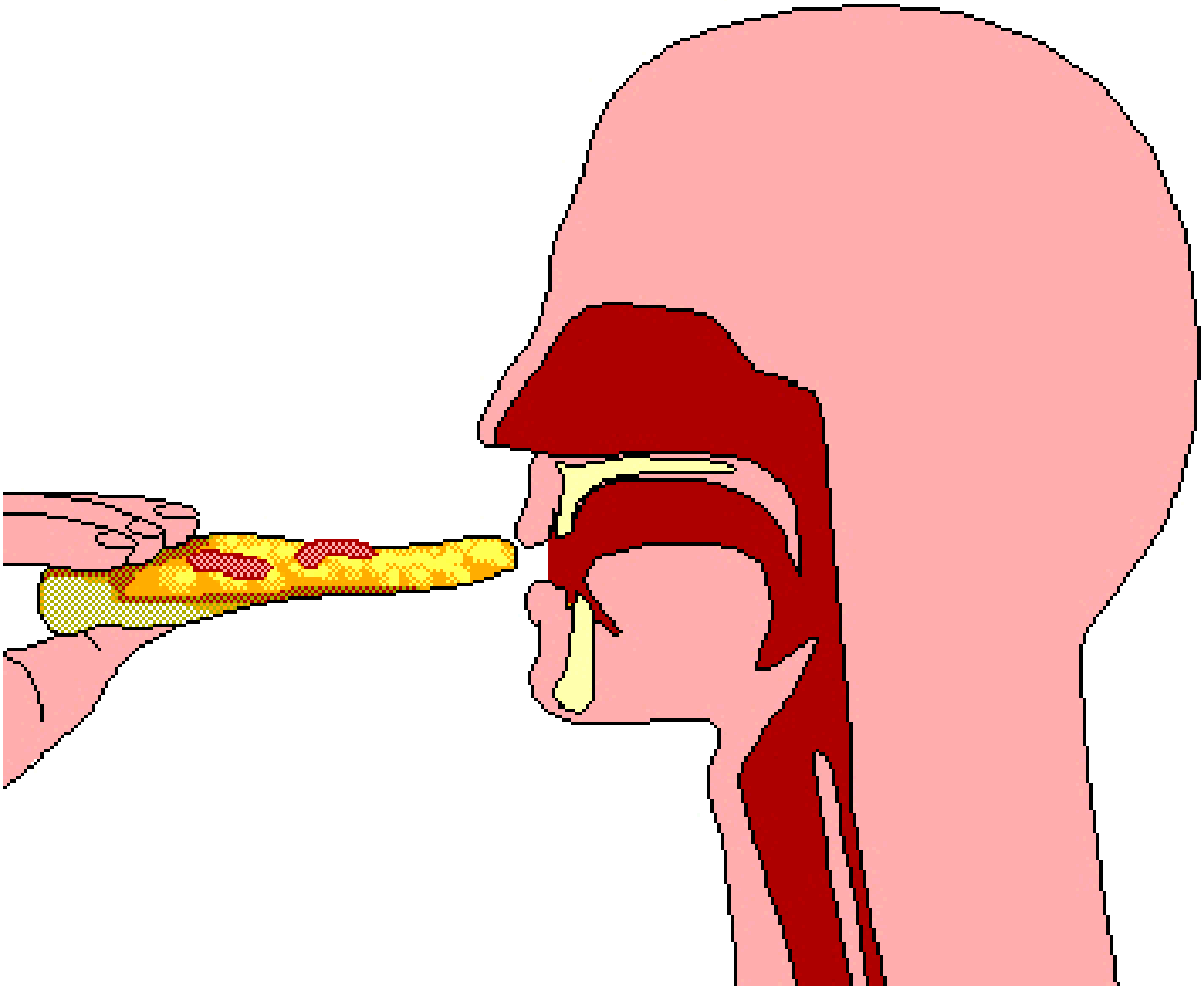
Function: When food is placed on the 'reflex center' by the tongue, the following things happen:

a) the **soft palate covers** the opening to the **nose**

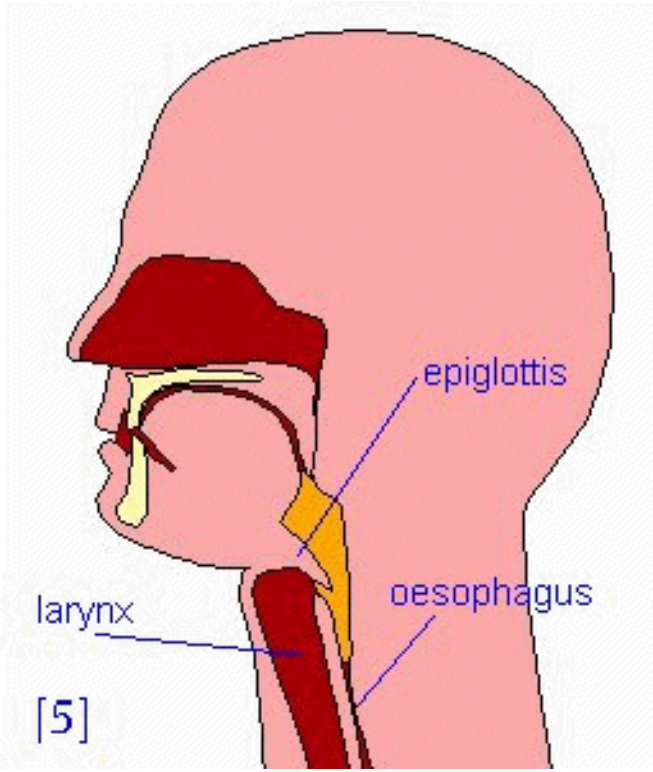
b) the **epiglottis covers the trachea**

c) **peristalsis** of the esophagus begins





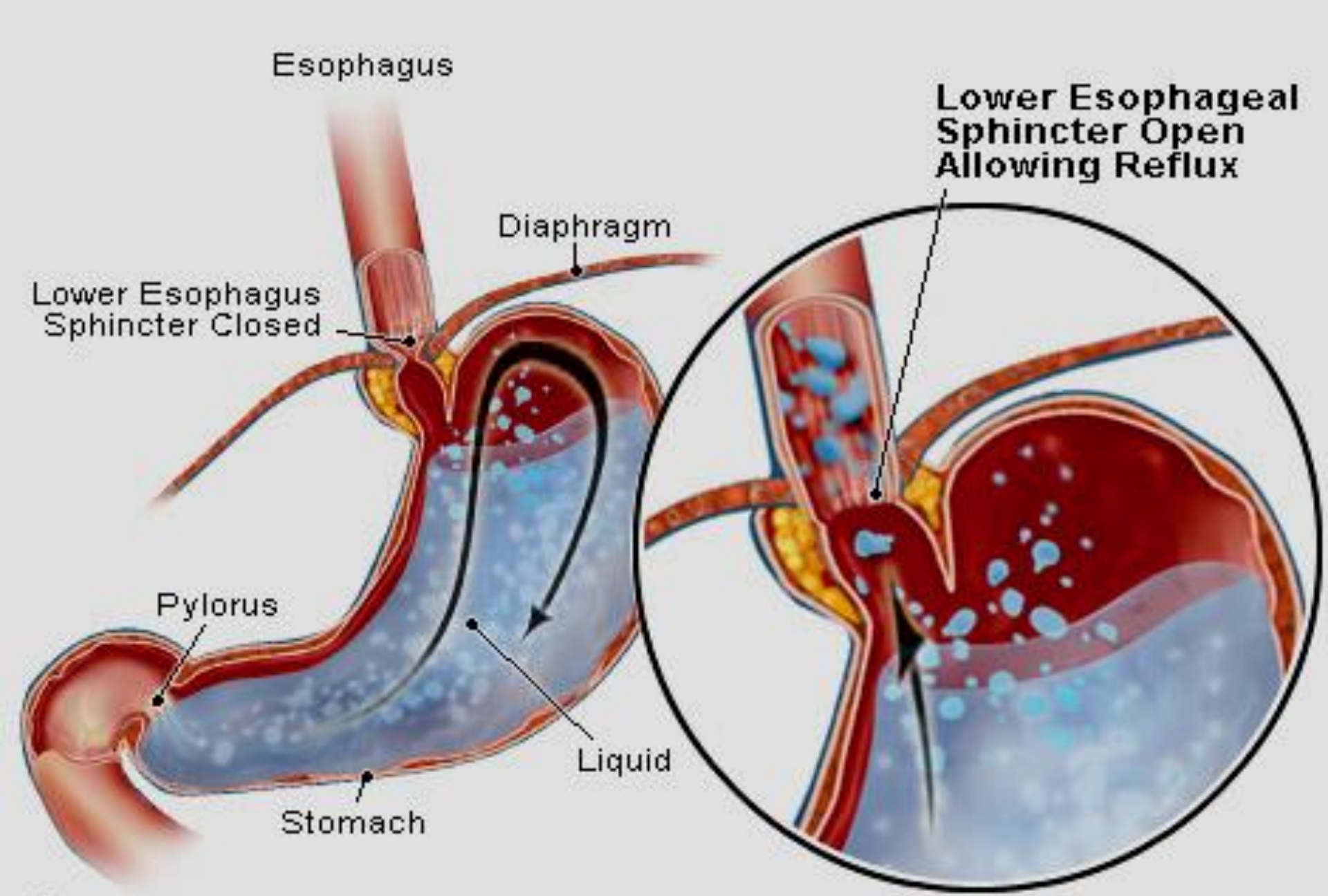
EPIGLOTTIS



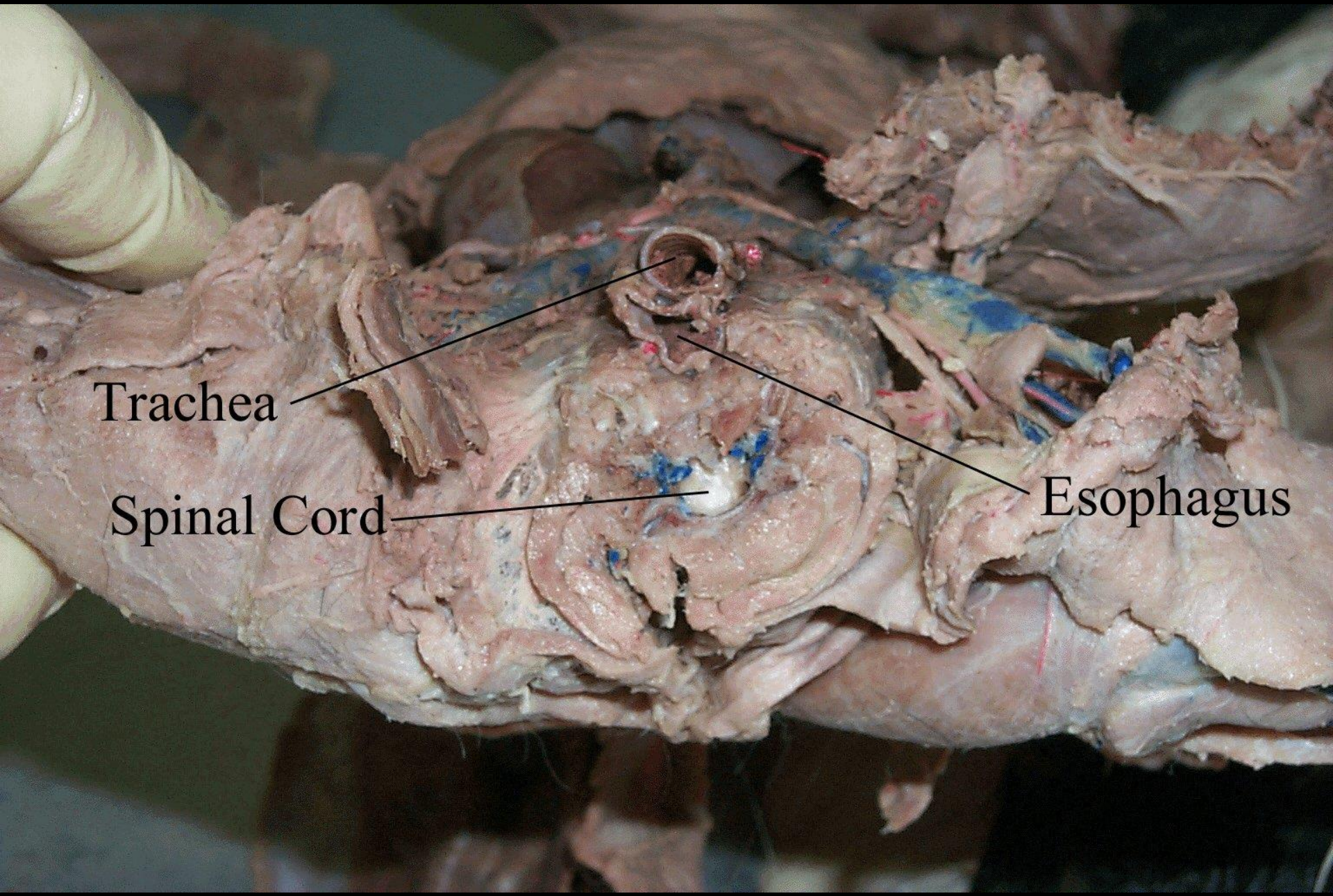
Covers the trachea (lungs) when we swallow food

ESOPHAGUS: structure

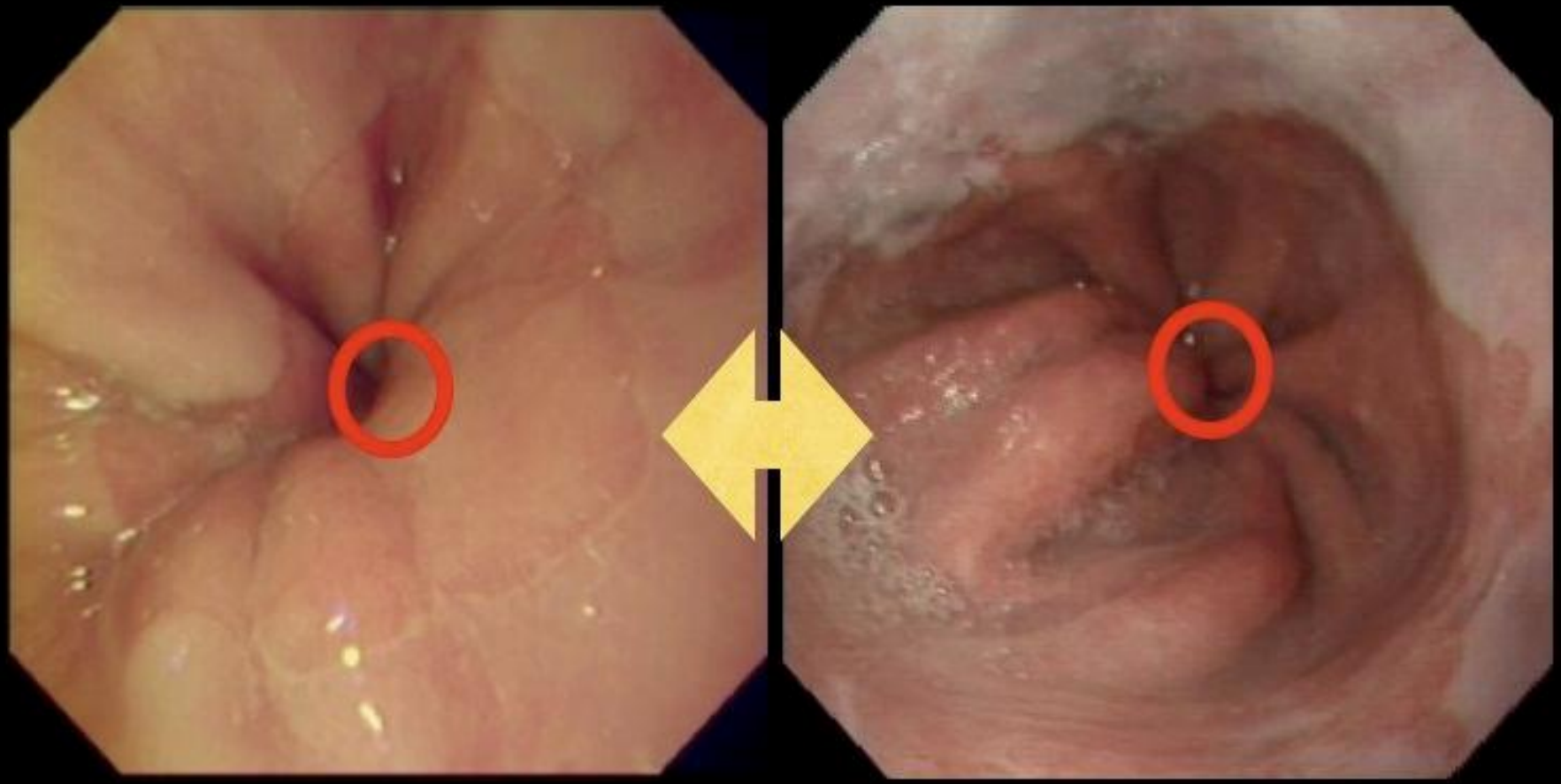
- **30cm** long tube
- Connects the pharynx to the stomach.
- **No digestion** occurs.
- At the beginning of the stomach, there is a ring of muscle called the **cardiac sphincter** which stops food from re-entering the esophagus.



Gastroesophageal Reflux


Trachea
Spinal Cord
Esophagus

The esophagogastric junction can not be assessed by endoscopy, but requires histopathology

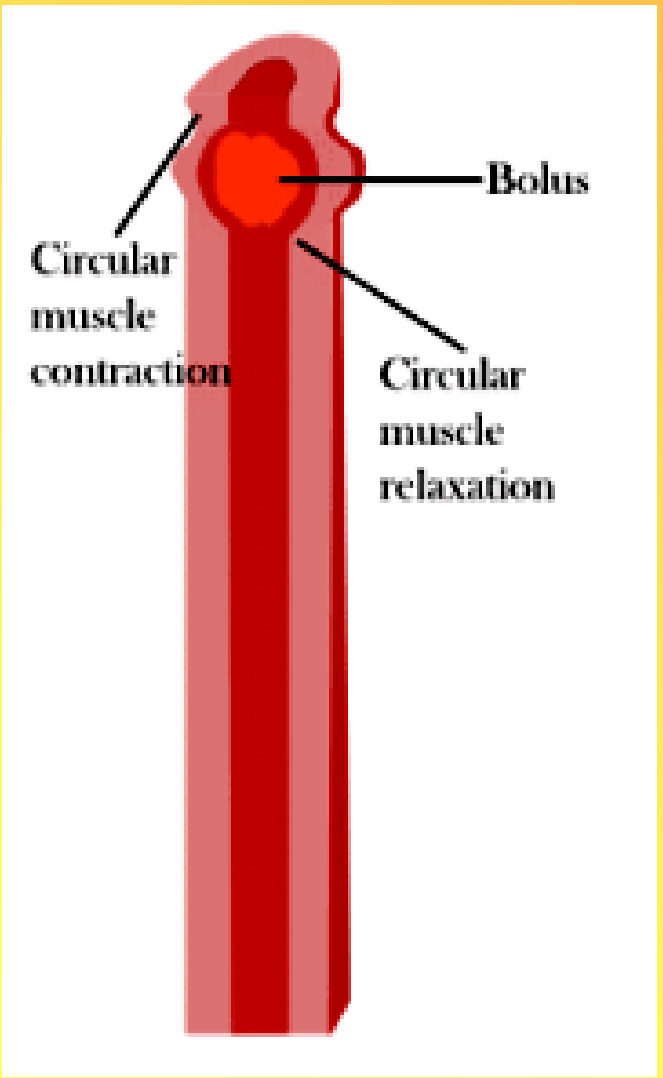


rise of endoscopic gastric folds

histologic „Junction“: transition from CLE to oxyntic mucosa!

(Figure 13)

ESOPHAGUS: function



Food moves through the esophagus by a process called PERISTALSIS.

This is a slow, rhythmic contraction that pushes the BOLUS along.

***Peristalsis continues down the length of the* entire digestive tract.**

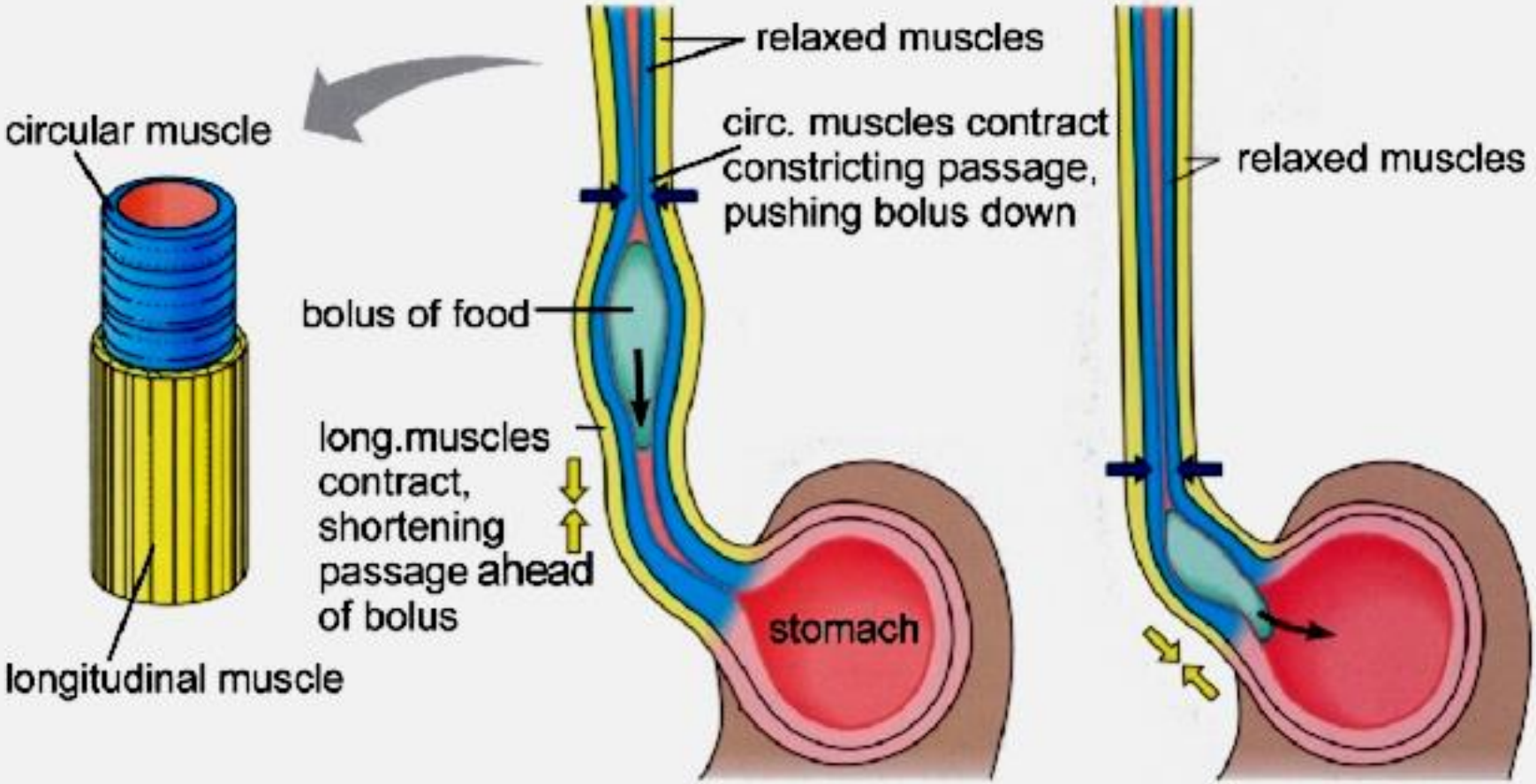
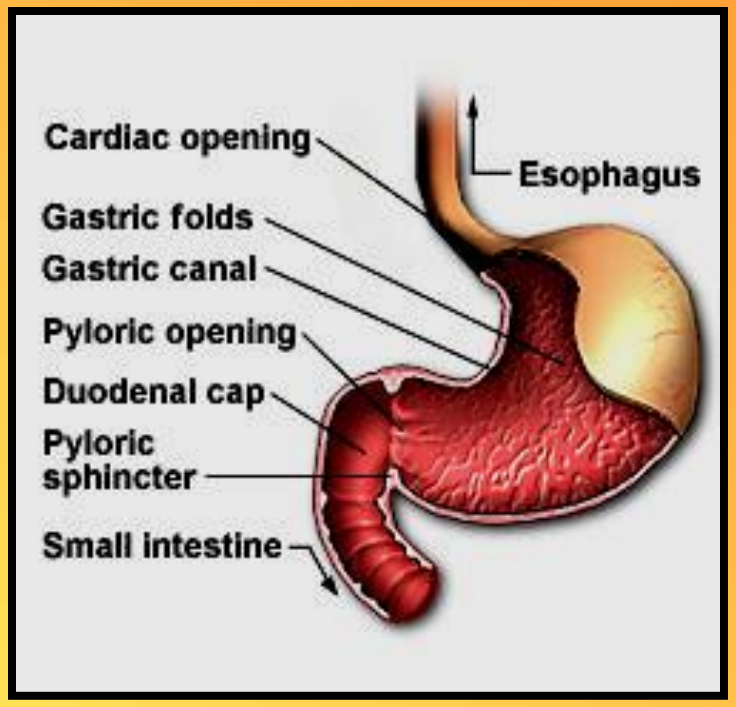


Fig. 21.7. Peristalsis pushes food down the esophagus to the stomach

STOMACH: structure

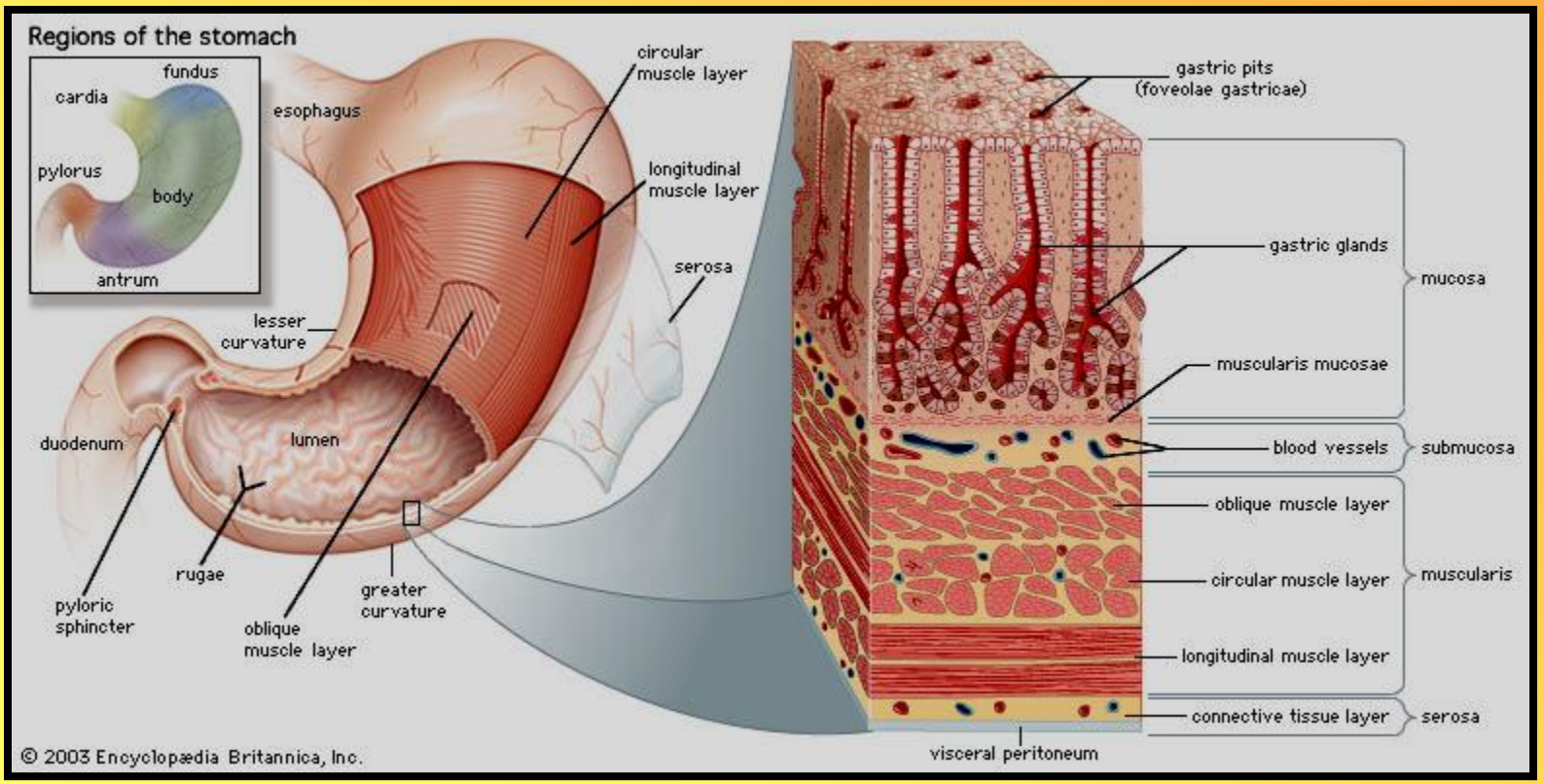
- It is a ‘J’ shaped organ.
- It can hold **2.3 Litres** of food.
- It has **3 layers of muscle**
  - Circular
  - Longitudinal
  - Transverse



STOMACH: function

Churns food and liquifies it (mechanical digestion).

This process is aided by the ridges in the mucosa layer of the stomach.



RUGAE

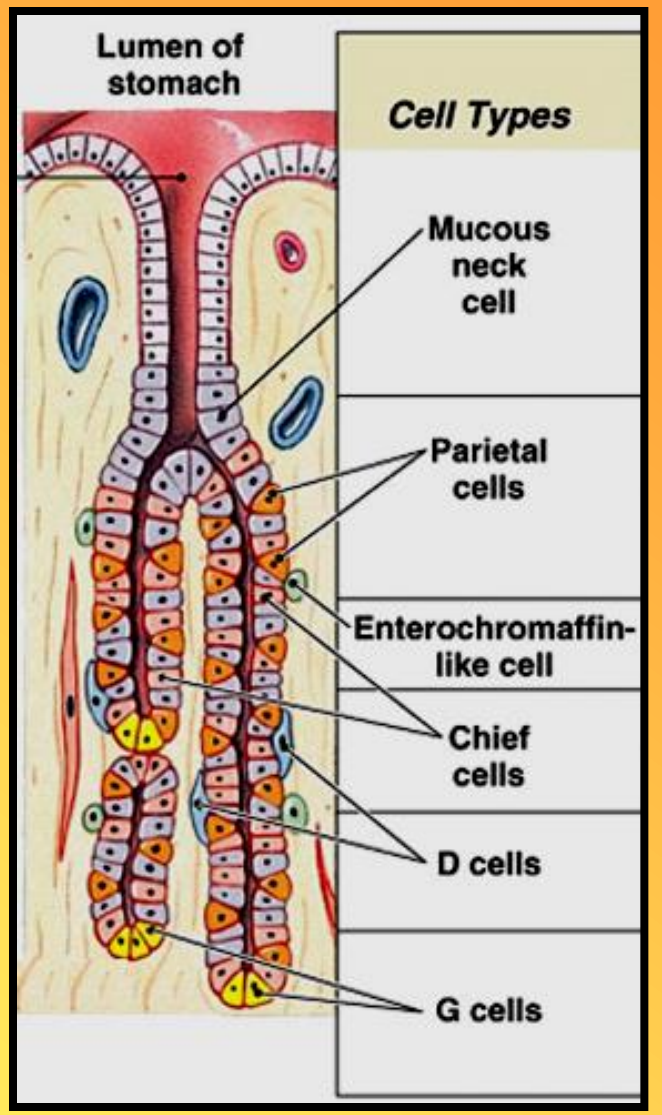
STOMACH: function

Begins the chemical digestion of proteins with 3 cell types

1.One type makes the inactive enzyme PEPSINOGEN.
These cells have lots of mitochondria for active transport.

2. Chief Cells produce 3M Hydrochloric Acid (HCl).

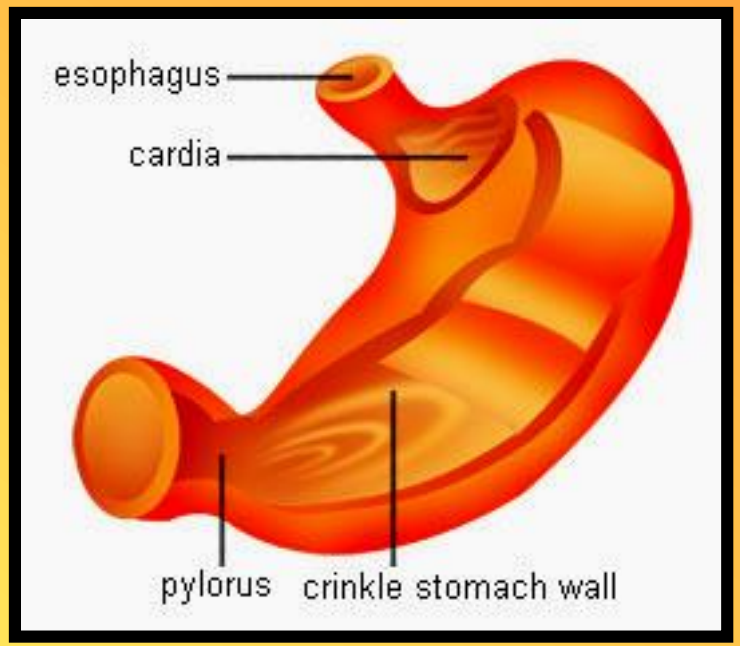
3. Mucous cells produce mucous to protect the mucosa cells (inner stomach lining) from the HCl.



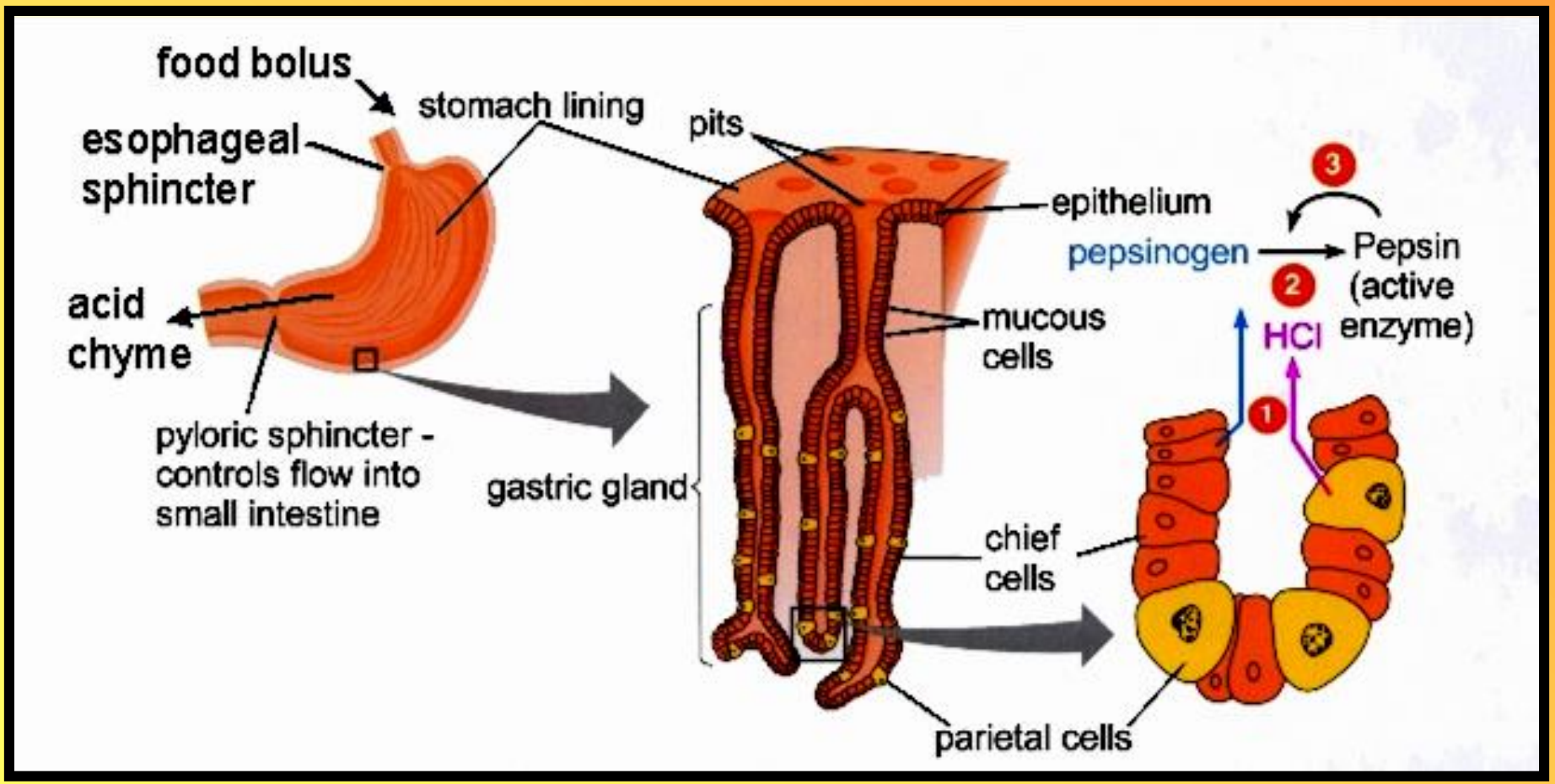
GASTRIC JUICES

Gastric Juices contain:

1. **Pepsinogen**
2. **Hydrochloric Acid**
3. **Mucous**



STOMACH: function



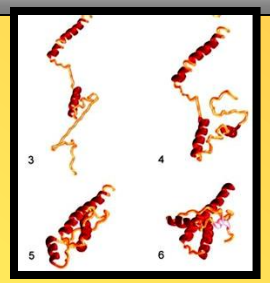
STOMACH: function

Hydrochloric acid (HCl) is released **when proteins enter** the stomach. This creates a **pH of 2.5**.

This **transforms pepsinogen into** an **active** hydrolytic enzyme **PEPSIN**, which begins the digestion of the proteins into smaller amino acid chains.

Pepsinogen → **HYDROCHLORIC ACID** → **PEPSIN**

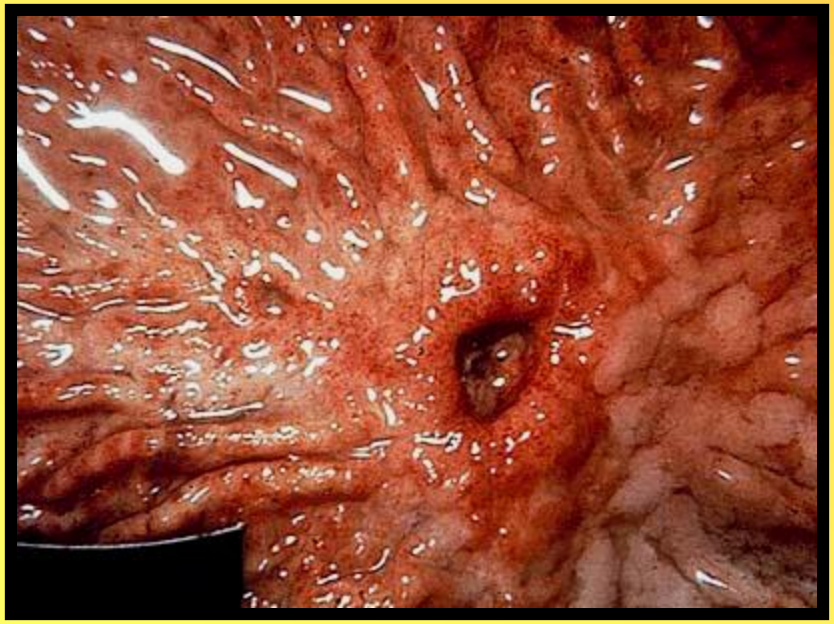
Protein → smaller polypeptides

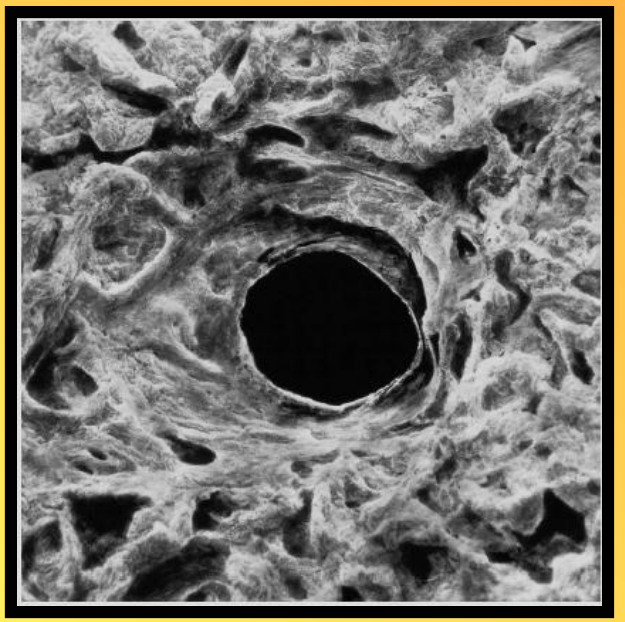


STOMACH: function

HCl will also be released, however, when you are **stressed** and there is chronic stimulation of your autonomic nervous system.

This dissolves the mucosa layer of the stomach lining, and results in an **ULCER**.

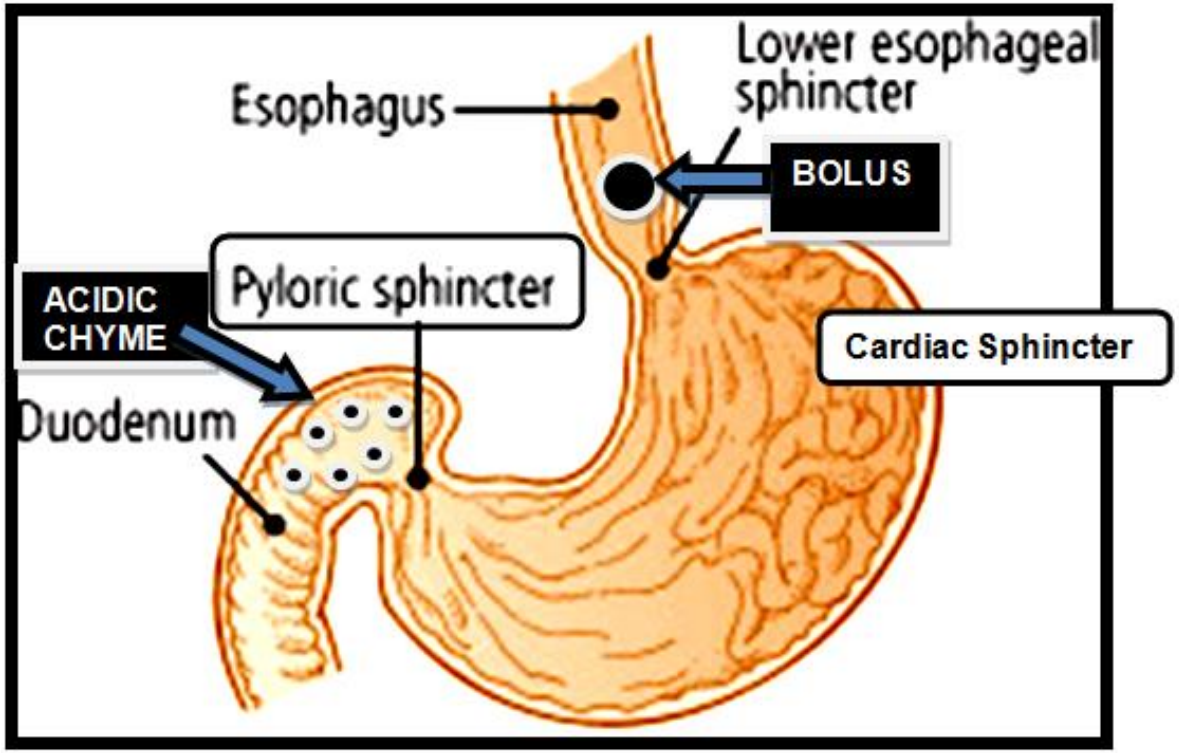


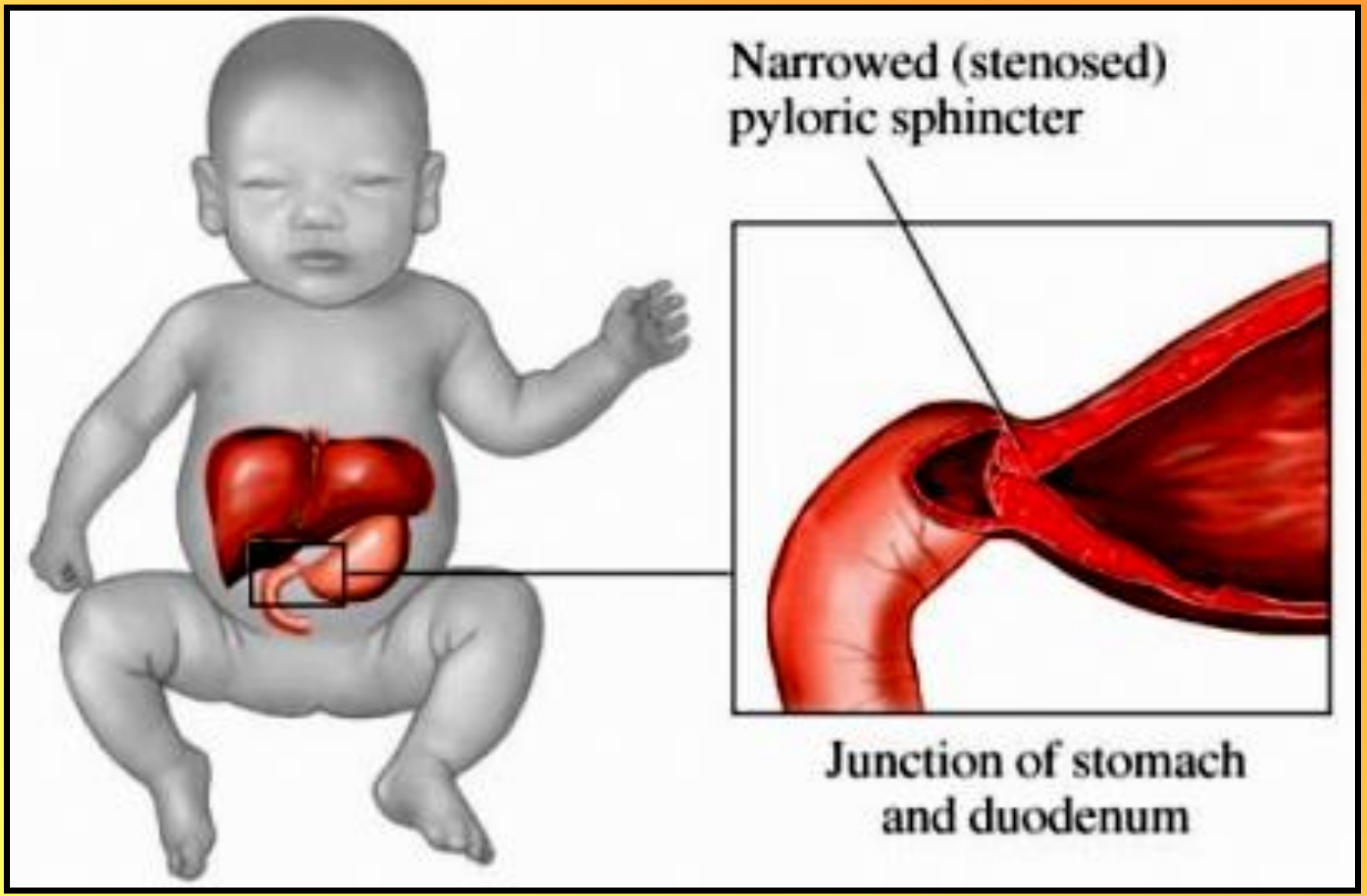


STOMACH: function

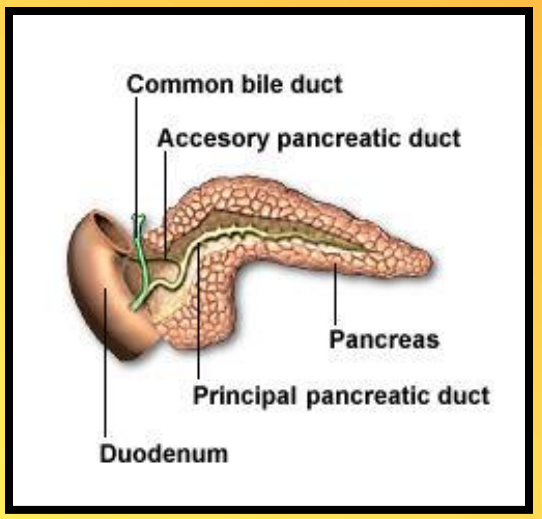
The stomach empties within **4 hours**. What leaves the stomach is an acidic liquid called **CHYME**.

The **pyloric sphincter** at the base of the stomach will meter out the chyme into the duodenum at a **slow, controlled rate**.





Almost all cases of pyloric stenosis happen in very young babies (usually 3-12 weeks old). This problem happens about 2-4 times out of every 1,000 births. It is much more common in males than in females.

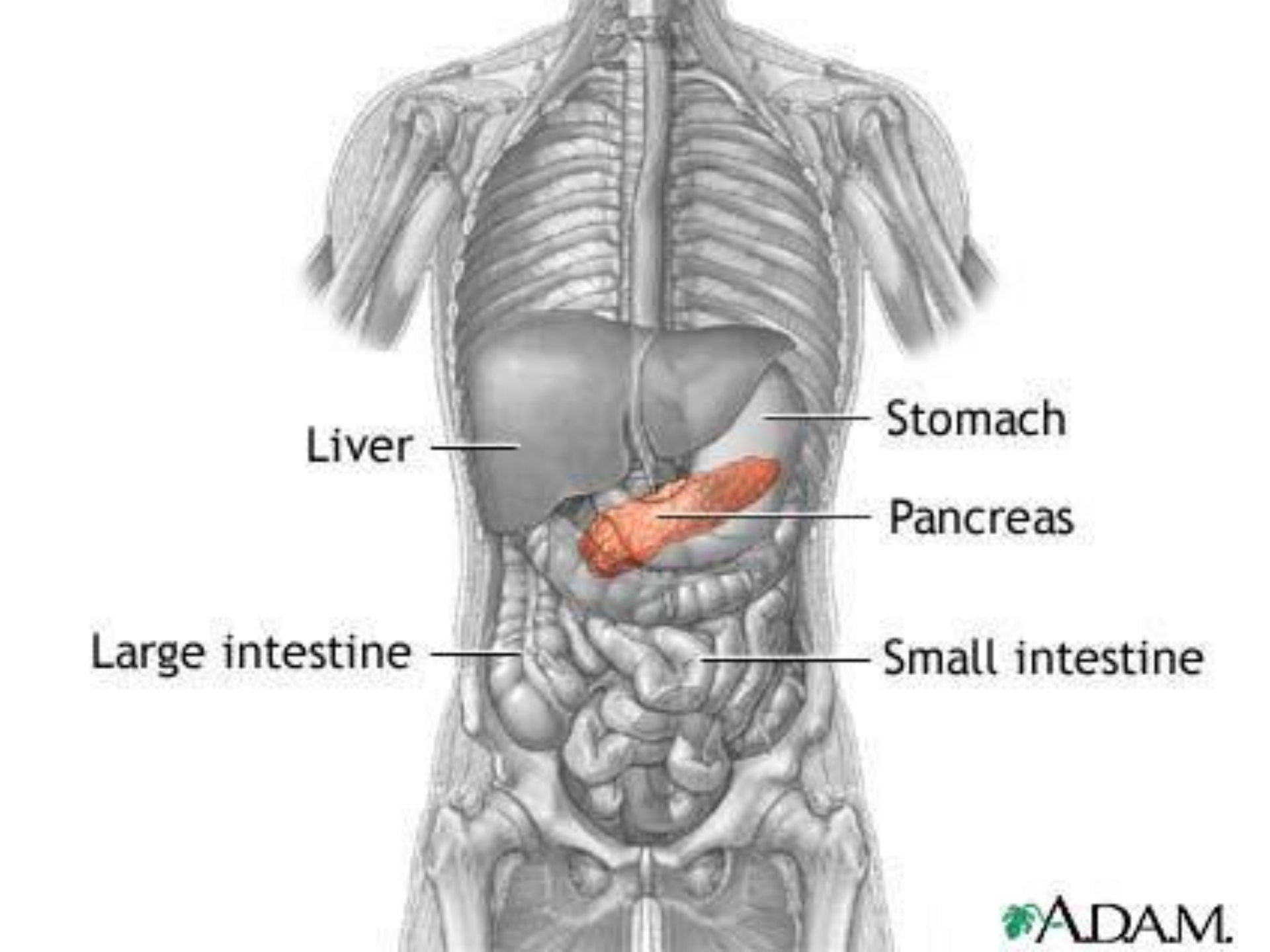


PANCREAS

The pancreas is a dual organ

1. **Half of it is an ENDOCRINE GLAND which makes hormones insulin and glucagon.**

2. **Half of it is an EXOCRINE GLAND which make the enzymes to digest carbs, fats, proteins and nucleic acids.**


Liver
Stomach
Pancreas
Large intestine
Small intestine
A.D.A.M.

PANCREAS: endocrine gland

Insulin and Glucagon are made by specialized cells of the pancreas called '**the islets of Langerhans**.

If there is **high blood sugar** (more than 0.1% glucose), the pancreas will release **insulin**.

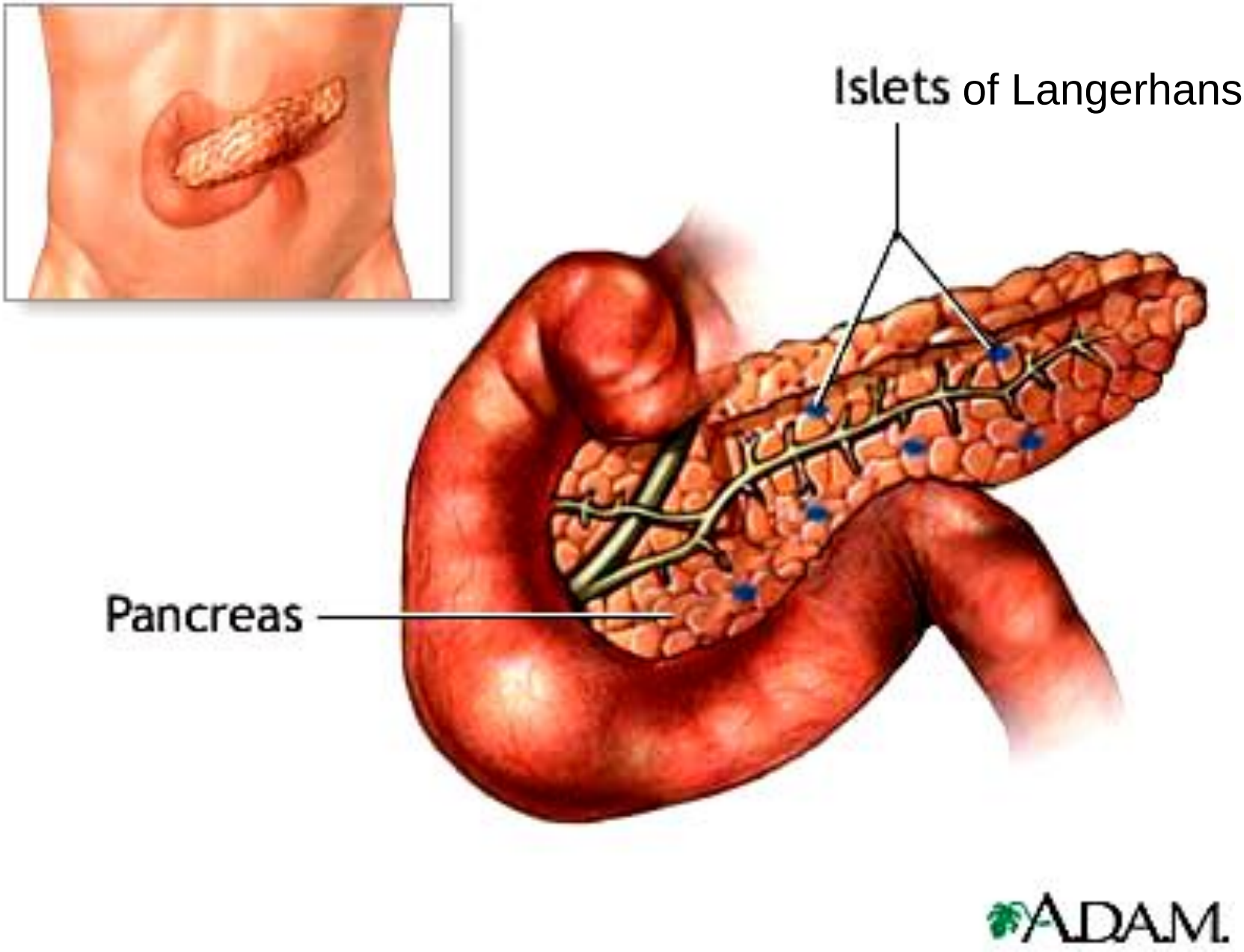
insulin removes glucose from the blood by:

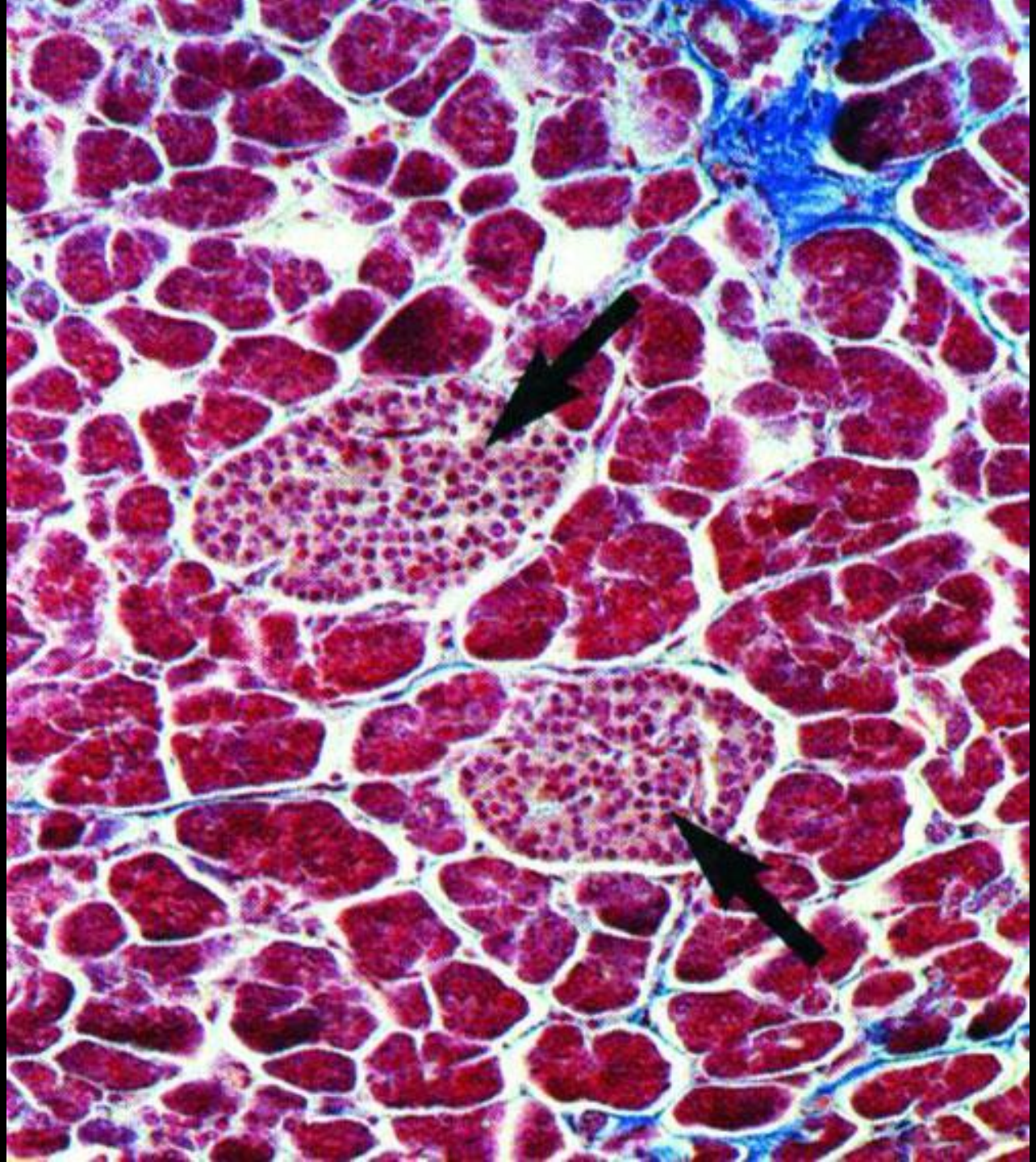
1. causes the liver to **store it as glycogen**
2. promotes **formation of fats**
3. causes **cells to absorb glucose**

If there is **low blood sugar** (less than 0.1% glucose), the pancreas will release **glucagon**.

glucagon adds glucose back into the blood by:

causes the liver to break down glycogen and **release glucose**

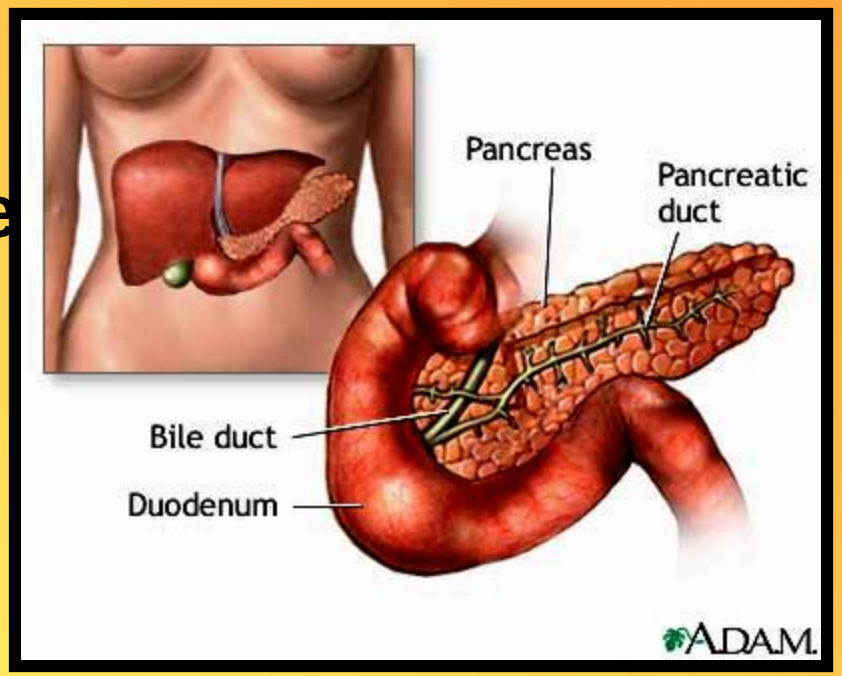

Islets of Langerhans
Pancreas
A.D.A.M.



PANCREATIC JUICES

Pancreatic Juices contain (SALT + N):

1. **Sodium Bicarbonate**
2. **Pancreatic Amylase**
3. **Lipase**
4. **Trypsin**
5. **Nucleases**

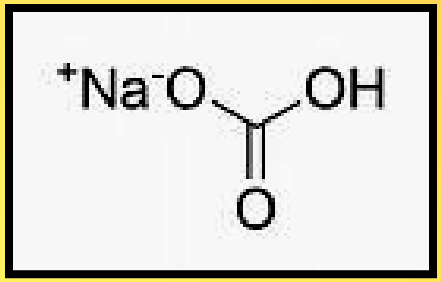


PANCREAS: exocrine gland

The pancreatic juices include **SALT + N**:

1. **Sodium Bicarbonate** ($NaHCO_3$) is a base and is released to **neutralize** the stomach acid.

Chyme pH 2.5 → **SODIUM BICARBONATE** → pH 8.5

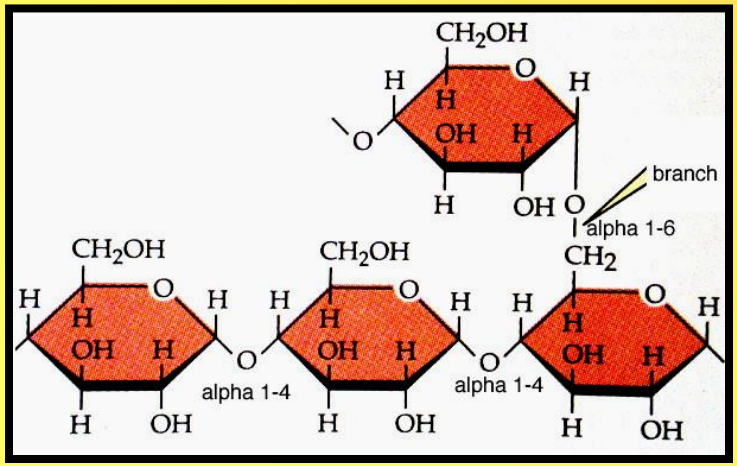


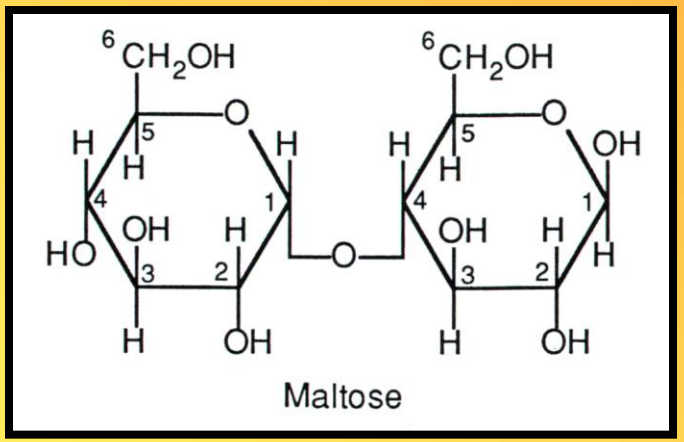
PANCREAS: exocrine gland

The pancreatic juices include SALT + N:

2. Amylase is an enzyme that converts uncooked carbohydrates to **maltose**.

Uncooked Starch → **PANCREATIC AMYLASE** → Maltose



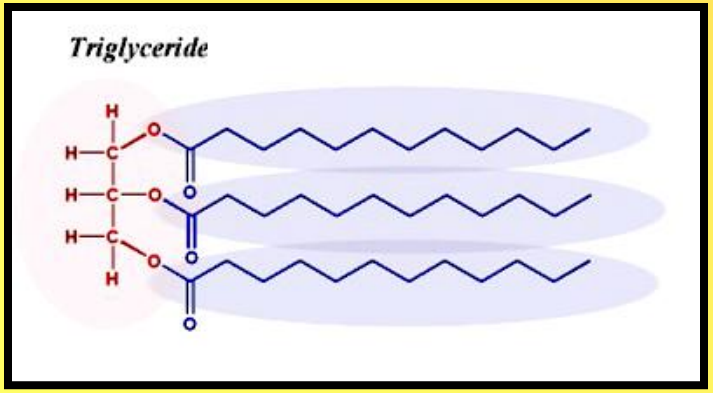


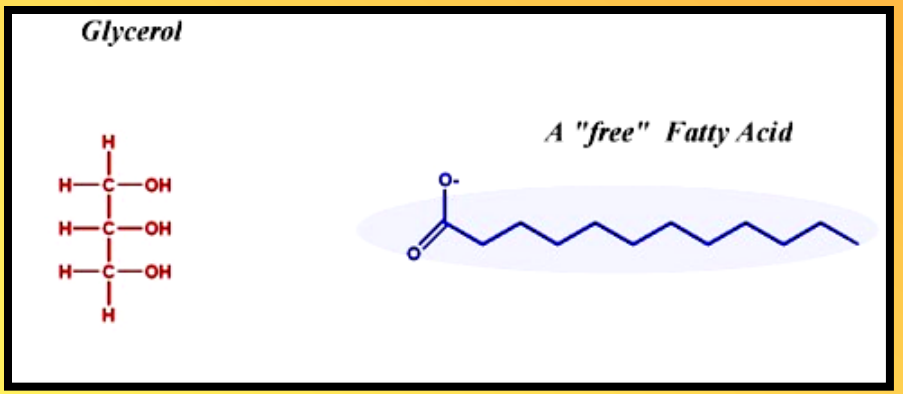
PANCREAS: exocrine gland

The pancreatic juices include SALT + N:

3. **Lipase** is an enzyme that converts lipids into **fatty acids and glycerol**

Lipids —(**LIPASE**)→ Fatty Acids & Glycerol



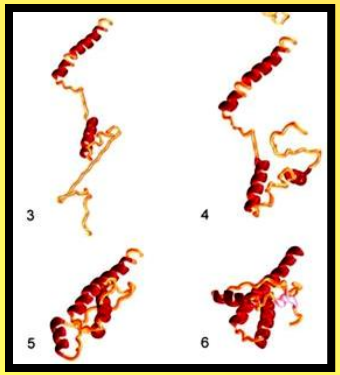


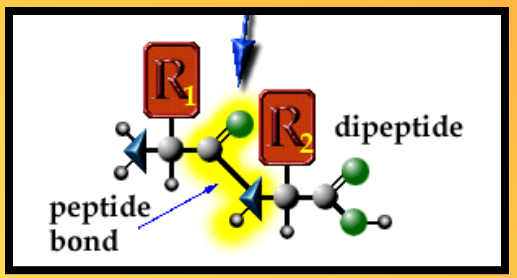
PANCREAS: exocrine gland

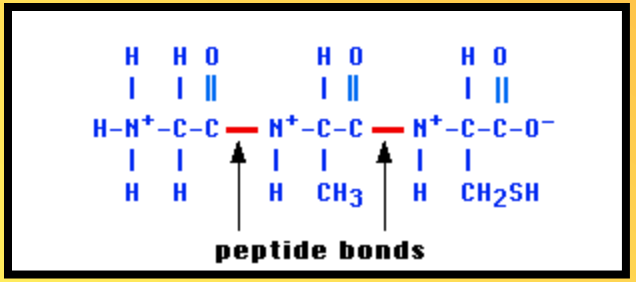
The pancreatic juices include SALT + N:

4. **Trypsin** is an enzyme that converts small protein chains into **dipeptides and tripeptides**.

Small polypeptides —**TRYPSIN**→ Di, Tri peptides





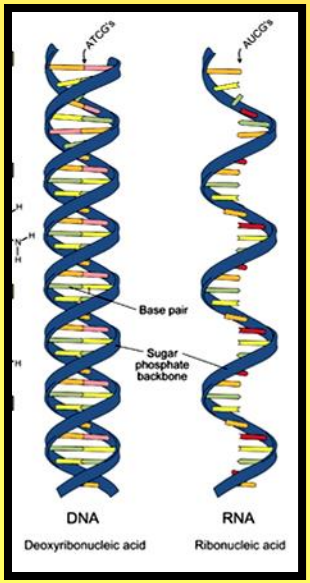


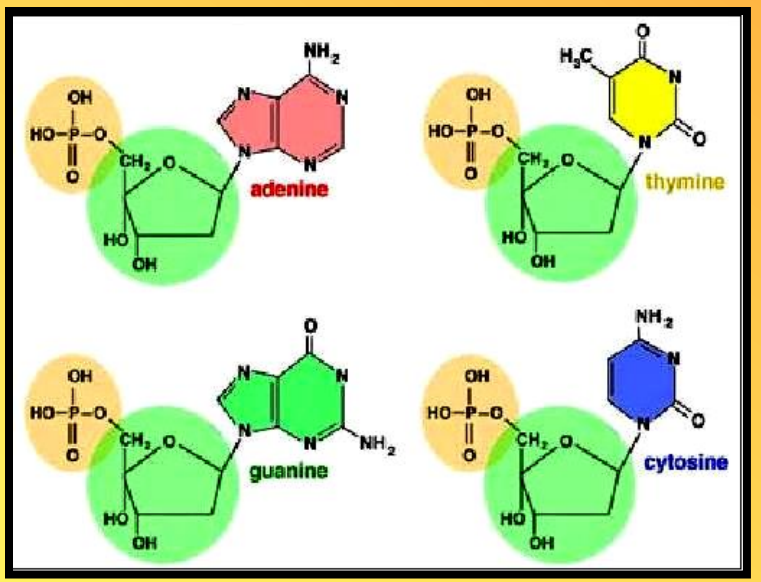
PANCREAS: exocrine gland

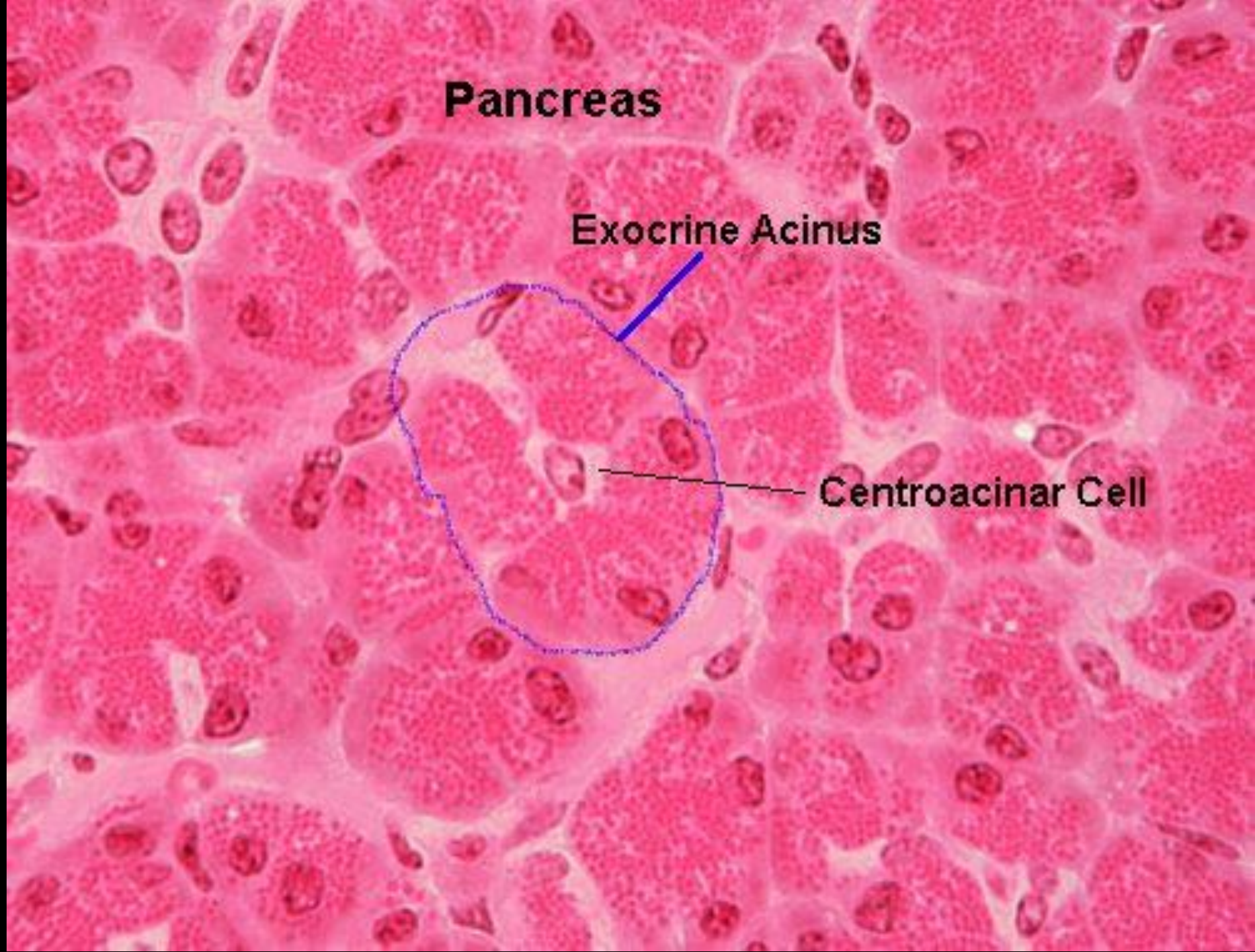
The pancreatic juices include SALT + N:

5. **N**ucleases are enzymes that convert nucleic acids (DNA and RNA) into **nucleotides**.

Nucleic Acids —**NUCLEASES**→ Nucleotides






Pancreas
Exocrine Acinus
Centroacinar Cell

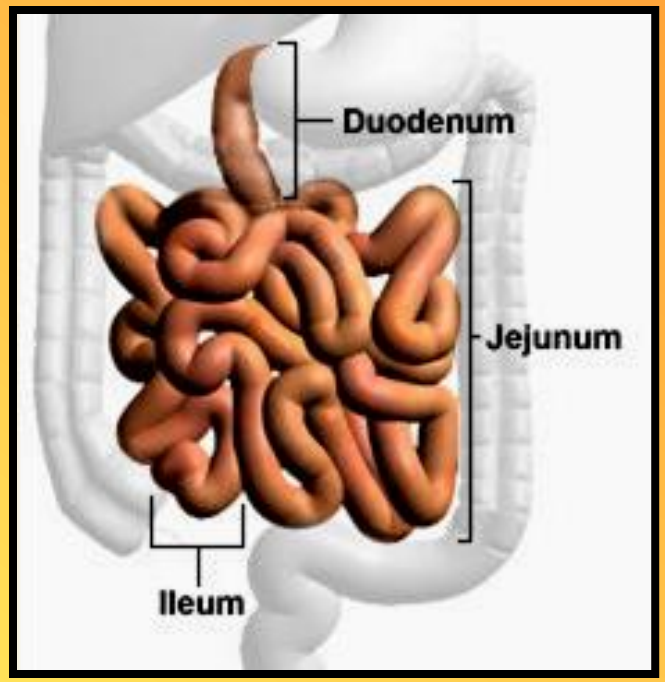
SMALL INTESTINE: structures

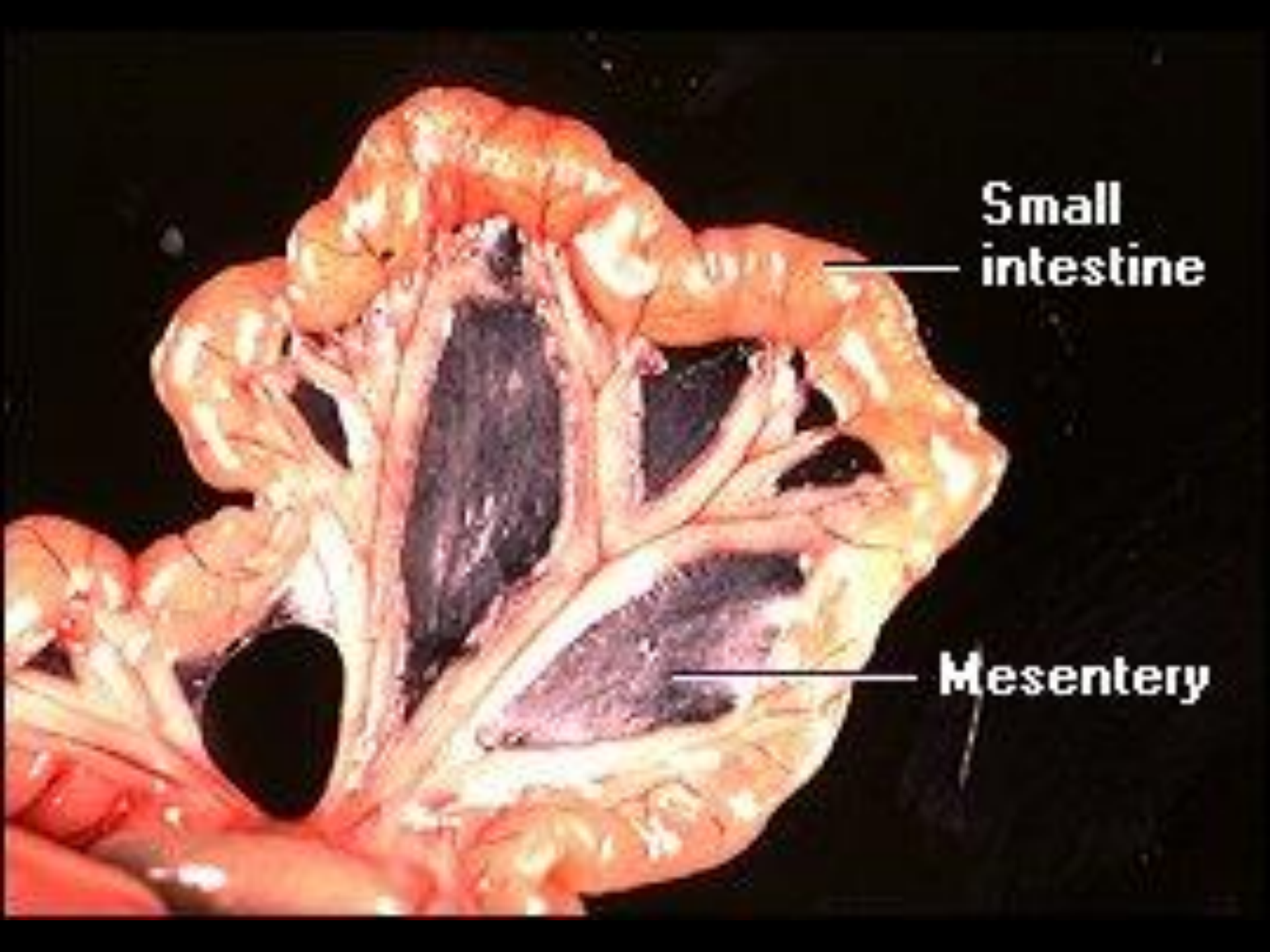
There are 3 regions:

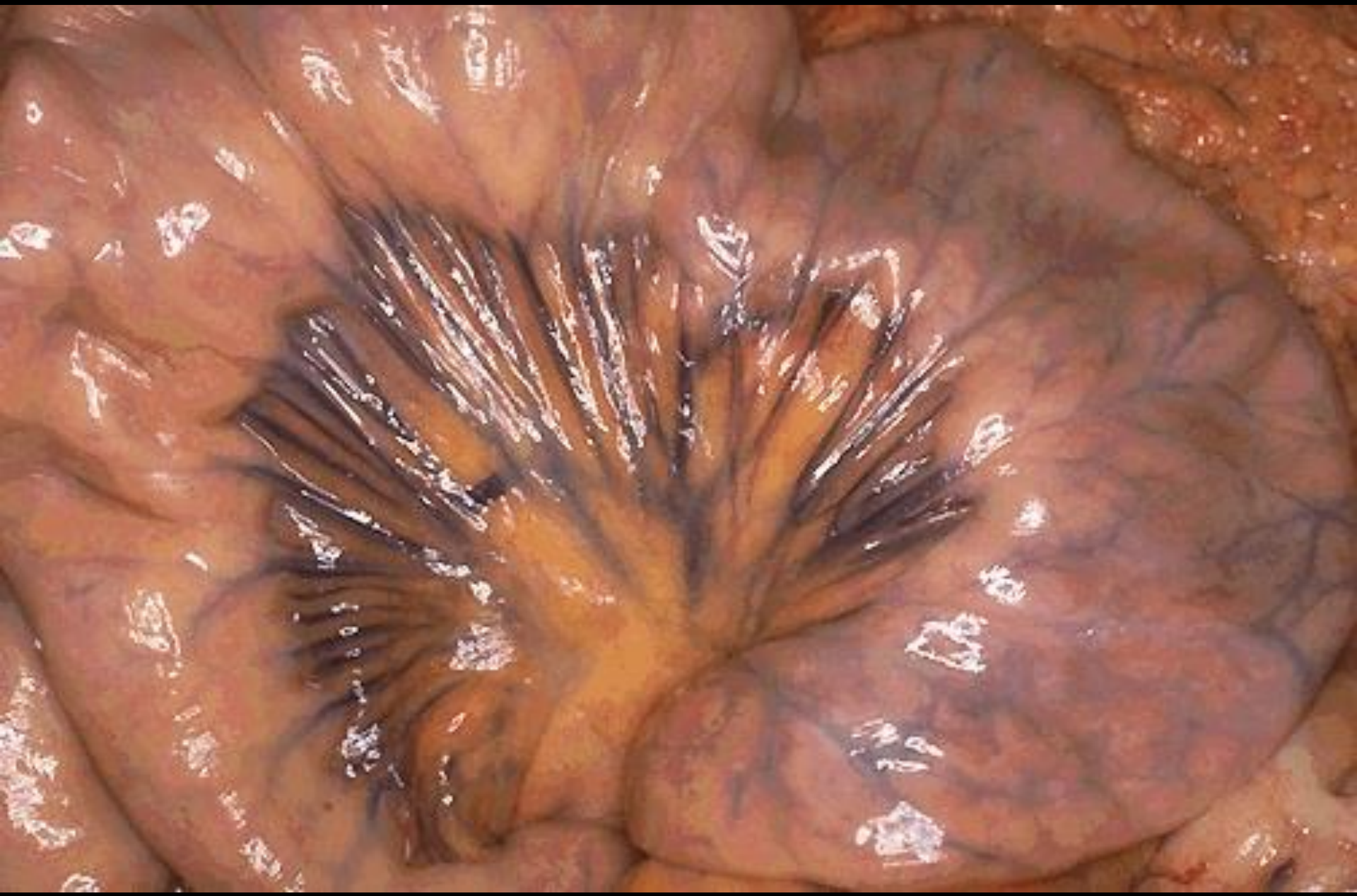
1. **Duodenum**: completes the chemical digestion

2. **Jejenum**: finishes digestion and begins absorption

3. **Ileum**: this is the longest section and its function is to absorb all of the nutrients into the circulatory and lymphatic systems.




Small intestine
Mesentery

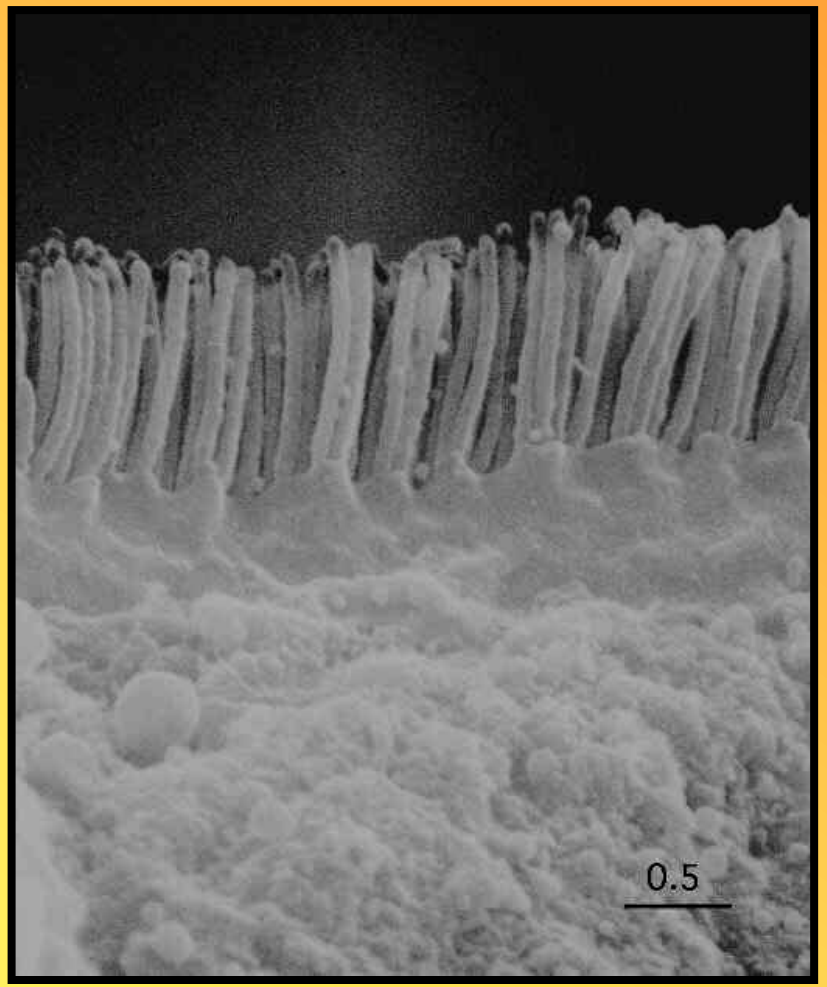


SMALL INTESTINE: structures

The small intestine has an increased rate of absorption (speeds up diffusion) due to its **highly convoluted walls** with a **very large surface area**.

There are folds in the mucosa layer of the small intestine called **VILLI**.

These villi also have smaller folds called **MICROVILLI**.



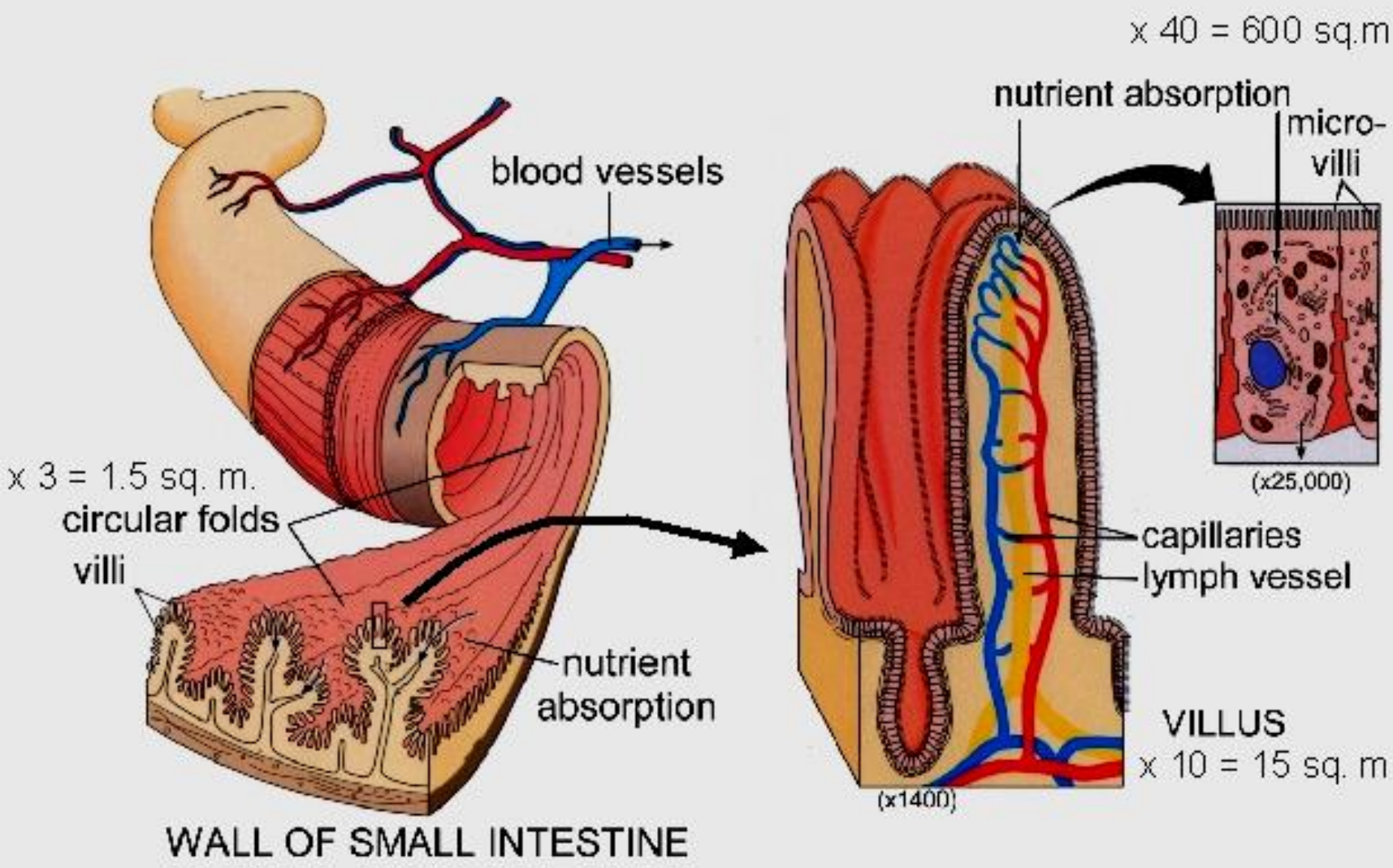
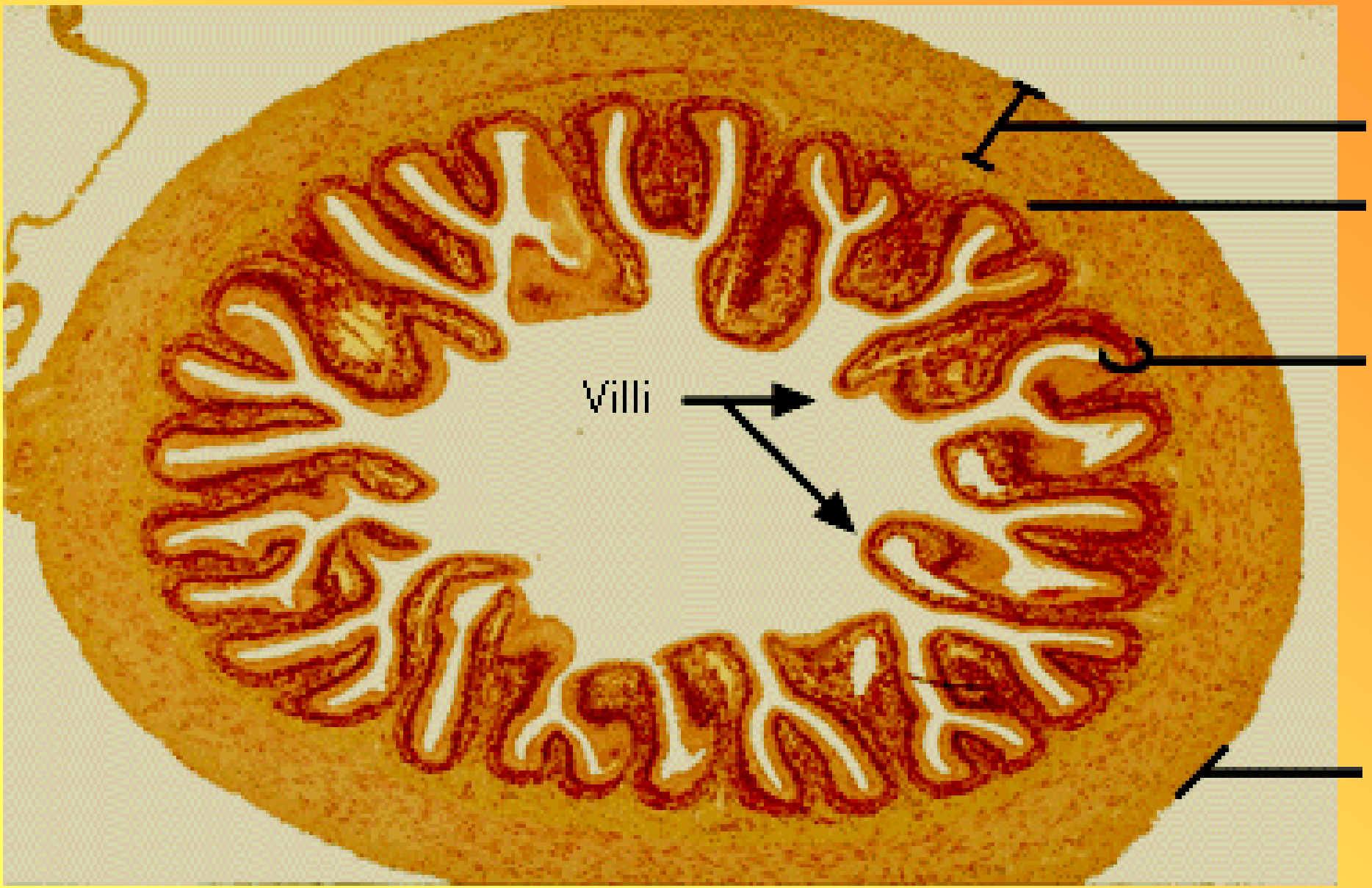


Fig. 21.10B. Structure of the Small Intestine

-2.5 cm (diameter) x 6.4 m (length) =0.5 sq. m. (area)

increased surface area

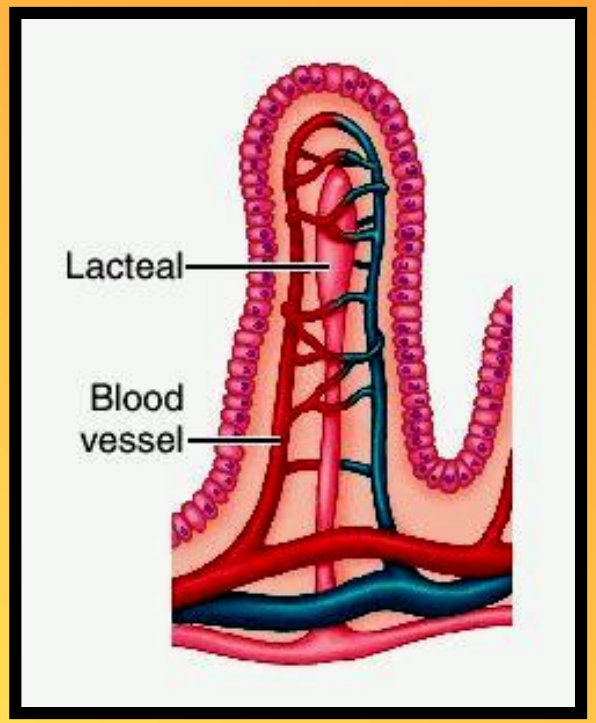


SMALL INTESTINE: structures

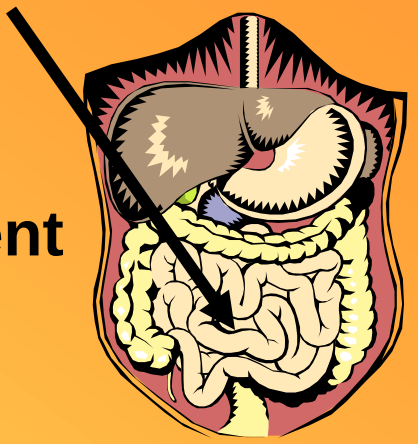
The **absorption** takes place through the collumnar cells of the microvilli.

This involves **active transport** and requires much **energy**.

The total surface area of the small intestine is **180m^2** (this is the size of a tennis court).



SMALL INTESTINE: function



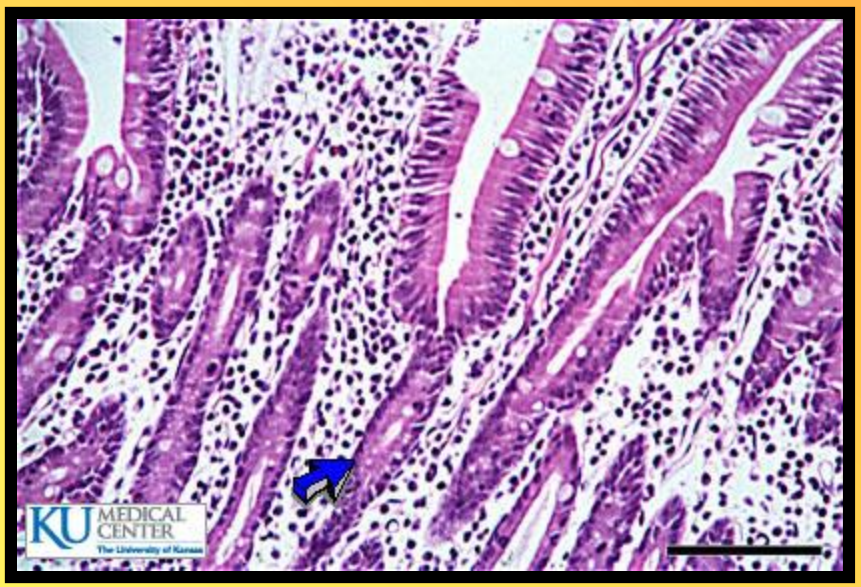
- To **complete the digestion** of all of the nutrient types:
  - a) Proteins
  - b) Carbohydrates
  - c) Nucleic Acids
  - d) Lipids

- To **begin the absorption** of nutrients:
  - a) Amino acids (into the blood stream)
  - b) Glucose and other monomers of carbs (into the blood stream)
  - c) Nucleotides (into the blood stream)
  - d) Fatty acids and Glycerol (into the lactael -- lymphatic system)

SMALL INTESTINE: function

The Walls of the Duodenum : The glands in the duodenum produce and release intestinal juices.

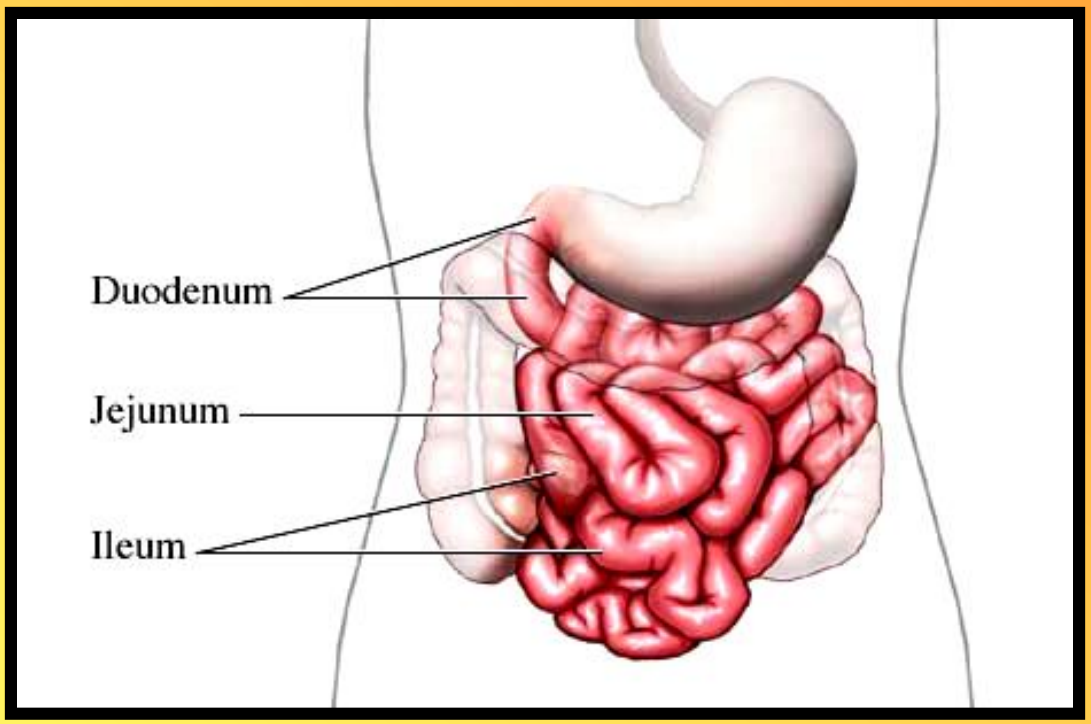
What is in the **INTESTINAL JUICES**? All of the enzymes that are required to complete the digestion of all of the food types.



INTESTINAL JUICES

Intestinal Juices contain:

1. **Peptidases**
2. **Nucleases**
3. **Maltase**
4. **Sucrase**
5. **Lactase**



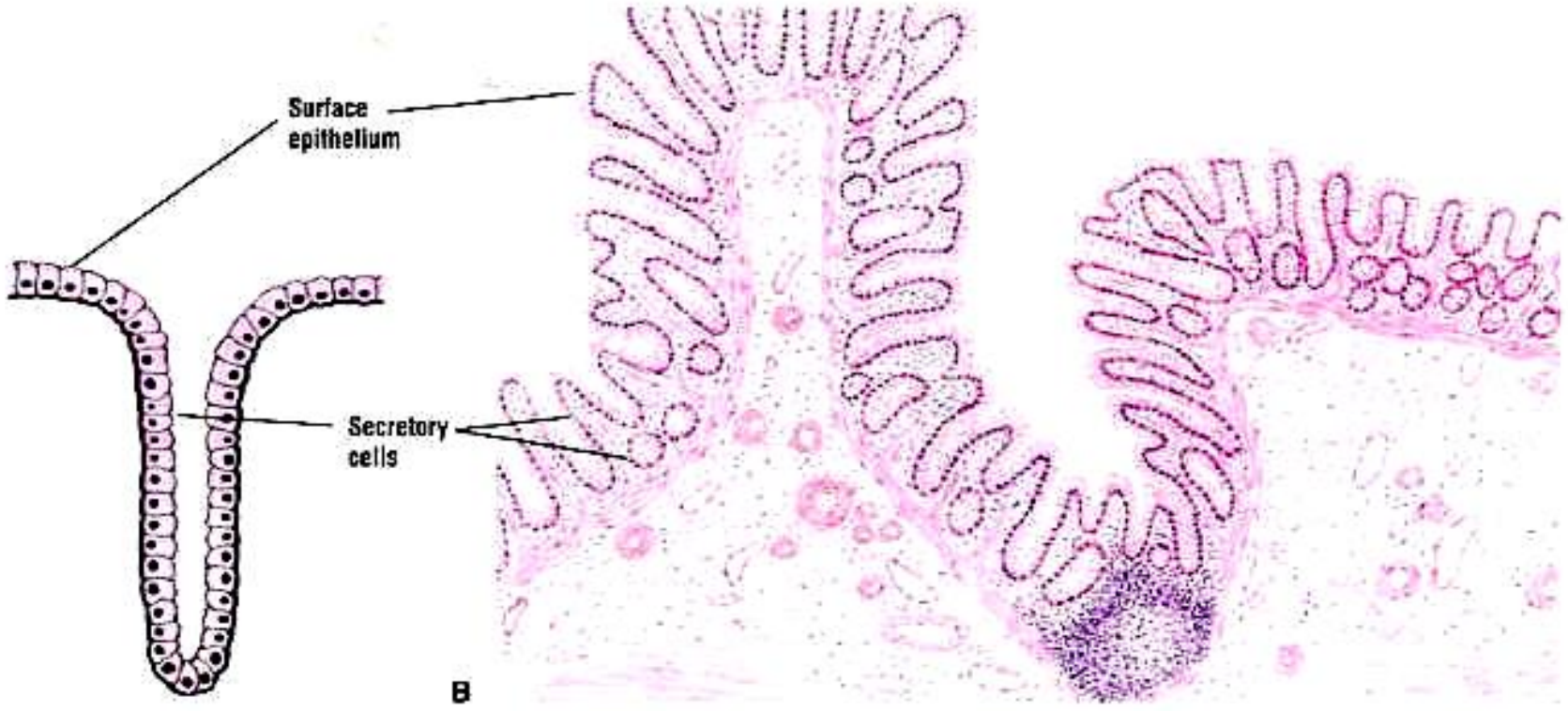


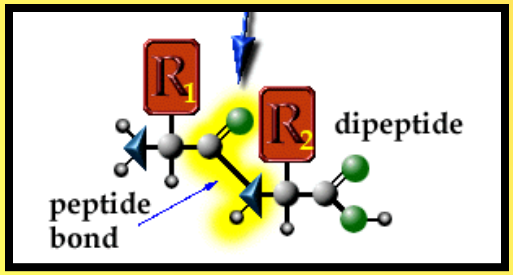
Fig. 1-11 Unbranched Simple Tubular Exocrine Glands: Intestinal Glands. (A) Diagram of gland. (B) Transverse section. Stain: hematoxylin-eosin. Medium magnification.

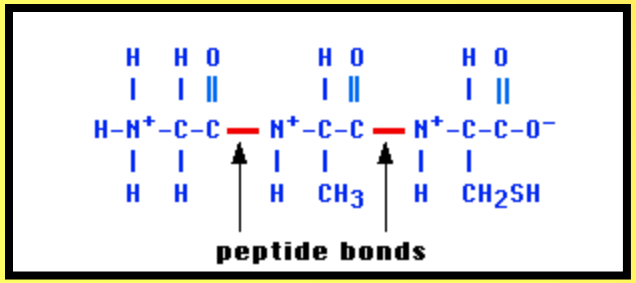
الواقع والحياد

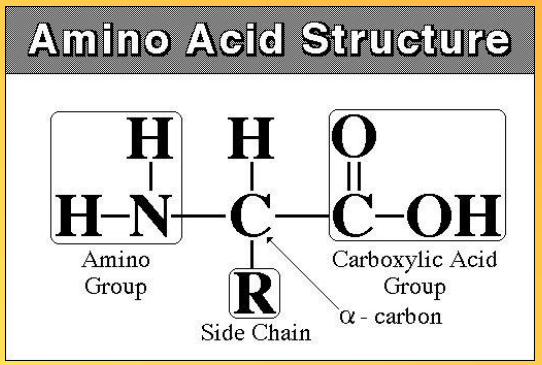
SMALL INTESTINE: function

1. **Peptidases** digest the tri and di-peptides into **amino acids.**

Di, Tri peptides —**PEPTIDASES**→ Amino Acids



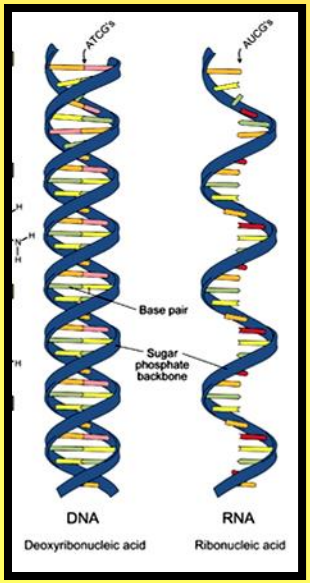


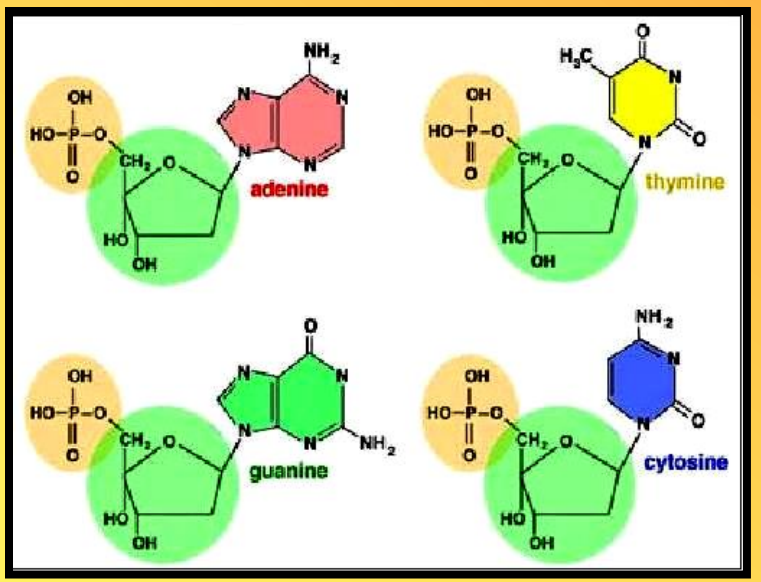


SMALL INTESTINE: function

2. **Nucleases** digest the rest of the nucleic acids into **nucleotides**.

Nucleic Acids —**NUCLEASES**→ Nucleotides

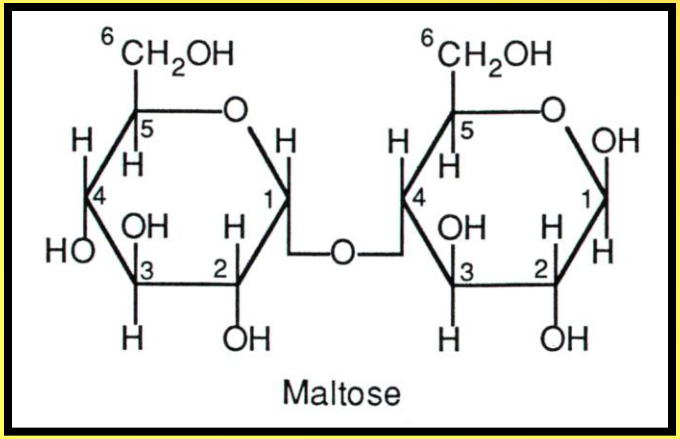


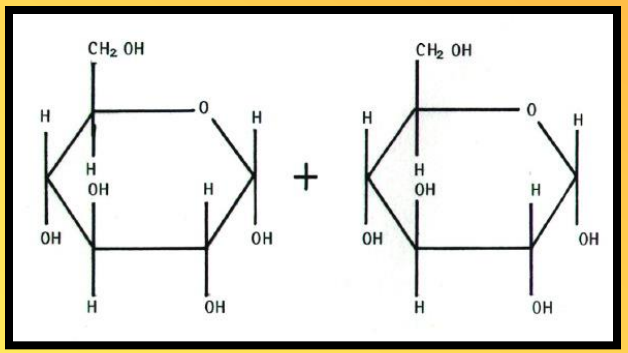


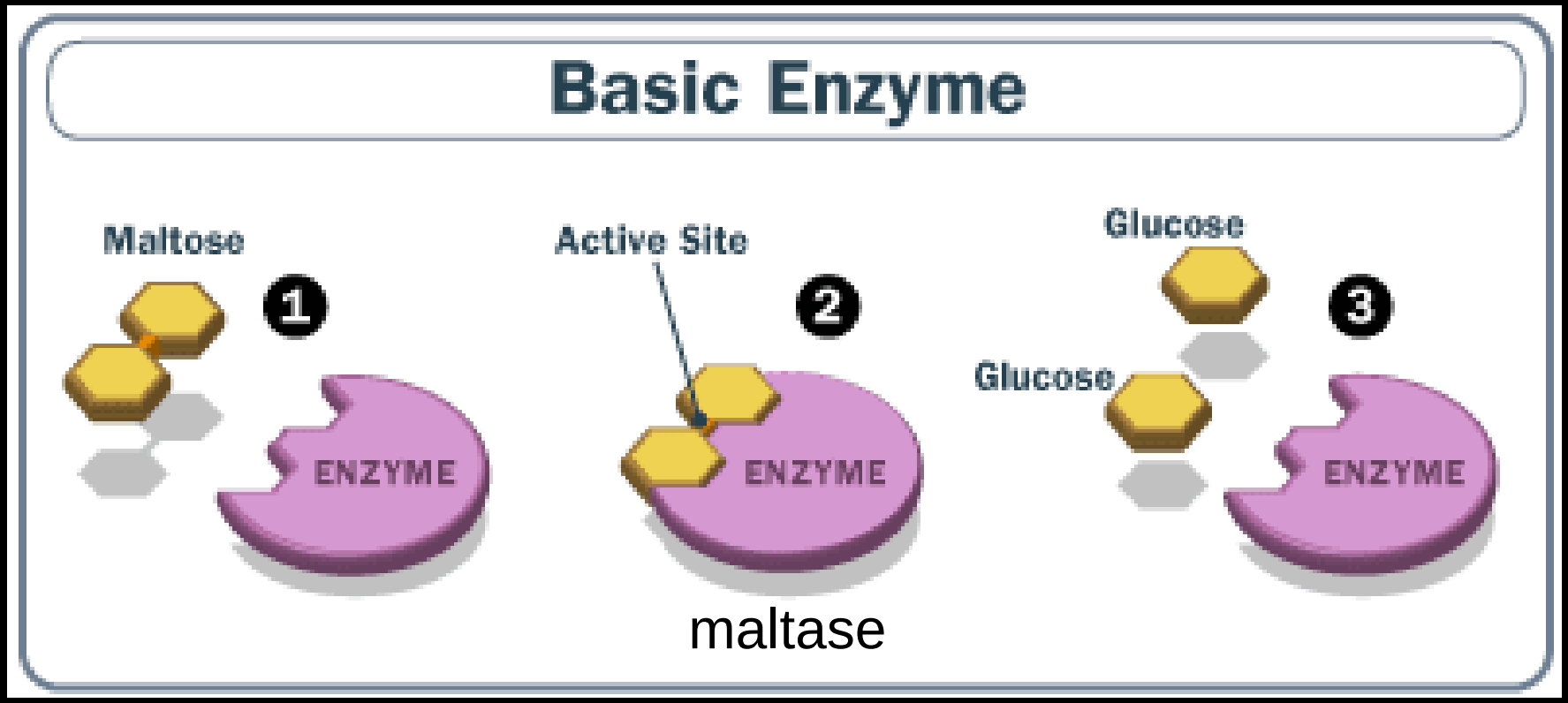
SMALL INTESTINE: function

3. **Maltase** digests the maltose into **2 glucose** molecules

Maltose —(MALTASE)→ Glucose + Glucose





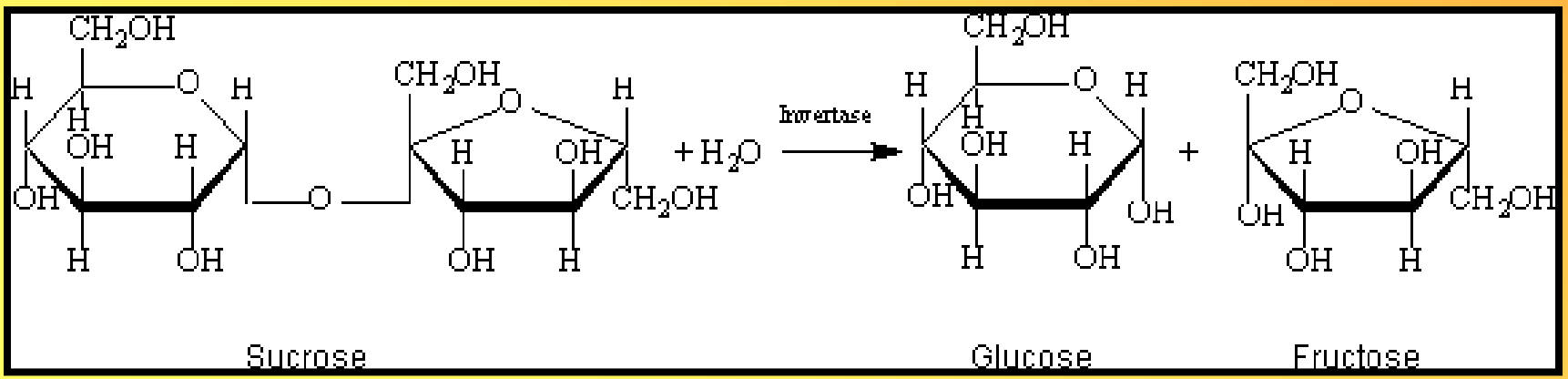

Basic Enzyme
Maltose
1
ENZYME
Active Site
2
ENZYME
Glucose
3
Glucose
ENZYME

maltase

SMALL INTESTINE: function

4. **Sucrase** digests sucrose into its **monomers**.

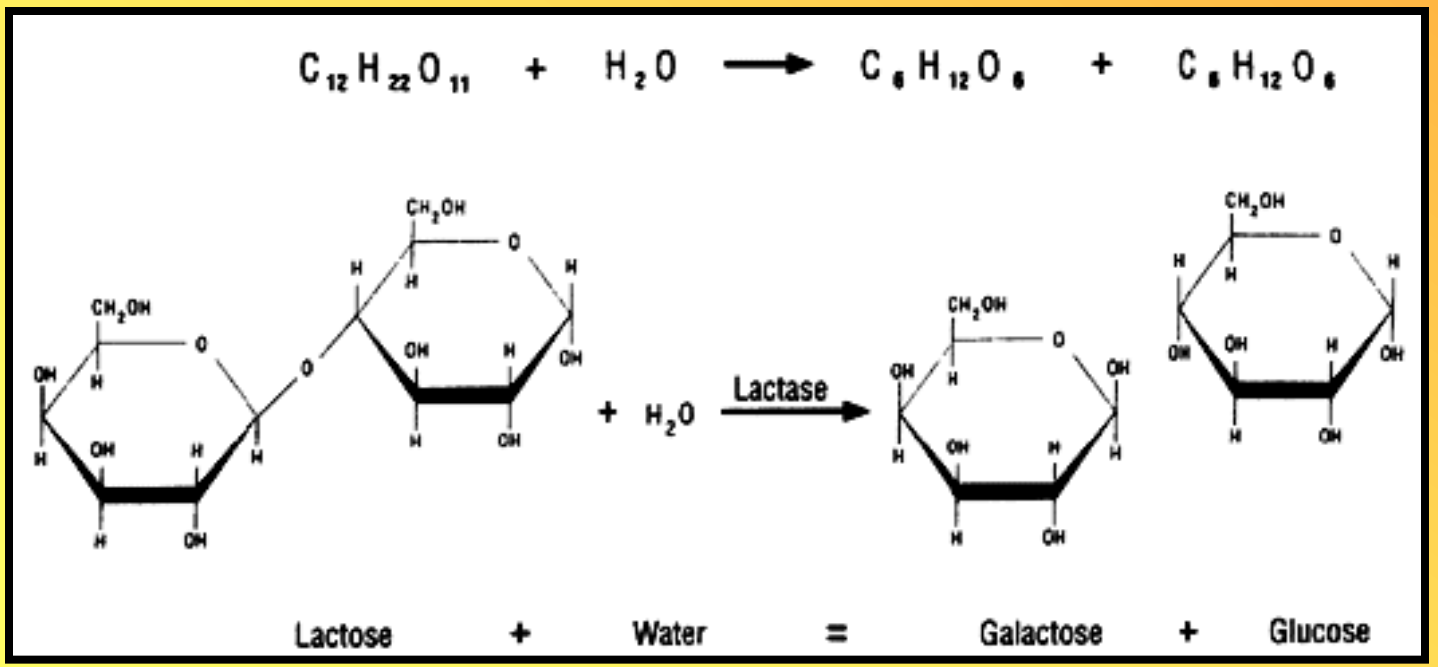
Sucrose —(SUCRASE)→ glucose + fructose

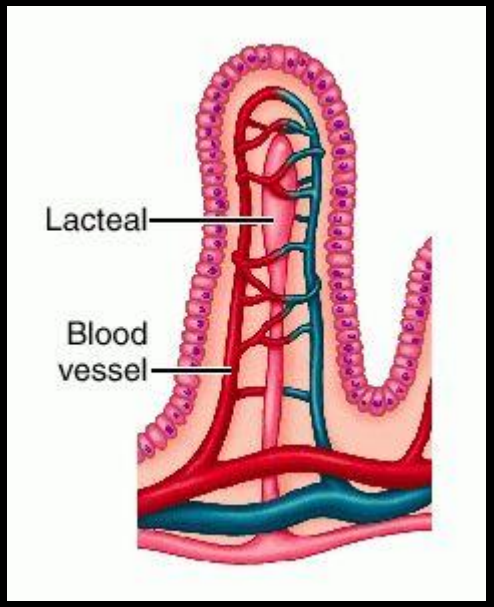


SMALL INTESTINE: function

5. **Lactase** digests lactose into its **monomers**.

Lactose —(LACTASE)→ glucose + galactose





Sugars, amino acids, & nucleotides are absorbed by the capillaries in the villi.

Glycerol & fatty acids are absorbed by the lymph lacteals in the villi.

The water, juices, and **indigestible food** continues on to the large intestine through the **ileocecal sphincter.**

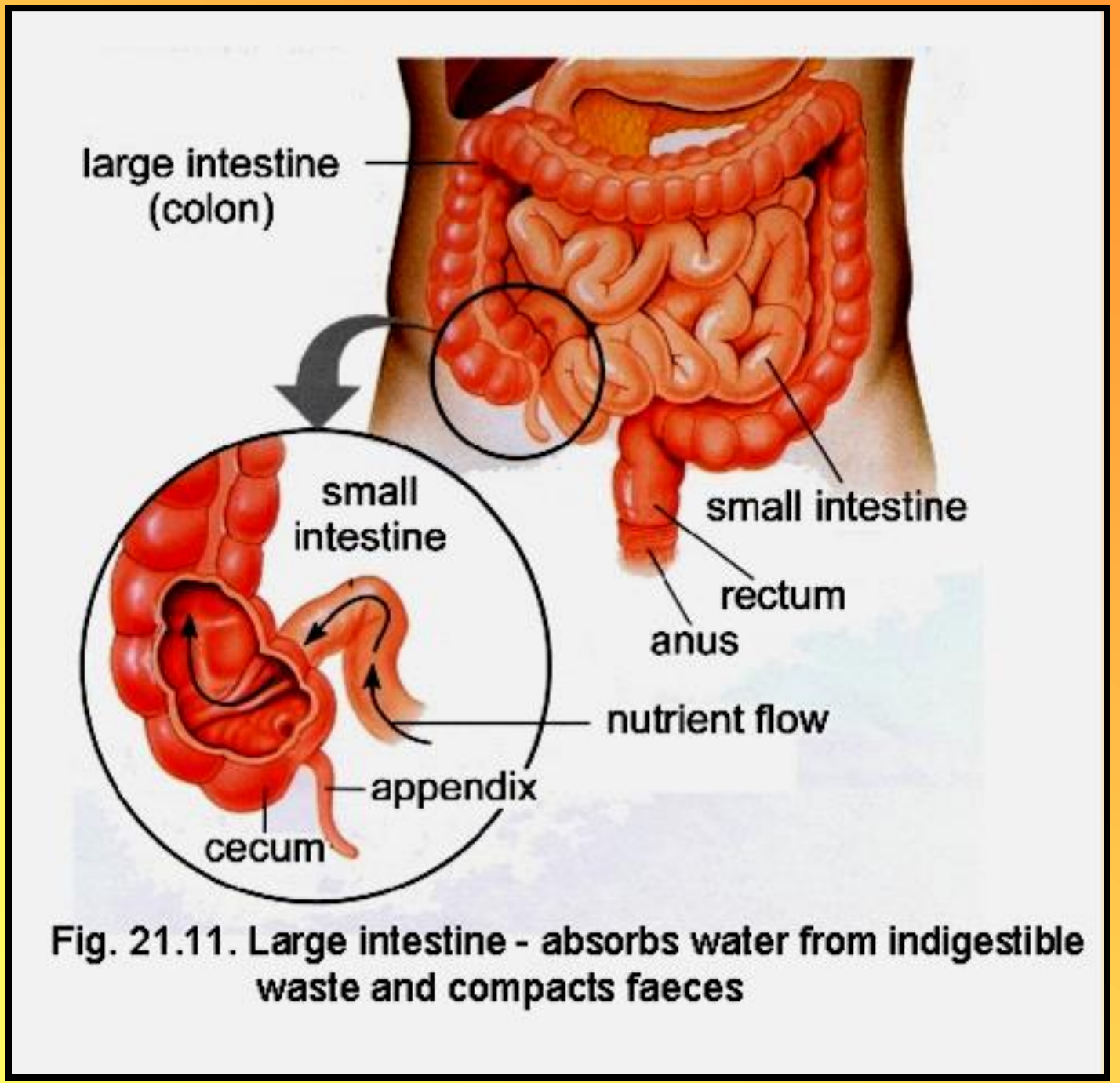


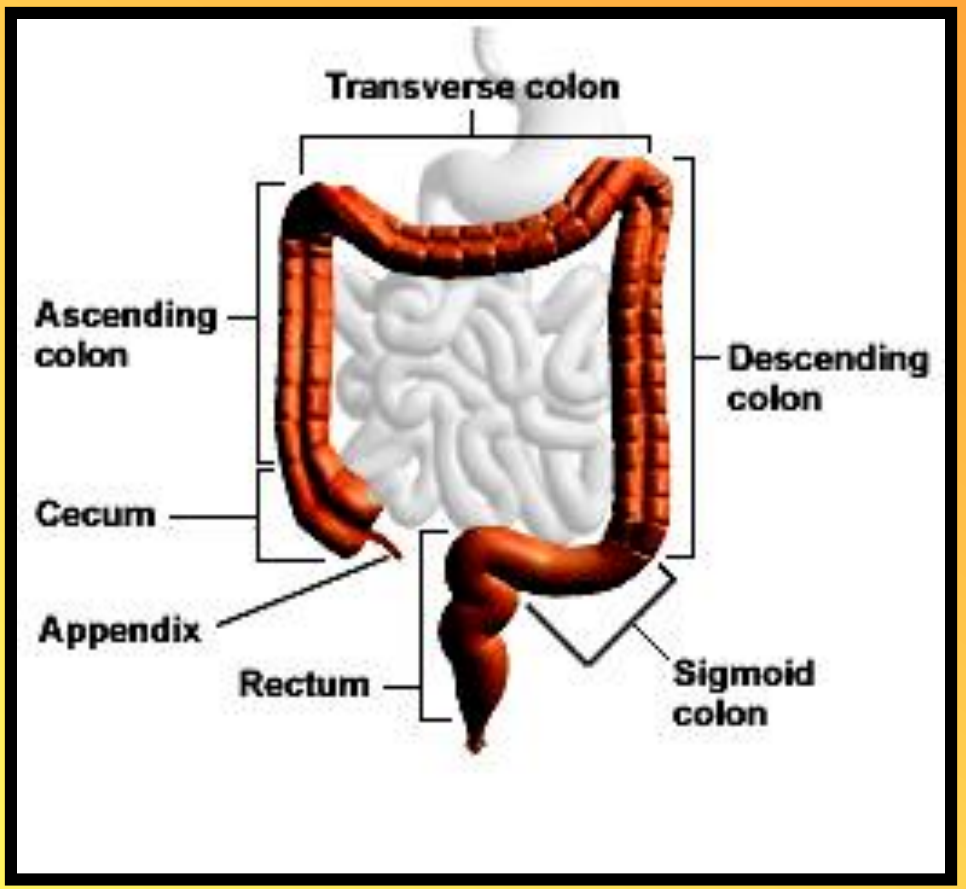
Fig. 21.11. Large intestine - absorbs water from indigestible waste and compacts faeces

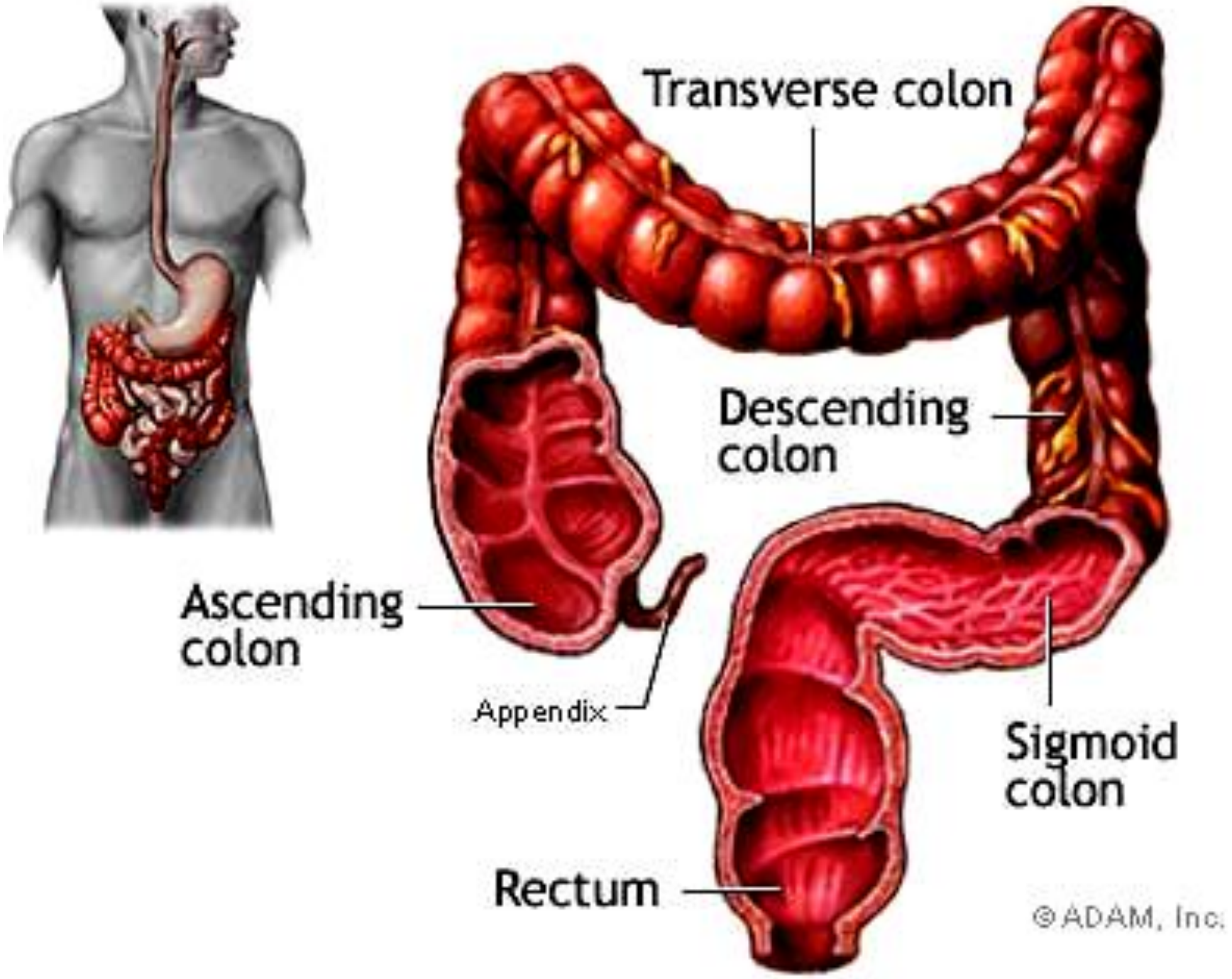
LARGE INTESTINE: structures

The large intestine is large in diameter, but is shorter than the small intestine.

It consists of 5 parts:

1. **Ascending Colon**
2. **Transverse Colon**
3. **Descending Colon**
4. **Sigmoid Colon**
5. **Rectum**




Transverse colon
Descending colon
Ascending colon
Appendix
Sigmoid colon
Rectum
©ADAM, Inc.

LARGE INTESTINE: functions

Main Job: Absorption of the water and salts that were used in the digestive process.

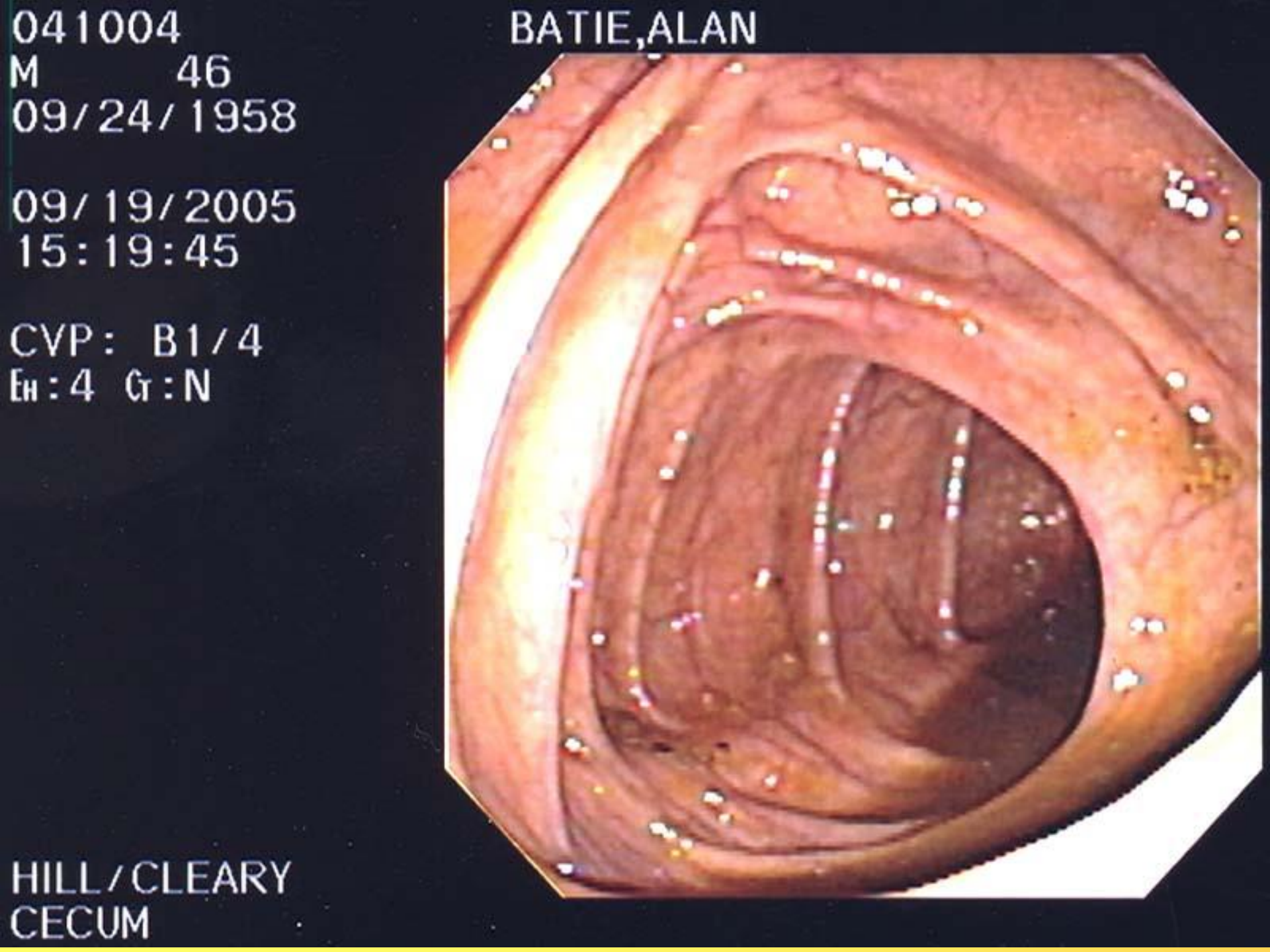
The E.Coli bacteria in the large intestine do 4 things:

1. They slow the movement of waste through the colon, which allows time for the water to be re-absorbed.

2. They eat the wastes and produce useful things that we need to survive. (ie: vitamin K and amino acids)

3.T hey produce growth factors (proteins that stimulate cell growth)

4. Produce waste of their own (methane gas) Phew!


041004
M 46
09/24/1958
09/19/2005
15:19:45
CVP: B1/4
EH:4 GT:N
BATIE,ALAN
HILL/CLEARY
CECUM

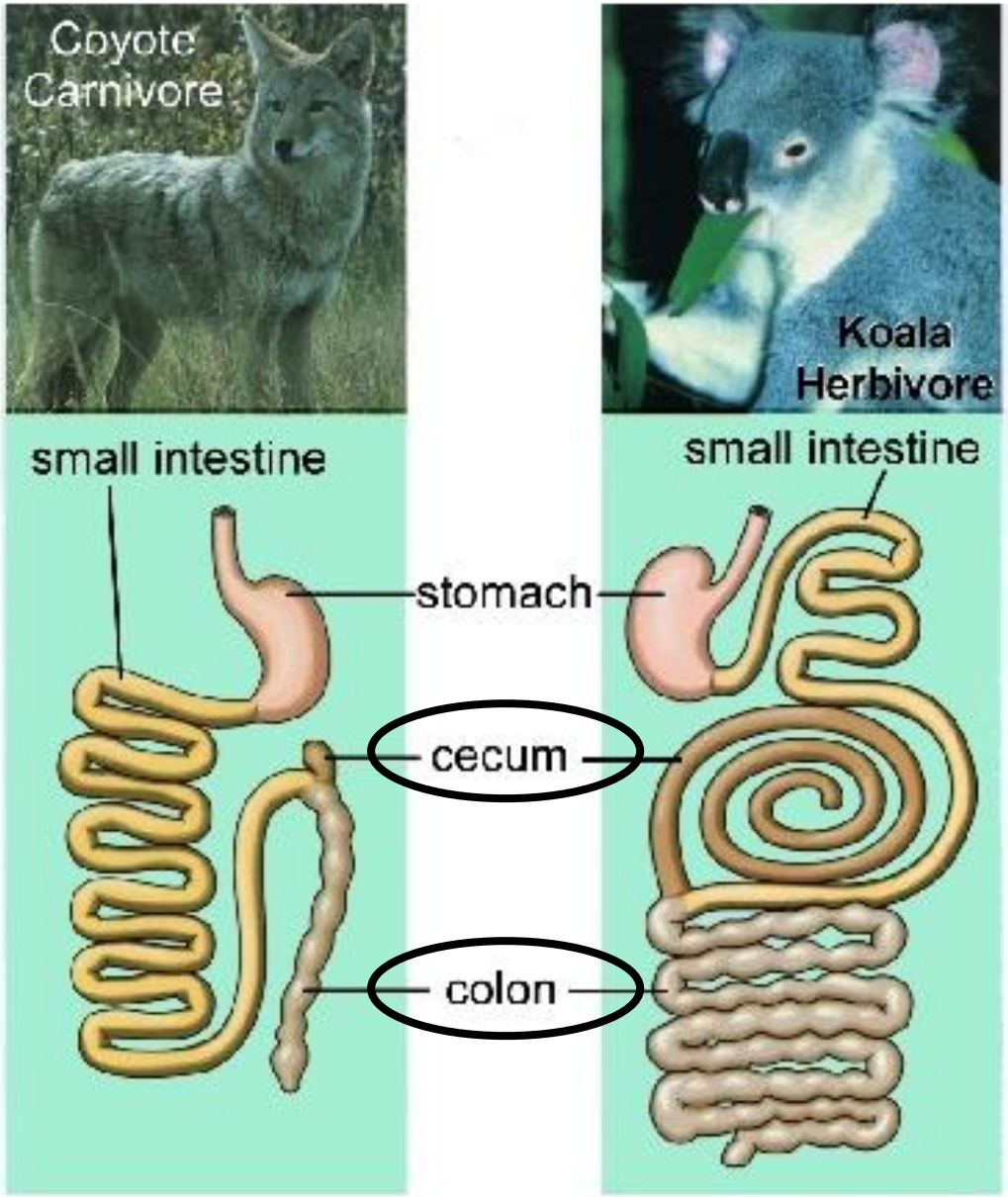
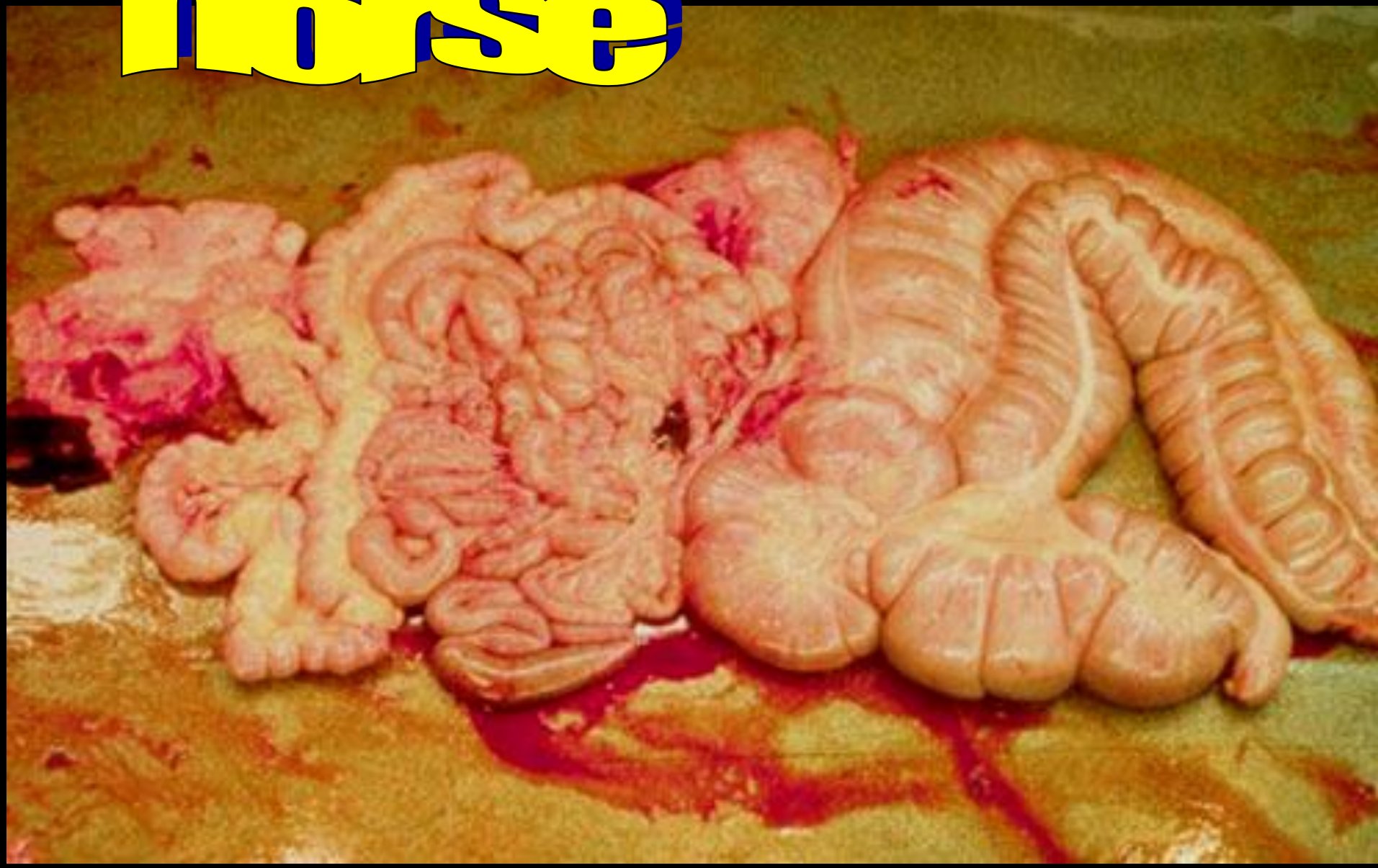
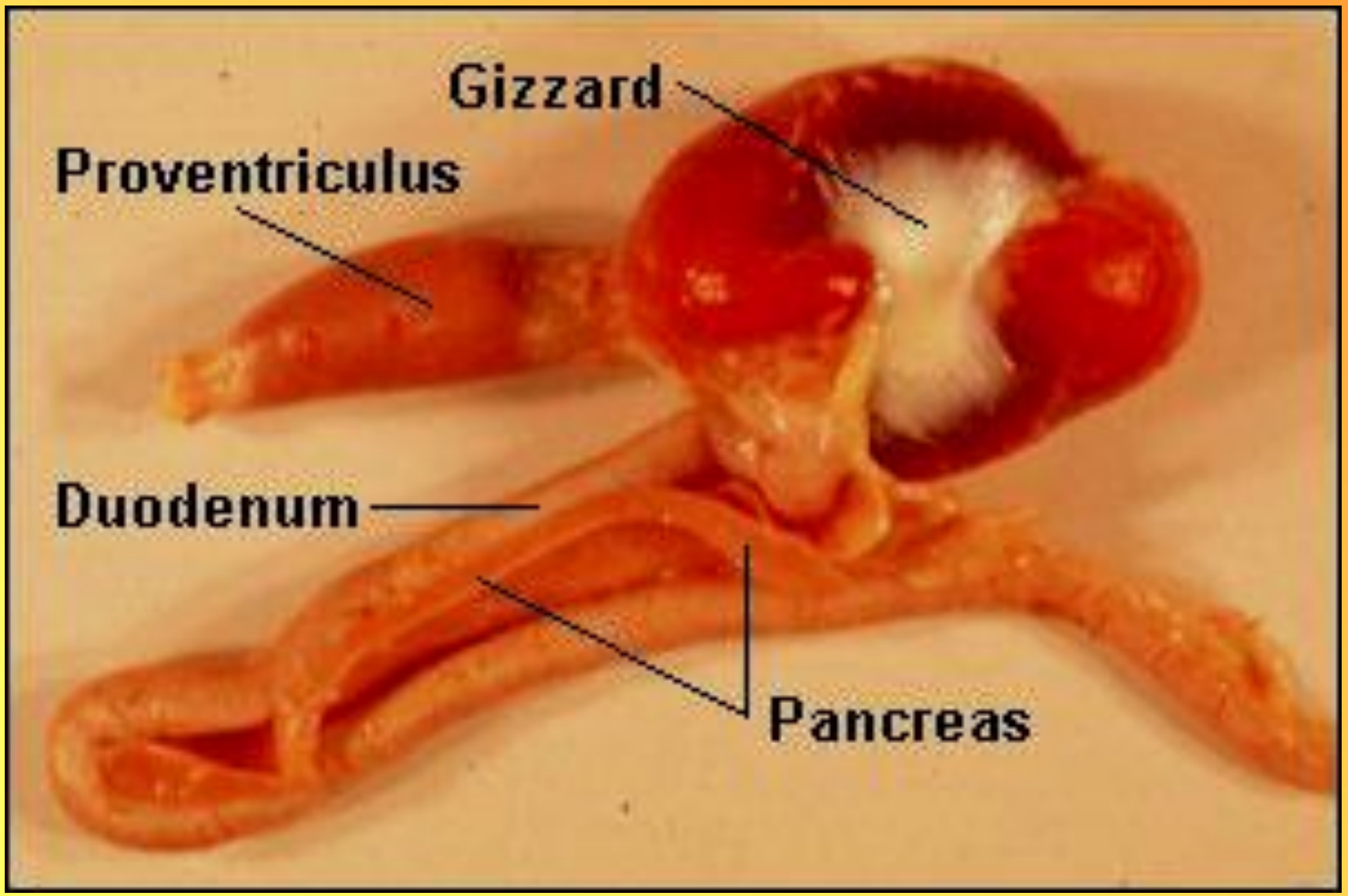


Fig. 21.12A. Digestive tracts of carnivores & herbivores

horse



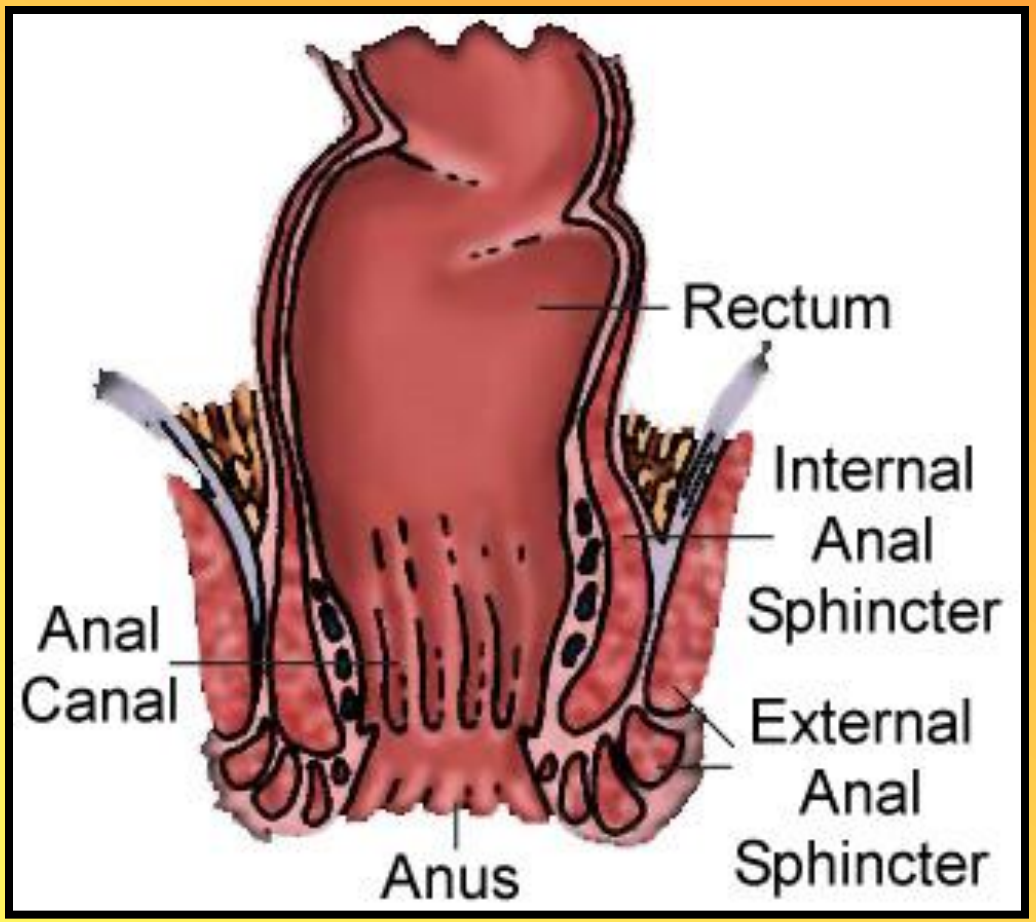
Birds eat stones to grind their food



RECTUM & ANUS

By the end of the large intestine wastes are transformed into pasty '<u>feces</u>'.

The entire process of digestion from the mouth to the anus lasts <u>24 hours</u>.



RECTUM & ANUS

If these wastes moves through the large intestine too quickly.

The intestines don't have time to absorb enough water.

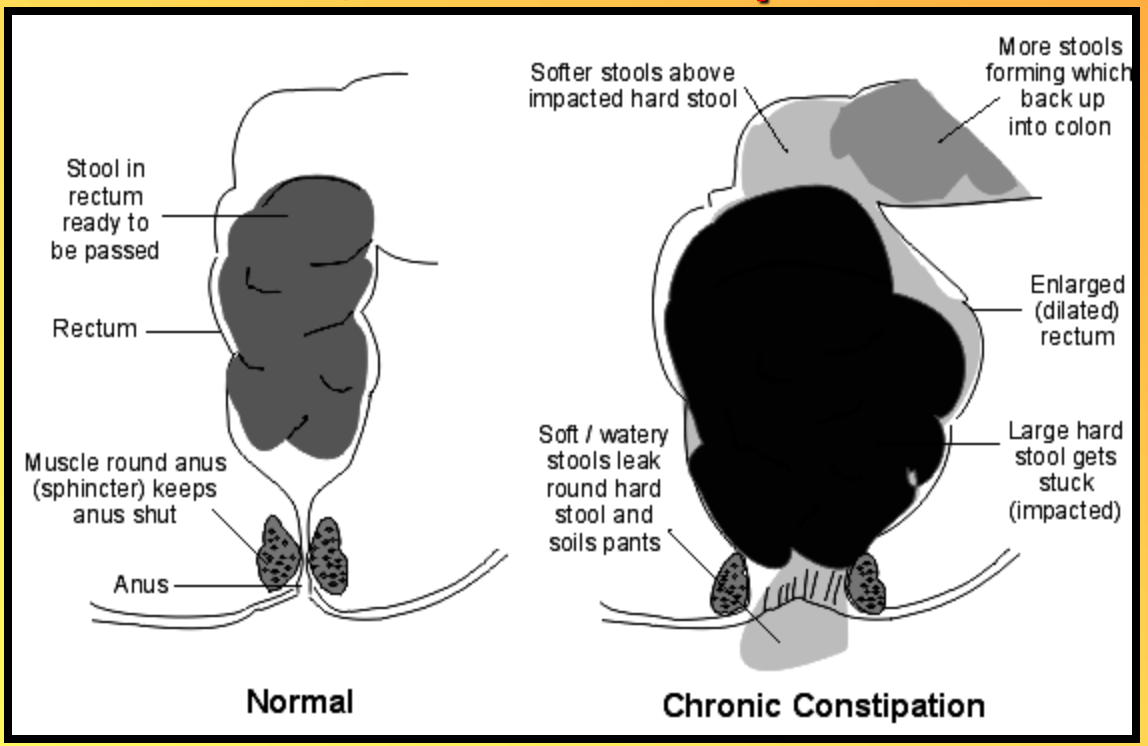
Your feces are liquified, and you have diarrhea.

RECTUM & ANUS

Sometimes the feces move through the large intestine too slowly.

Too much water is absorbed.

The feces become hard and then you are constipated.



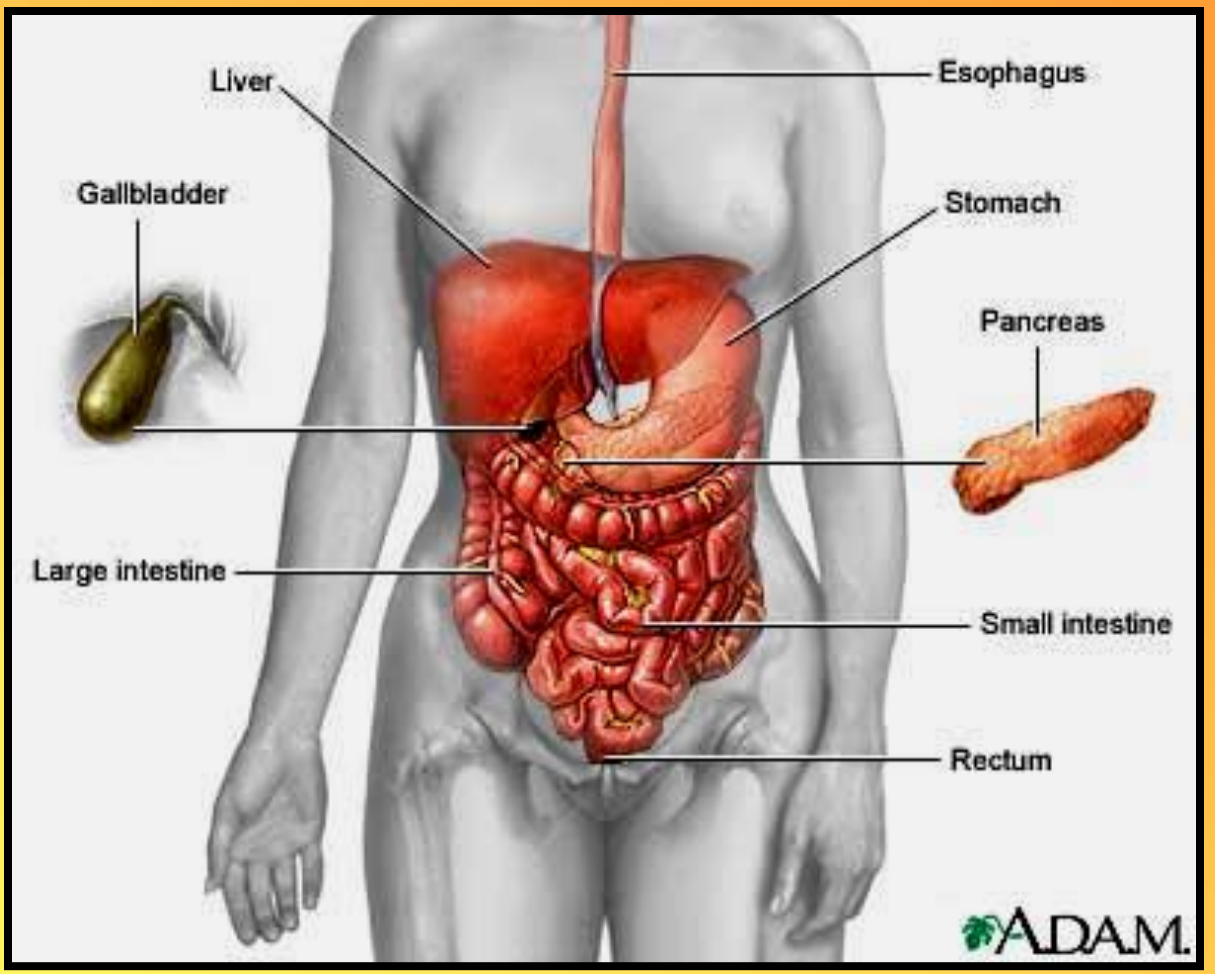
Fiber

Food sources of fiber include whole wheat, bran, fresh or dried fruits, and vegetables

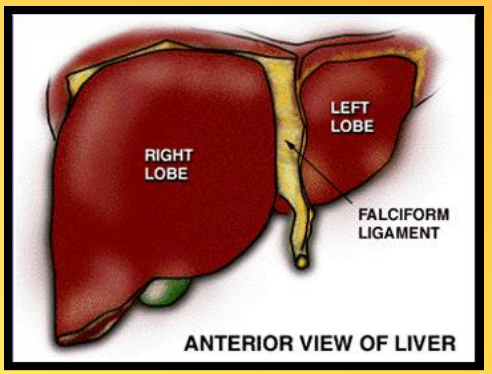
YOU TUBE OVERVIEW OF THE WHOLE DIGESTIVE SYSTEM: excellent!
http://www.youtube.com/watch?v=pXIO3J-hOqg

OTHER ACCESSORY ORGANS

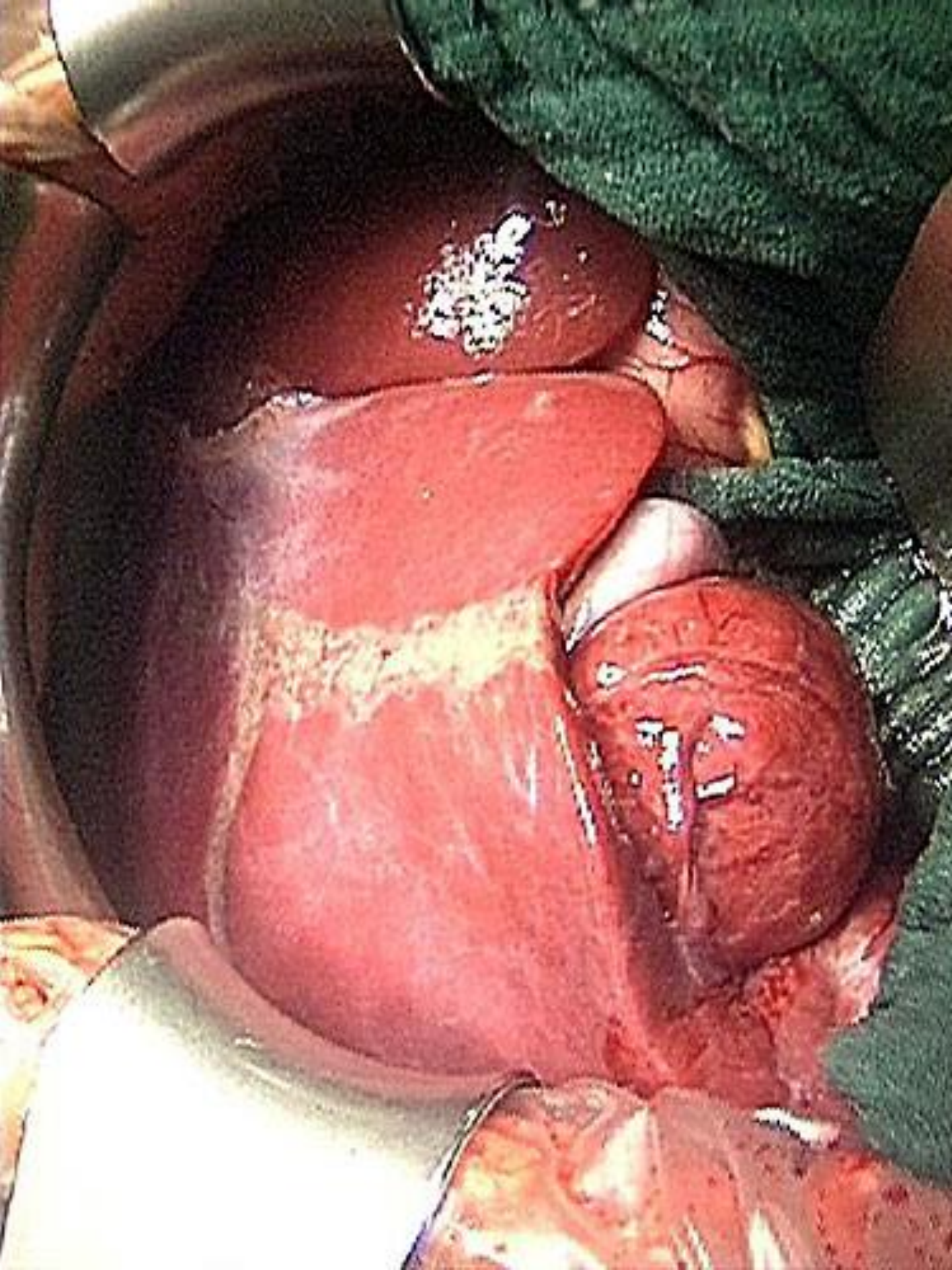
- **Liver**
- **Gall Bladder**



LIVER



- This is the **largest** internal organ.
- It has over **500 jobs**.
- All of the blood from the villi of the small intestines travels via the **hepatic portal vein** to the liver.
- The liver acts as a **'gatekeeper'** to the blood by keeping levels of various nutrients in the blood constant.



WHAT HAPPENS TO THE BLOOD IN THE LIVER?

1. **Detoxifies any poisons** or harmful substances that were absorbed by the digestive tract.

The liver turns alcohol into **fatty acids**.

Over time this can cause scarring of the liver tissue which gives rise to **cirrhosis**.

WHAT HAPPENS TO THE BLOOD IN THE LIVER?

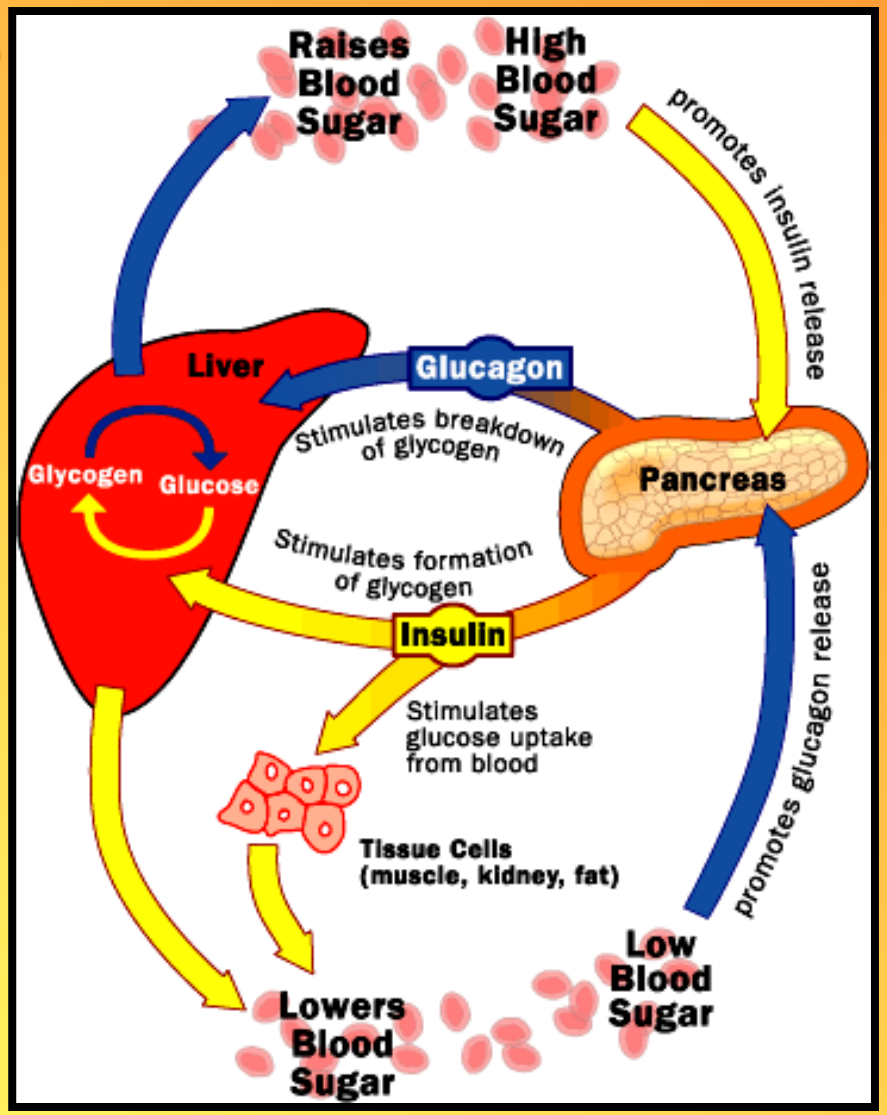
2. Regulates the **blood glucose level** at ~0.1% of plasma.

High blood sugar

Glucose **INSULIN** → Glycogen

Low blood sugar

Glycogen **GLUCAGON** → Glucose



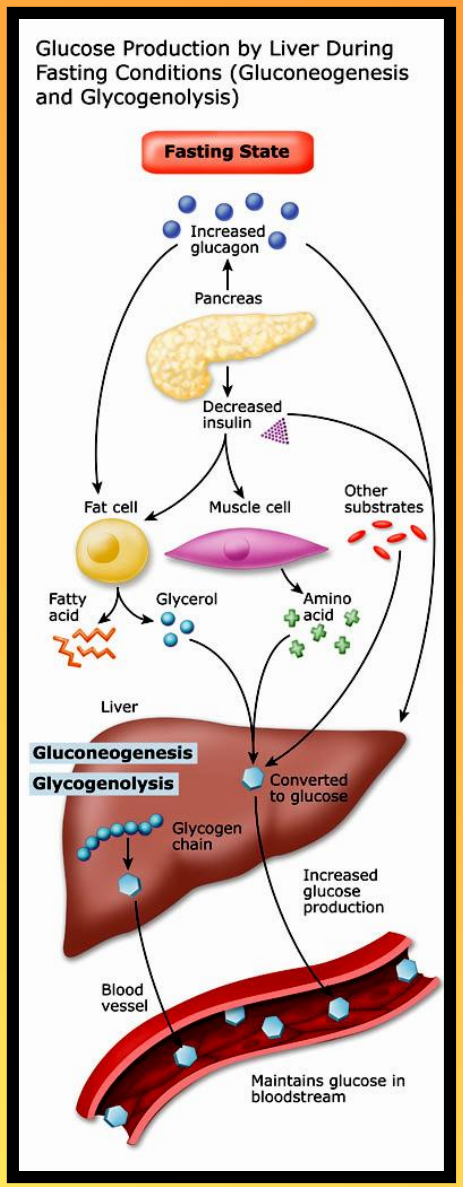
WHAT HAPPENS TO THE BLOOD IN THE LIVER?

3. **DEAMINATION of amino acids**.

If necessary the liver can **convert amino acids into glucose** to maintain glucose concentration of plasma. This is called **GLUCONEOGENESIS**.

This process releases the amino acids groups which the liver converts into **urea**.

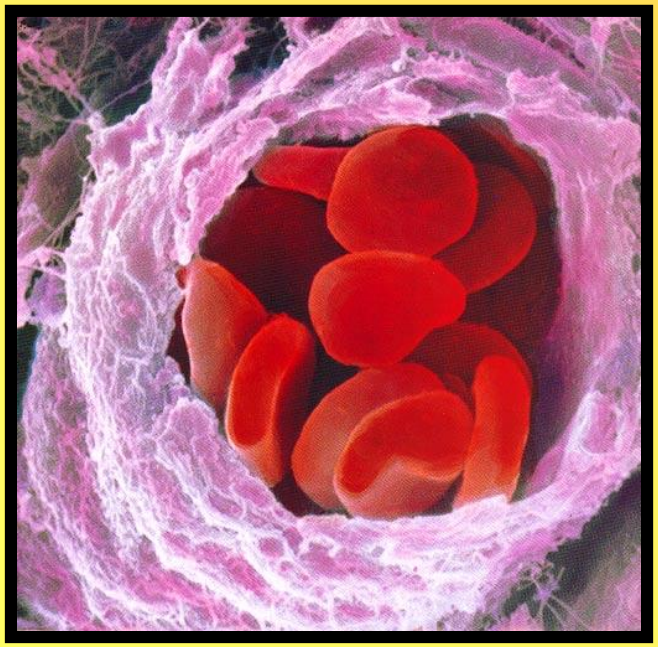
The urea is released into the blood, where it is removed by the **kidneys** in the production of **urine**.

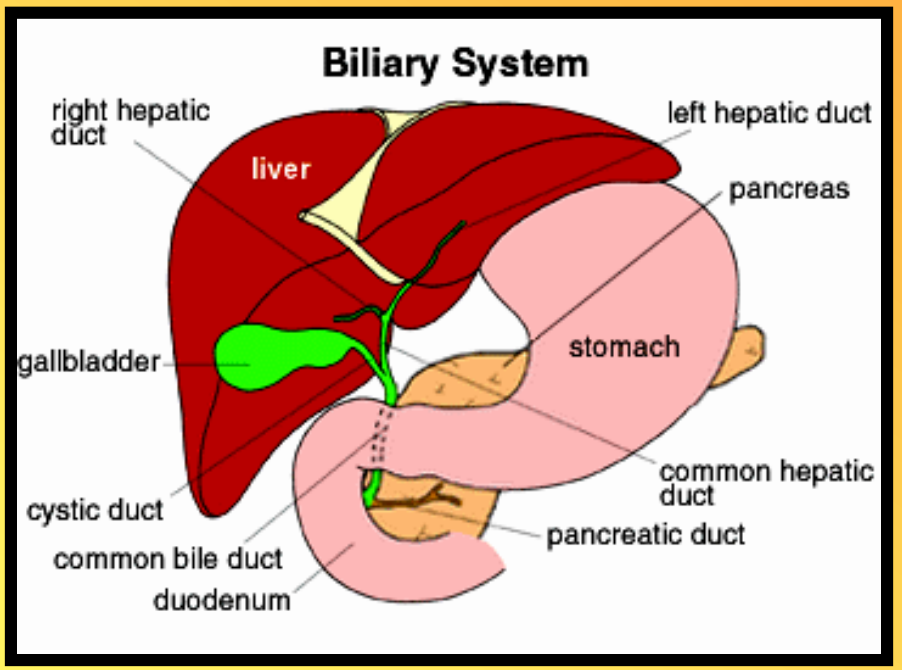


WHAT HAPPENS TO THE BLOOD IN THE LIVER?

4. **Destroys old red blood cells** (after ~ 4 months) and recycles **Hemoglobin**.

Most of the Hemoglobin is reused by the bone to make new RBC, the rest is ‘worn out’ and is converted into **bilirubin** and biliverdin (the components of **bile**).





WHAT HAPPENS TO THE BLOOD IN THE LIVER?

Excessive bilirubin in the blood leads to **JAUNDICE**.

Jaundice


Fluorescent light
Baby with mild jaundice

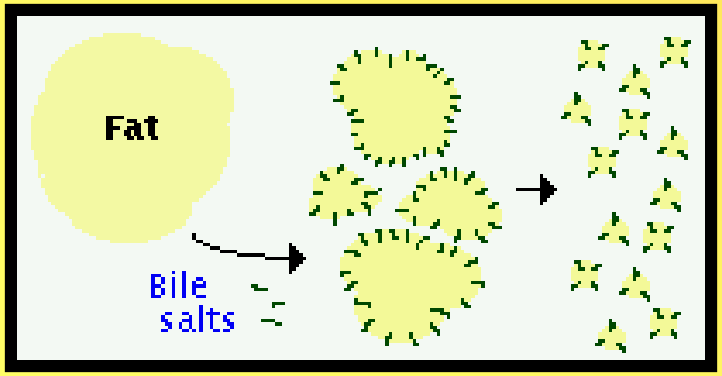

Before phototherapy
After phototherapy

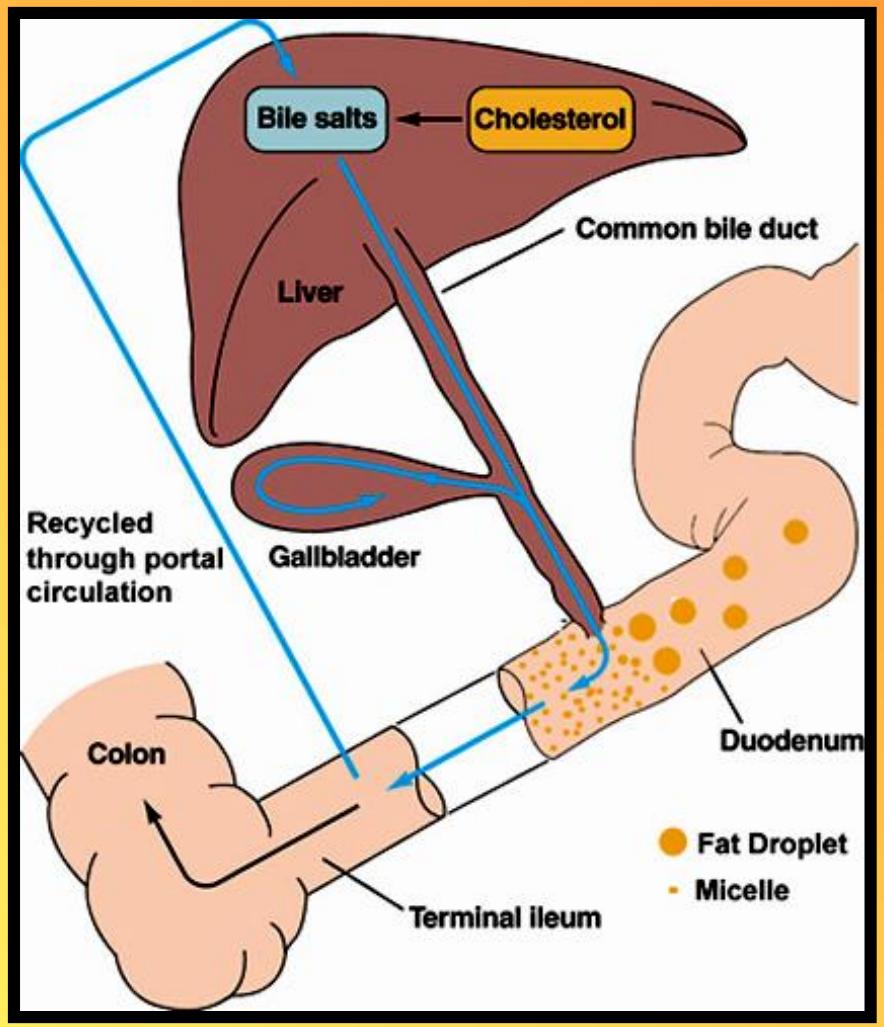
WHAT HAPPENS TO THE BLOOD IN THE LIVER?

5. **Produces bile** which **emulsifies** fats by breaking fats into smaller pieces.

This increases the **surface area of fats** for digestion.

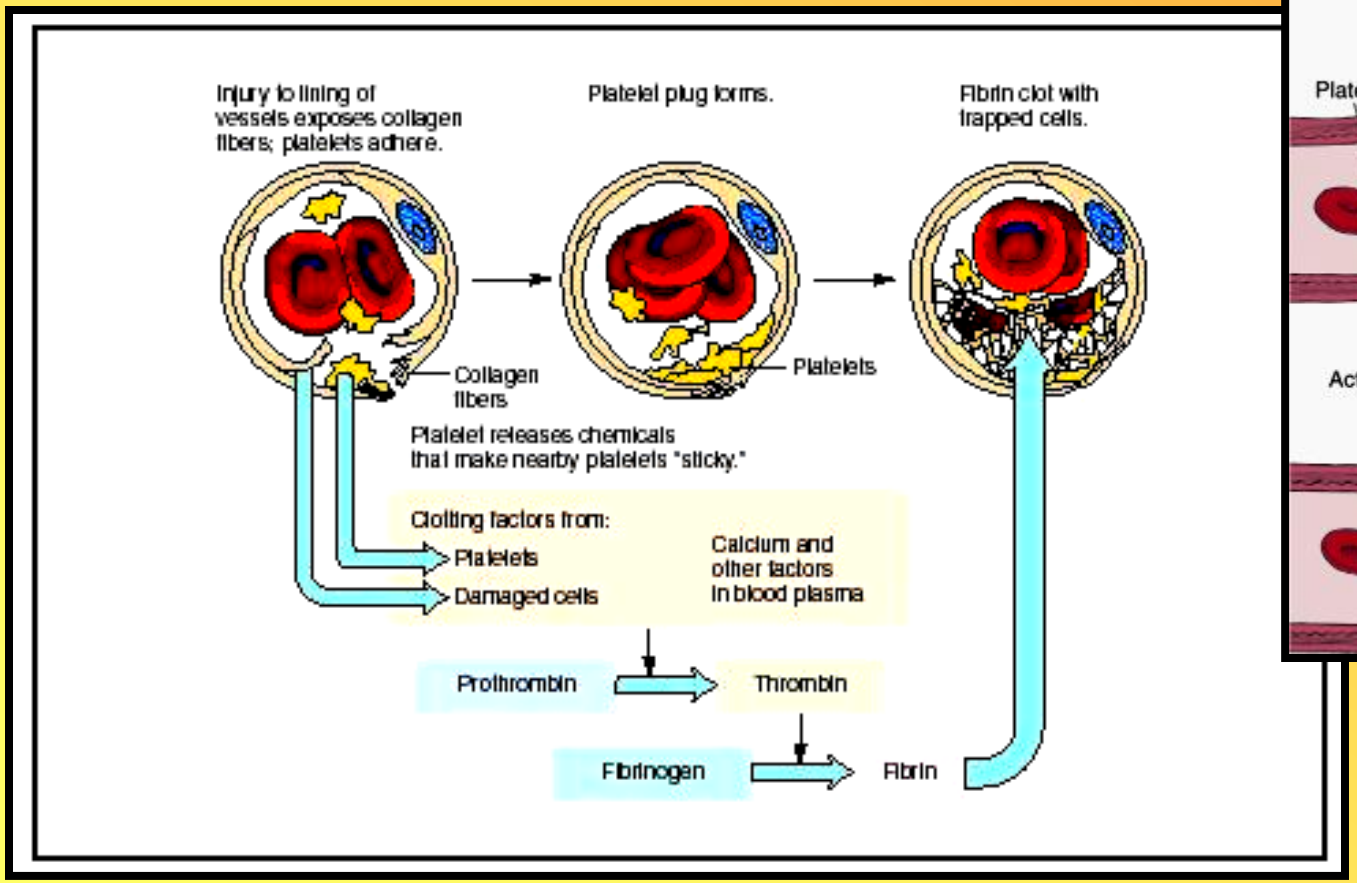
This makes the enzyme lipase much more **efficient**.

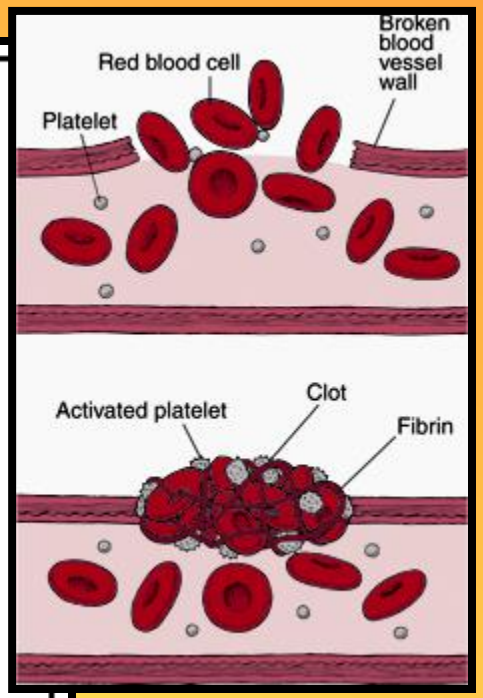




WHAT HAPPENS TO THE BLOOD IN THE LIVER?

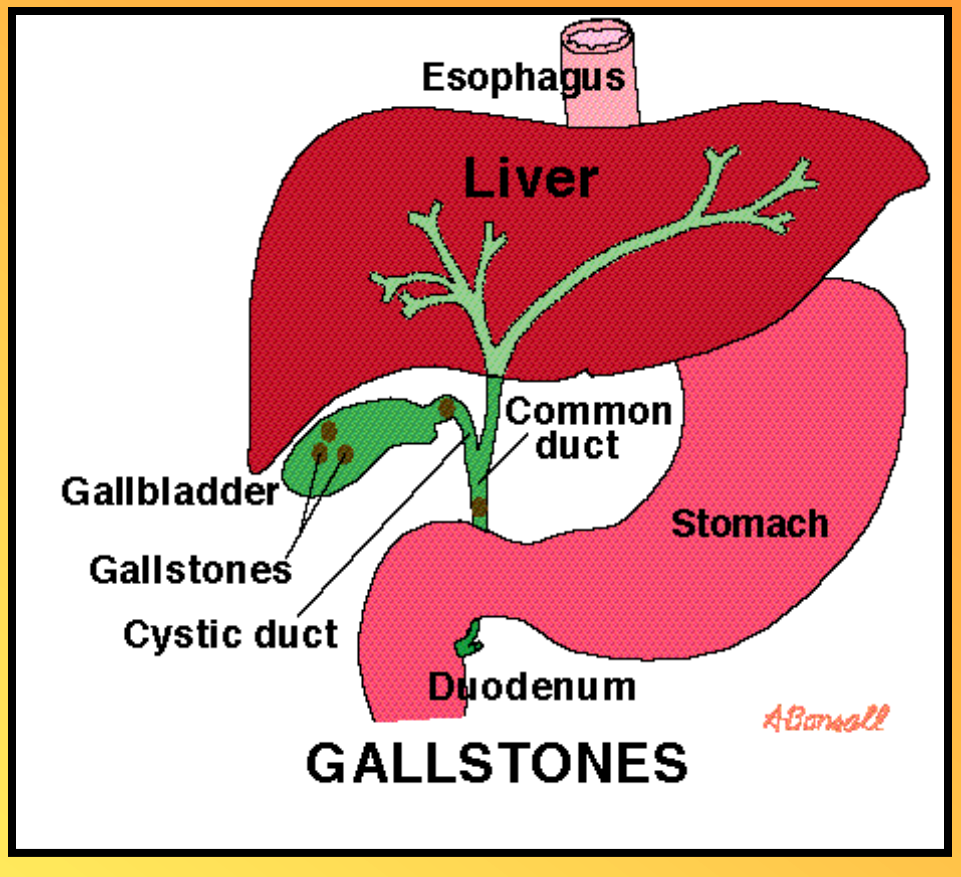
6. Makes **blood clotting proteins** (fibrinogen and prothrombin) and another protein called **albumin** which helps to maintain the osmotic pressure of the blood.

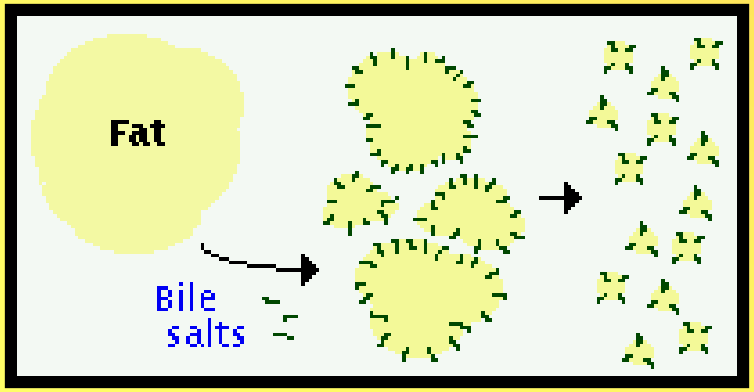


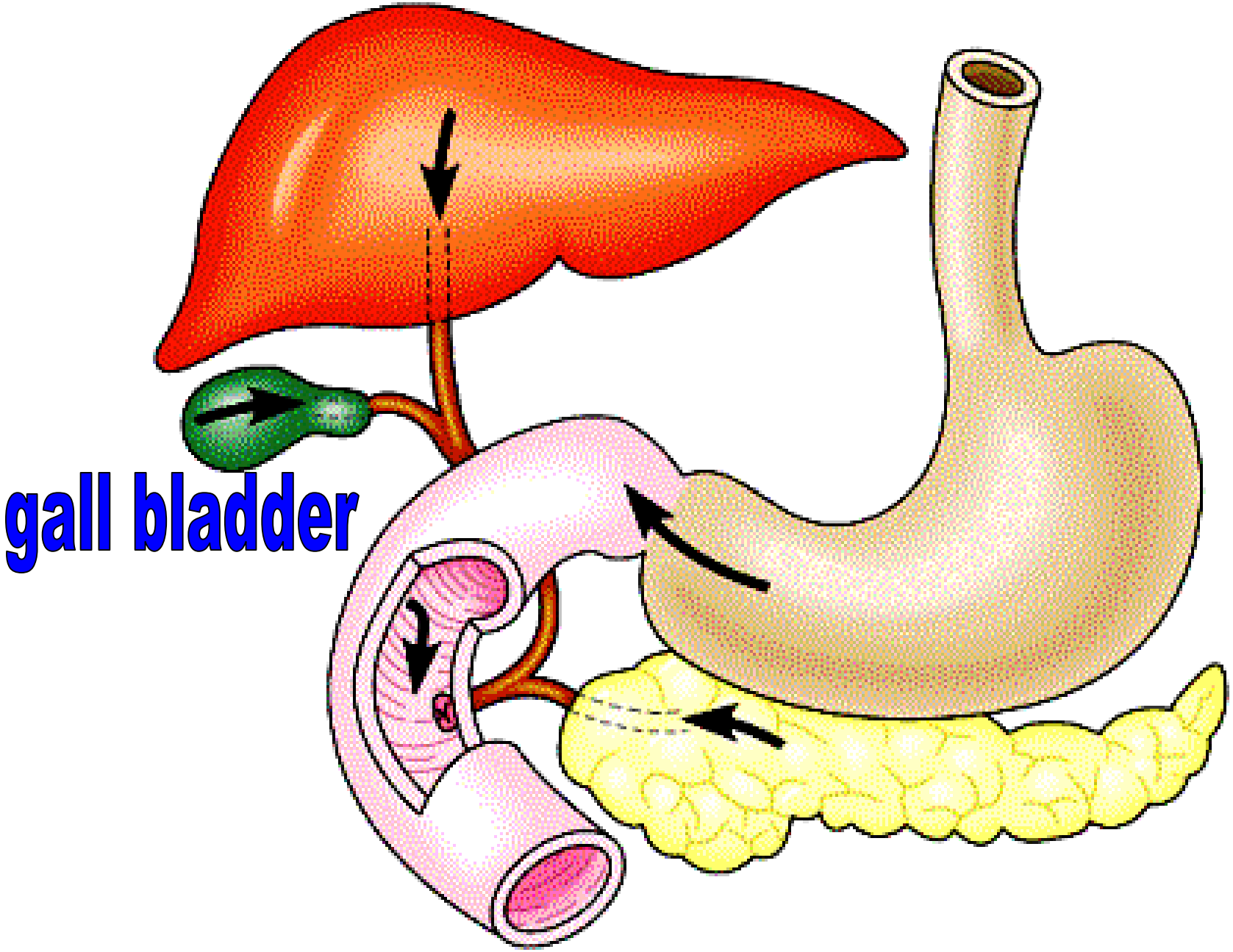


GALL BLADDER

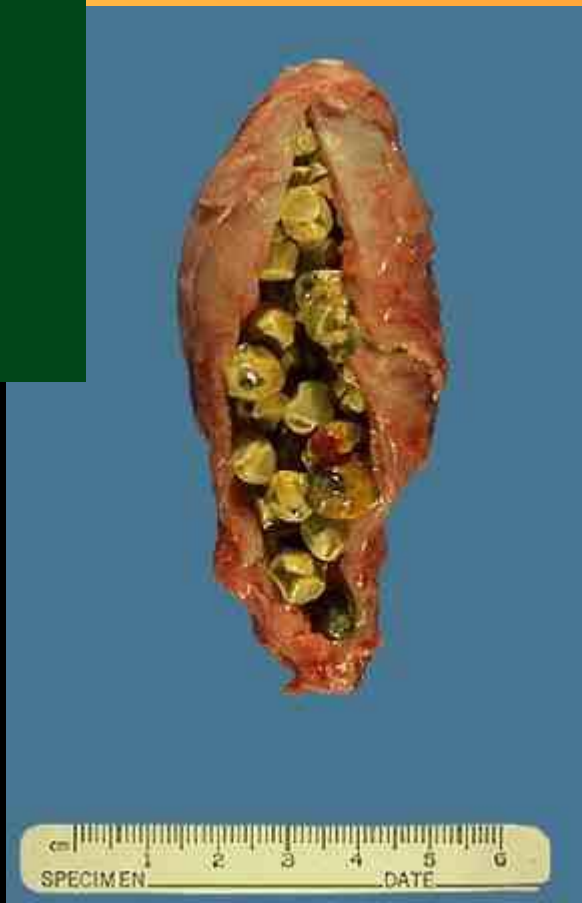
- **Stores Bile**
- **When we eat fat, the gall bladder sends bile to the small intestine through the common bile duct.**
- **The bile breaks fat blobs into smaller pieces (micelles) so they are easier to digest**

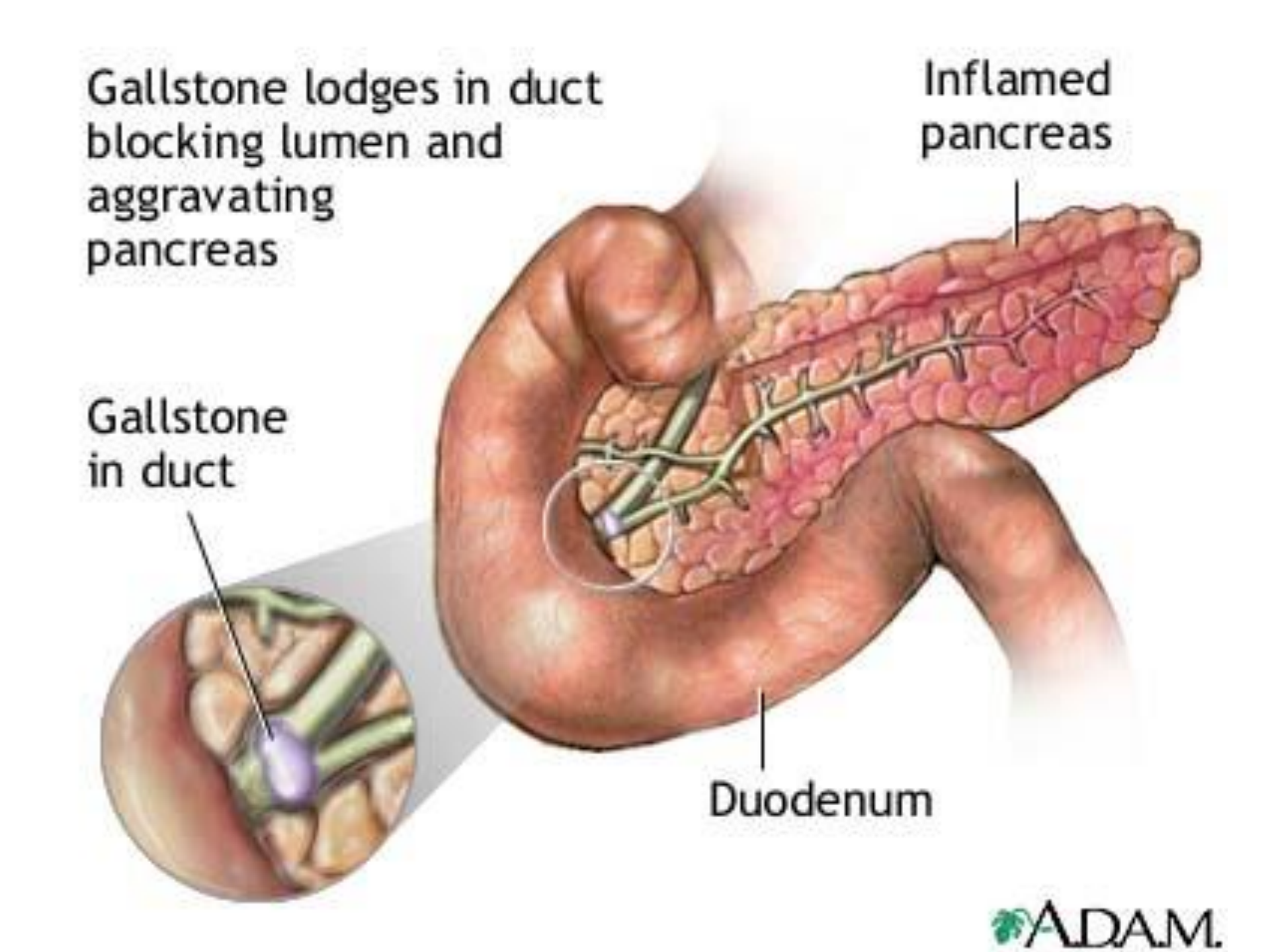






Gall Stones




Gallstone lodges in duct blocking lumen and aggravating pancreas
Inflamed pancreas
Gallstone in duct
Duodenum
A.D.A.M.

CONTROL OF DIGESTION

Enzymes are **energetically expensive** to make, so we only want enzymes in the gut when **food** is present.

This is controlled by **3 hormones**.

1. **Gastrin**
2. **Secretin**
3. **CCK** (Cholecystokinin)

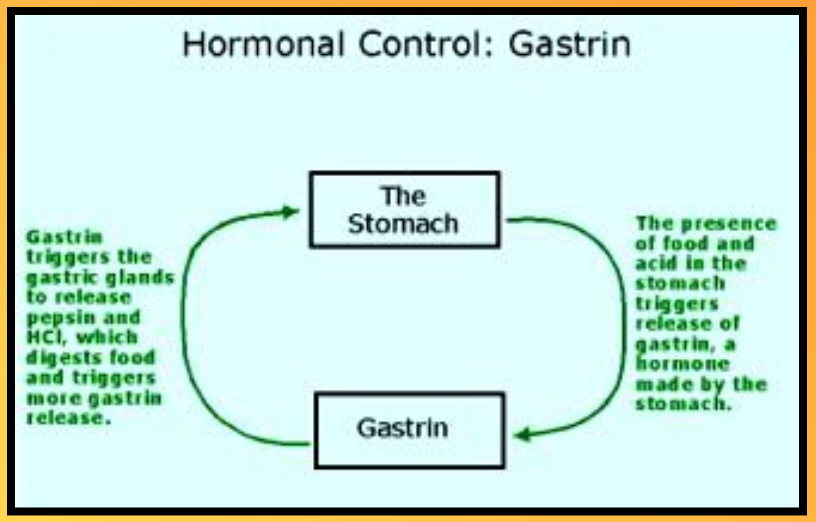
A hormone is a chemical messenger that is produced in the glandular tissue. It travels to some other target location in the body via the blood stream, where it has a desired effect.

DIGESTIVE HORMONES

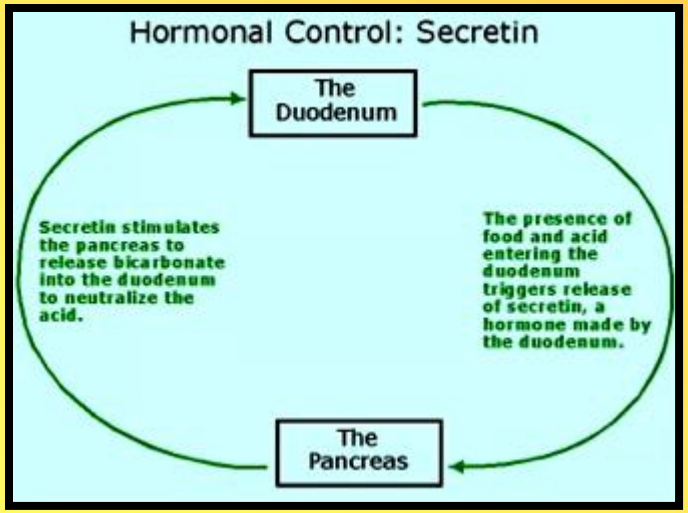
• **GASTRIN** **is** released by glands in the stomach **when food** (especially proteins) **enters the stomach**.

• It stimulates the cells of the stomach to secrete **gastric juice**, a mixture of hydrochloric acid and the enzyme pepsin.

• Pepsin will begin the **digestion of proteins**.

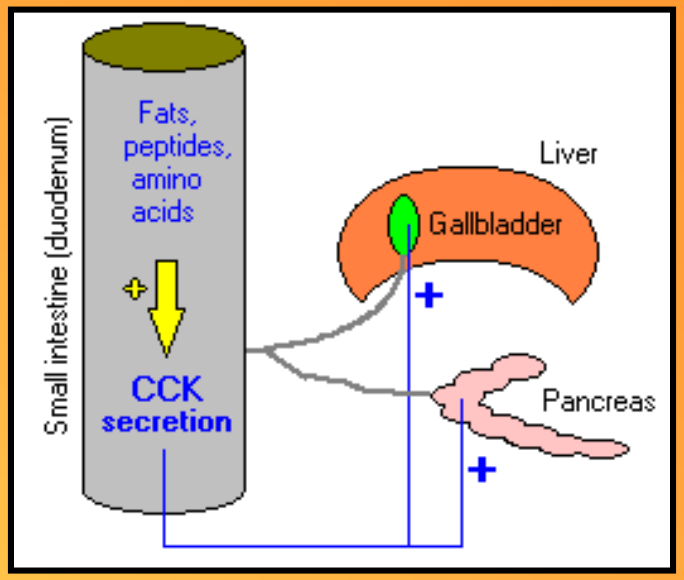


DIGESTIVE HORMONES



- **SECRETIN is** released by cells in the **duodenum** when they are exposed to the **acidic chyme** entering from the stomach.
- Secretin stimulates the **pancreas** to release its **pancreatic juices**.
- This includes **sodium bicarbonate** ($NaHCO_3$), which **neutralizes** the acid from the stomach => **pH 8.5**.
- Without this, the enzymes would all **denature** as they need an optimum pH of 8.5 to work properly.

• **Cholecystokinin (CCK) is** released by cells in the duodenum when they are exposed to the **fats and proteins** coming from the stomach.



•It 'tells' the **gall bladder** to contract and force its **bile** into the intestine and 'tells' the **pancreas** to release its **pancreatic juices** (SALT + N). These enzymes, with the help of bile, will help to **digest the fats and proteins**.

•*There is some evidence that CCK acts on the brain as a satiety signal (i.e., "that´s enough food for now").*

Put It All Together...

CHARTS!

Let's Put It All Together

CARBOHYDRATES

1. Eat carbohydrates and chew them with our mouth.
2. Saliva is released with salivary amylase and mucous.
3. The salivary amylase digests the cooked starch into maltose.
4. The bolus goes the to back of the throat and we swallow it.
5. The esophagus takes the bolus to the stomach via peristalsis.
6. When food reaches the stomach, GASTRIN is released.
7. Gastrin causes the release of the gastric juices (HCl, mucous, pepsinogen)
8. HCl kills the bacteria in the food and creates a pH of 2.5.
9. The stomach mixes the food around.
10. The acid chyme is slowly released in to the duodenum through the pyloric sphincter.

Let's Put It All Together

CARBOHYDRATES

11. When the CARBS enter the duodenum, the hormone SECRETIN is released.
12. SECRETIN causes the release of the pancreatic juices.
13. Sodium bicarbonate neutralizes the pH to 8.5 so all the enzymes can work at their optimum pH.
14. Pancreatic Amylase digests the uncooked starch into maltose.
15. The maltose moves further down into the smaller intestines.
16. The intestinal glands release the enzymes: peptidases, nucleases, maltase, sucrase, and lactase.
17. The maltase digests the maltose into 2 glucose molecules.
18. The sucrase digests the sucrose into glucose and fructose.
19. The lactase digests the lactose into glucose and galactose.
20. The glucose, fructose, and galactose move into the capillaries of the villi.
21. The capillaries are attached to the hepatic portal vein which takes the monosaccharides to the liver.
22. If the blood sugar is high the pancreas will release insulin.

Let's Put It All Together

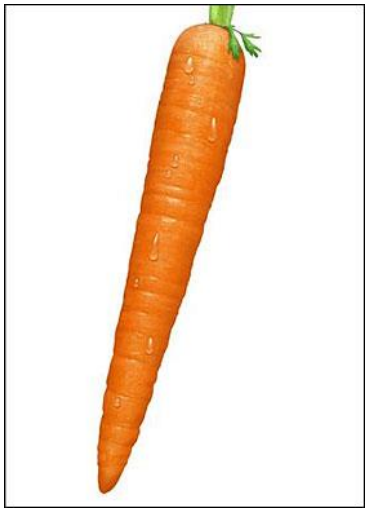
CARBOHYDRATES

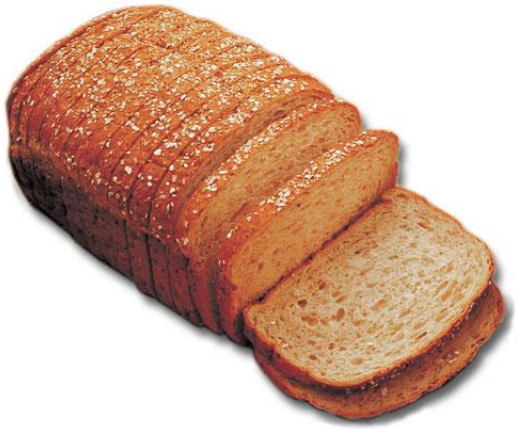
23. Insulin will cause the liver to store the glucose as glycogen.
24. When blood sugar drops again, the pancreas will release glucagon.
25. Glucagon will cause the liver to release the glucose into the blood stream.
26. The blood will go to the heart where it will be pumped to the body cells.
27. The glucose will enter the cells and go into the mitochondria.
28. The mitochondria turns the glucose into ATP via cellular respiration.
29. The indigestible wastes continue into the large intestines, where water is reabsorbed and the feces are released from the body when the anal sphincter relaxes.

Let's Put It All Together

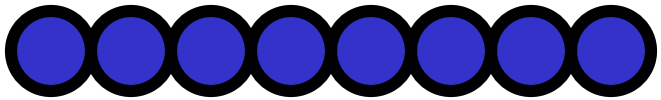
CARBOHYDRATES

Step 1: eat carbs & chew with teeth.





Uncooked starch



Cooked starch

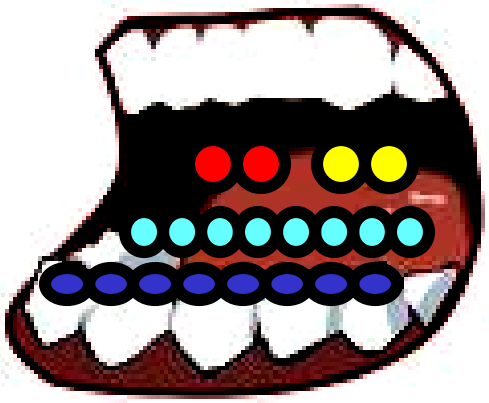
lactose

sucrose

Let's Put It All Together

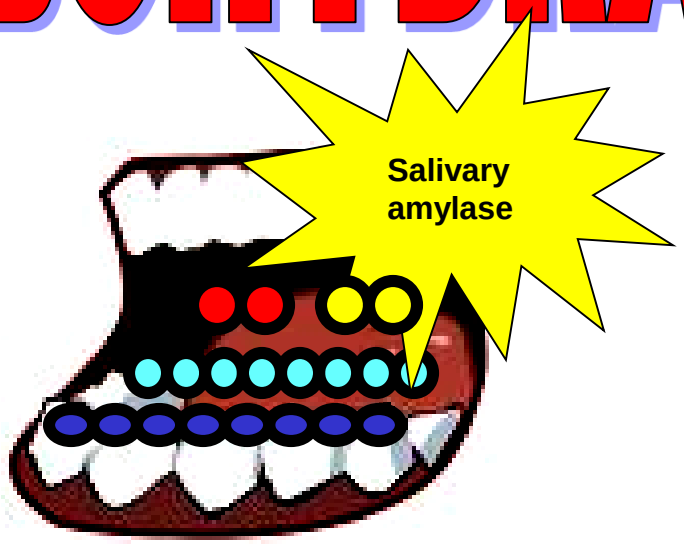
CARBOHYDRATES

Step 2: saliva is released with salivary amylase and mucous.



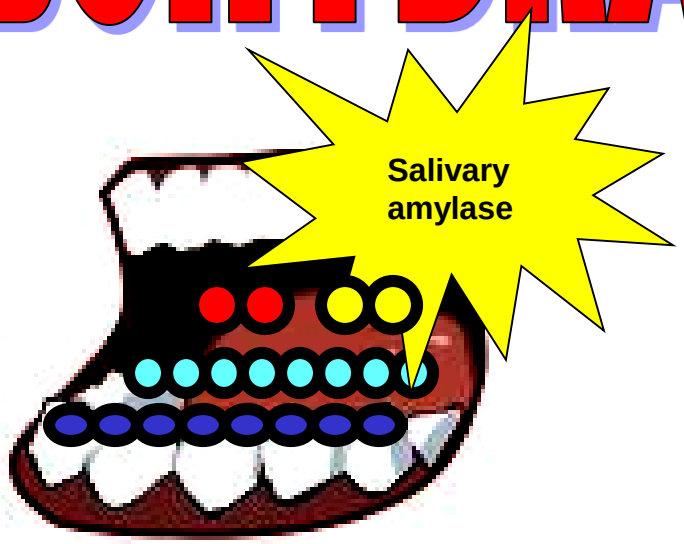
Let's Put It All Together

CARBOHYDRATES



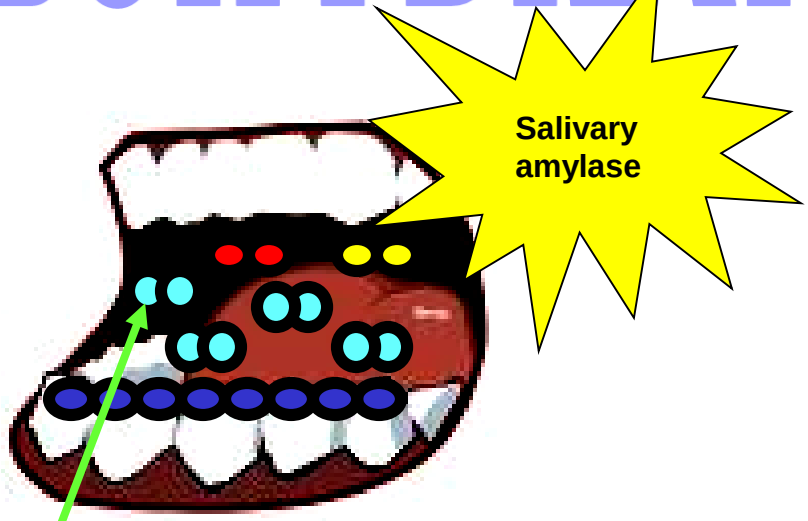
Let's Put It All Together

CARBOHYDRATES



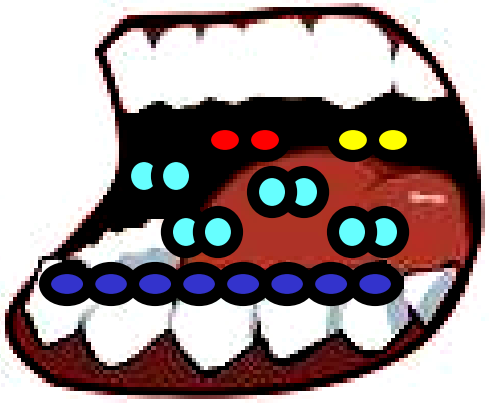
Let's Put It All Together

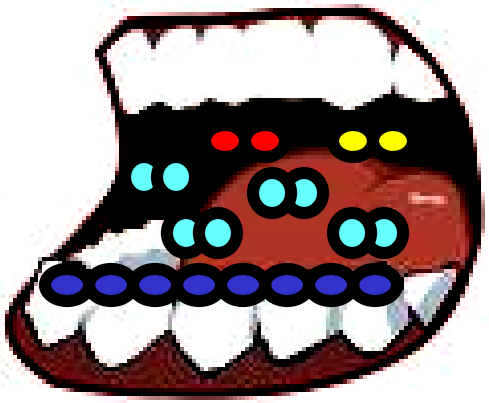
CARBOHYDRATES

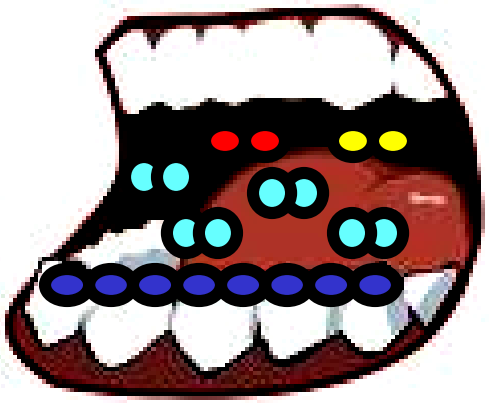


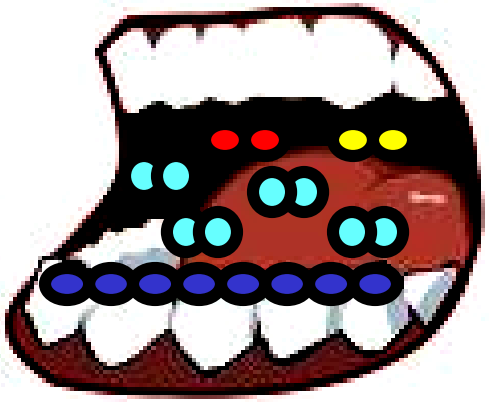
MALTOSE

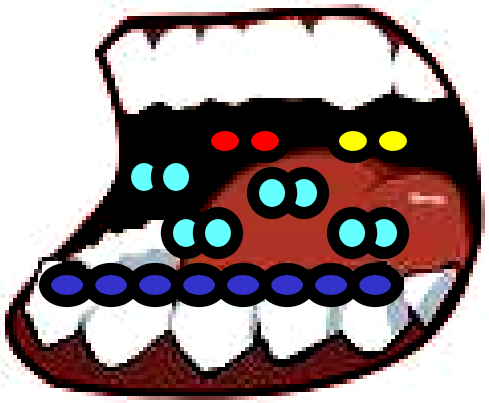
Step 3: salivary amylase breaks cooked starch down into maltose.

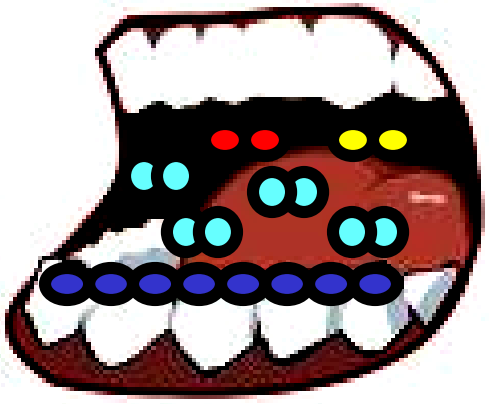


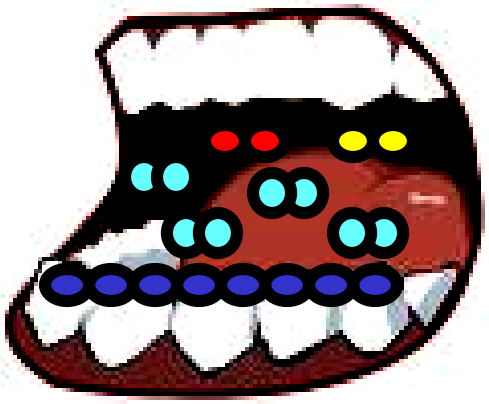




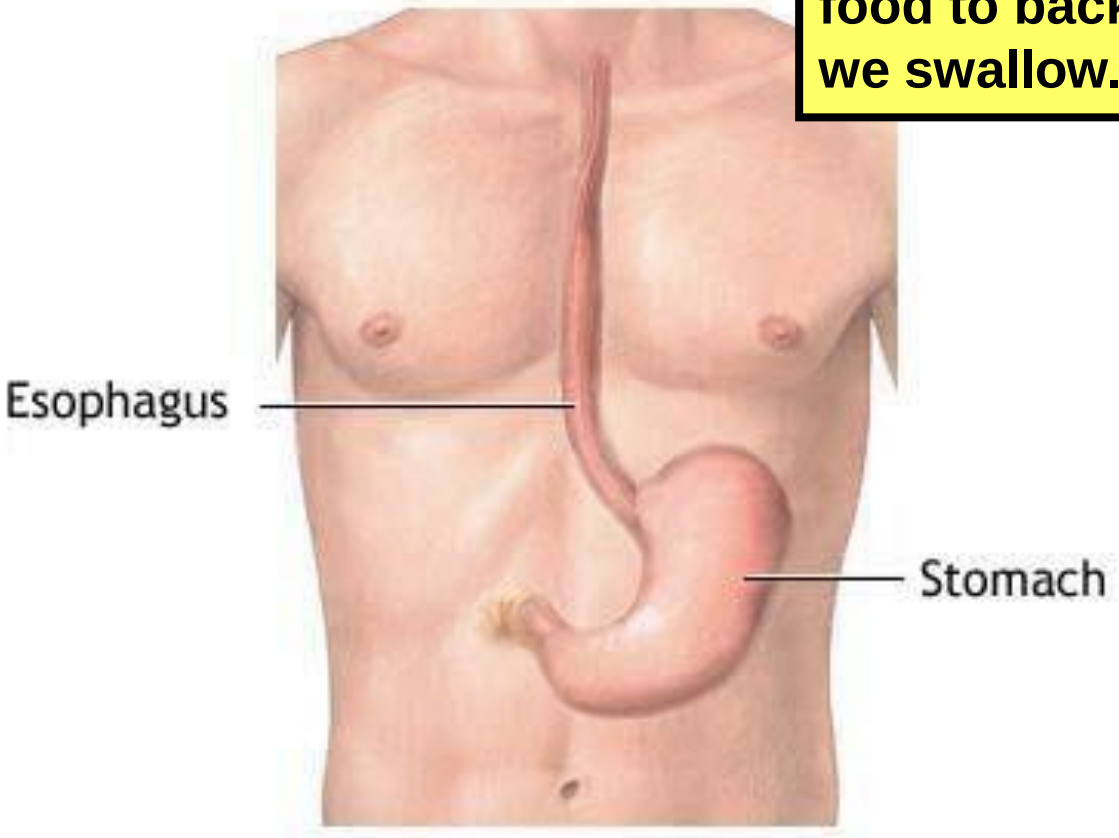




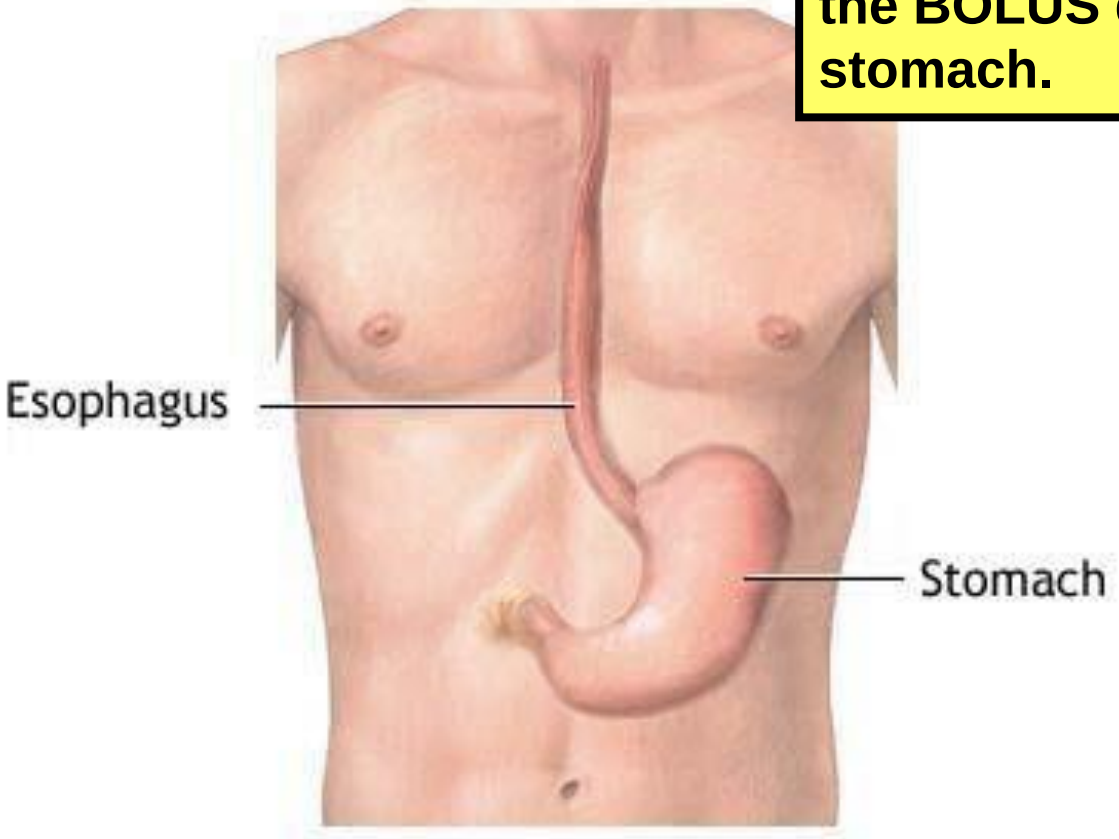




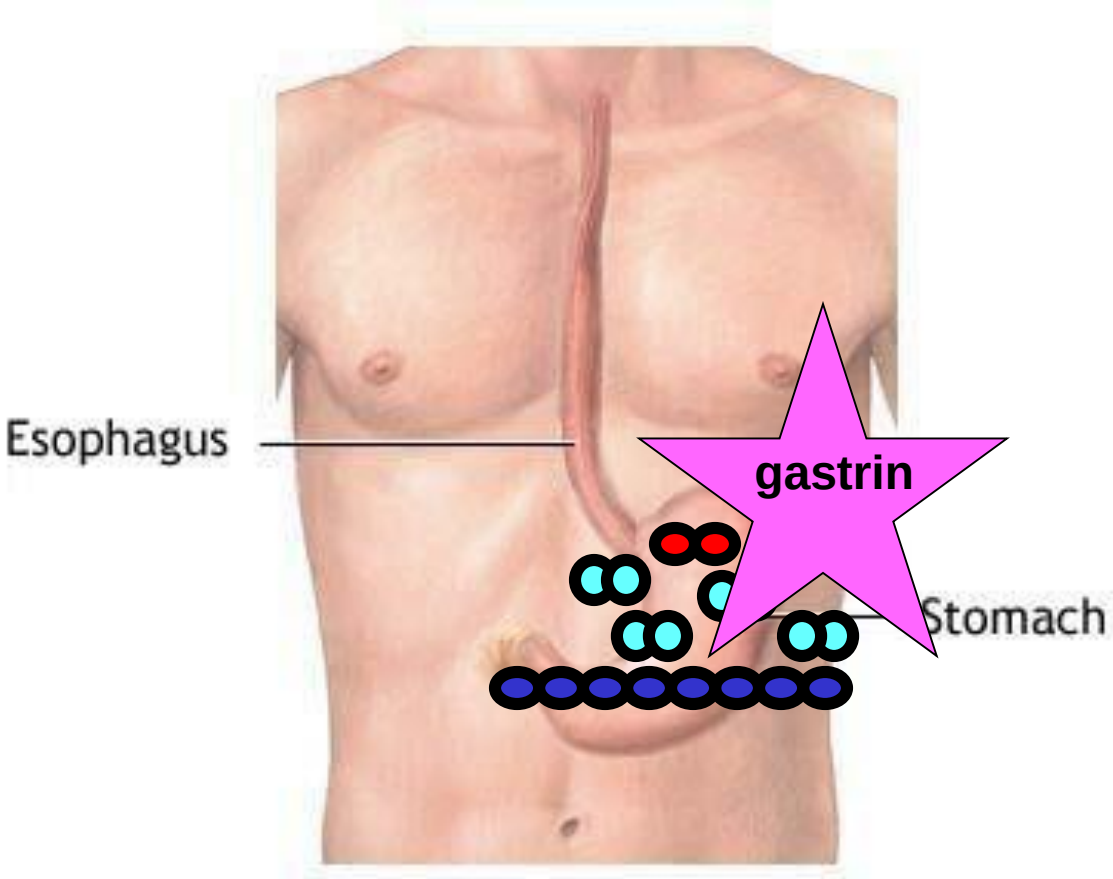
Step 4: tongue pushes food to back of throat and we swallow.



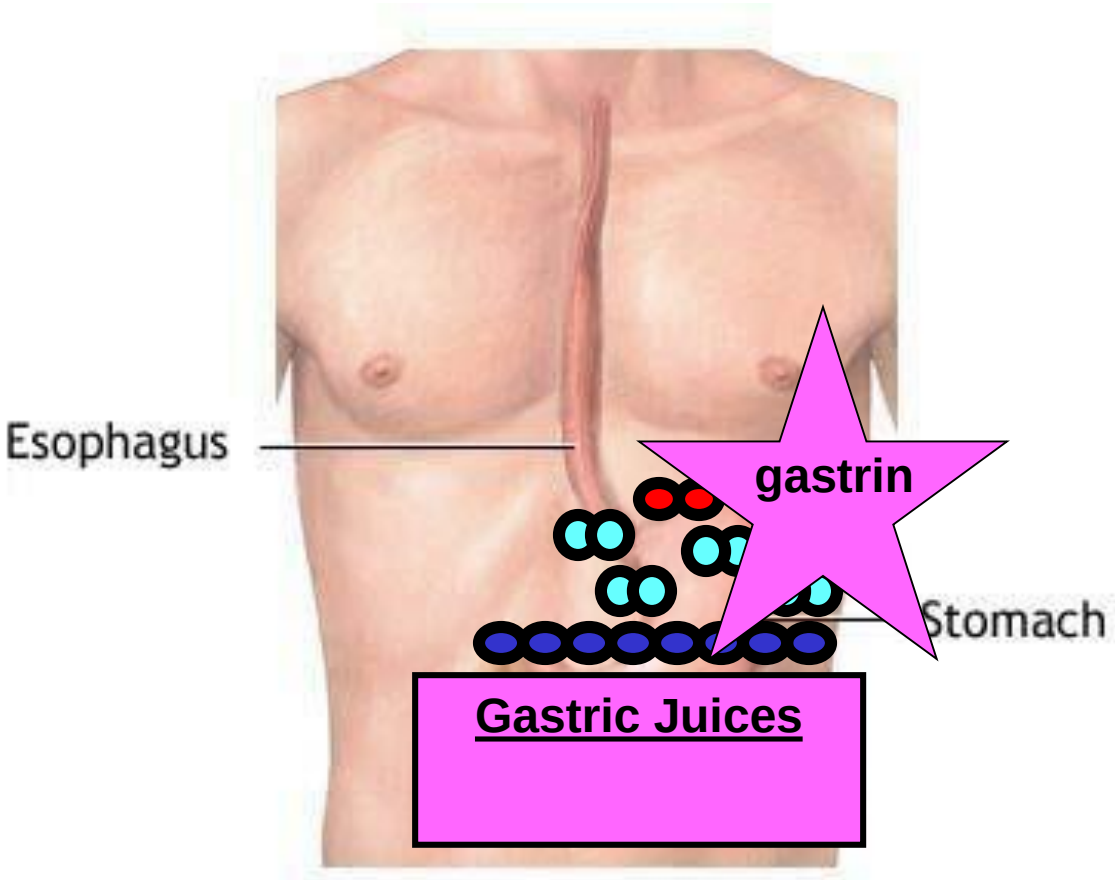
Step 5: peristalsis pushes the BOLUS down to the stomach.



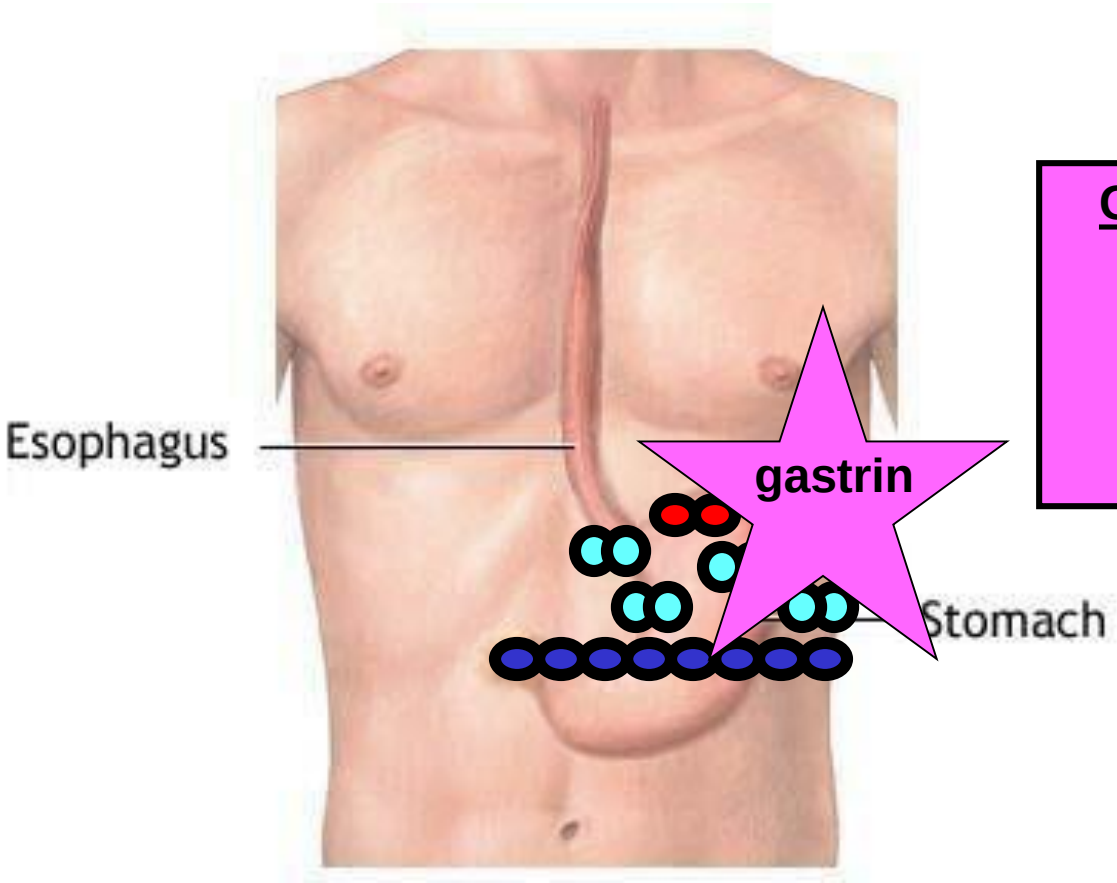
Step 6: when food reaches the stomach, GASTRIN is released.



Step 6: GASTRIN causes the release of all of the gastric juices.

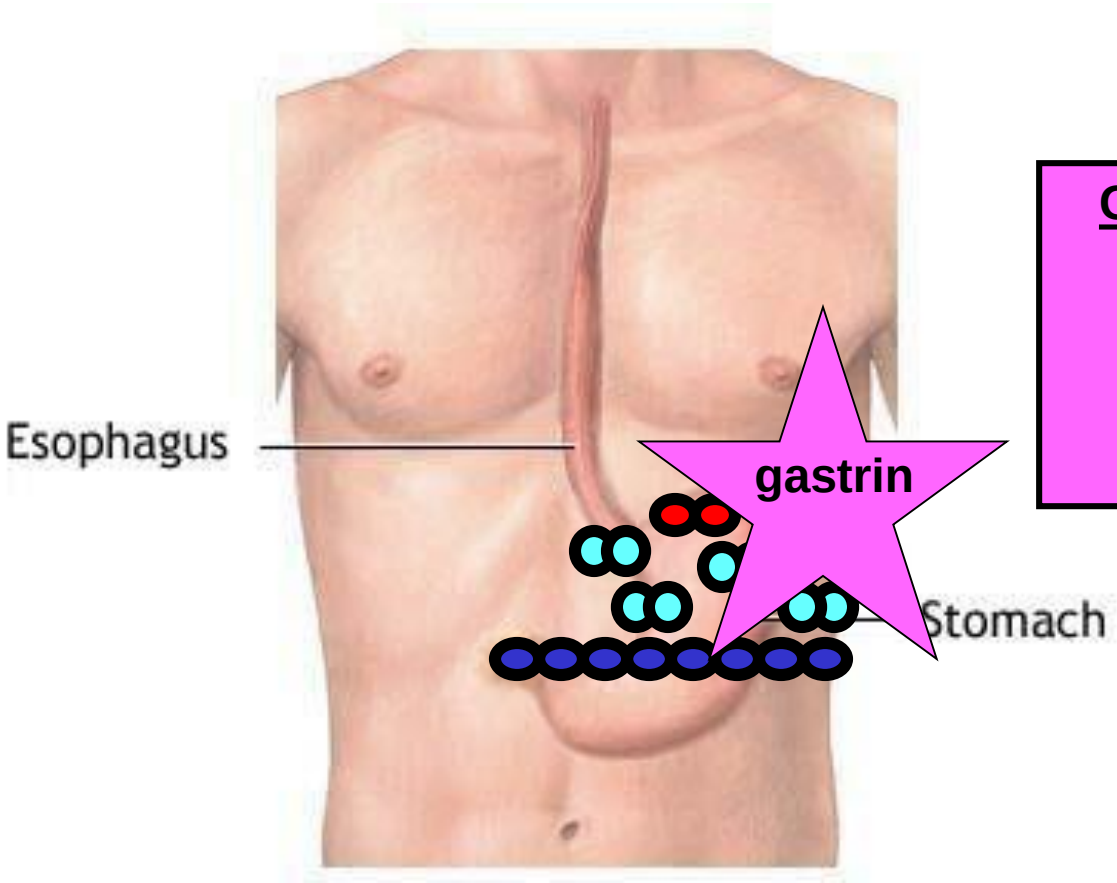


Step 7: HCl kills bacteria in food and creates a pH of 2.5.



Gastric Juices

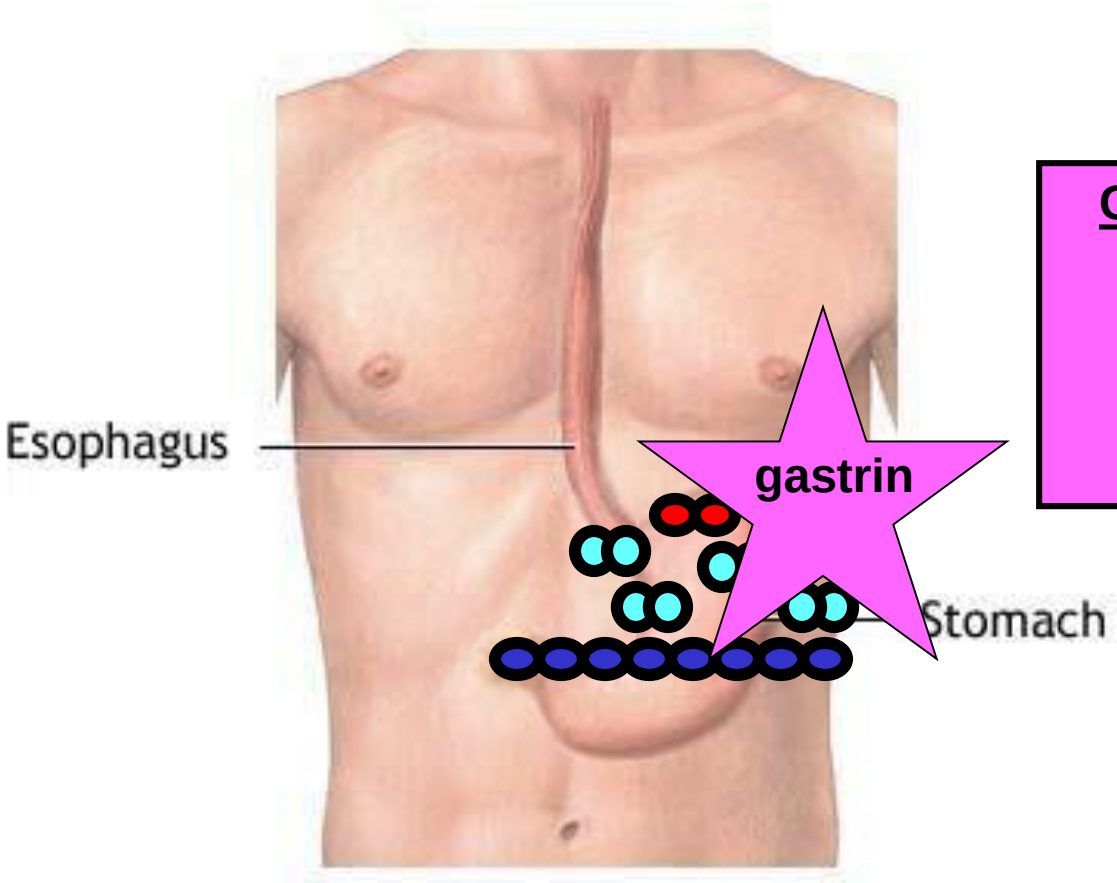
HCl



Gastric Juices

HCl

Pepsinogen



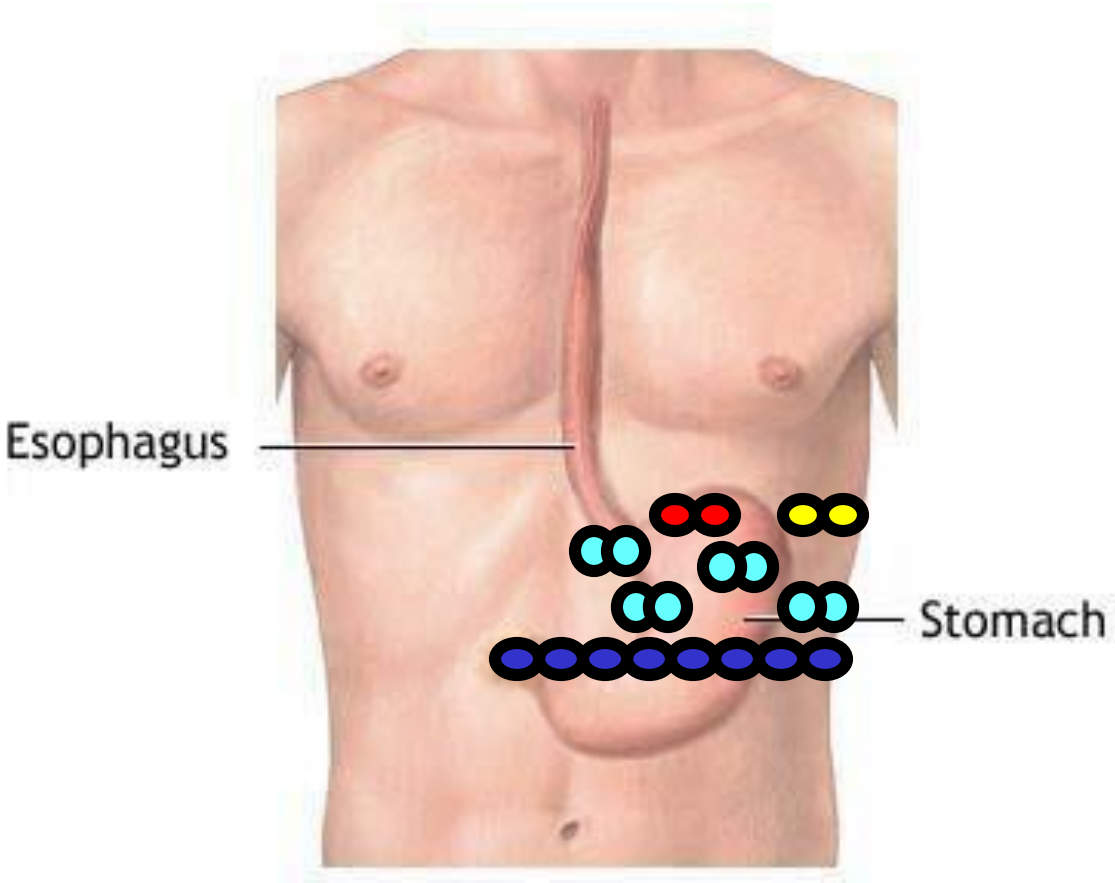
Gastric Juices

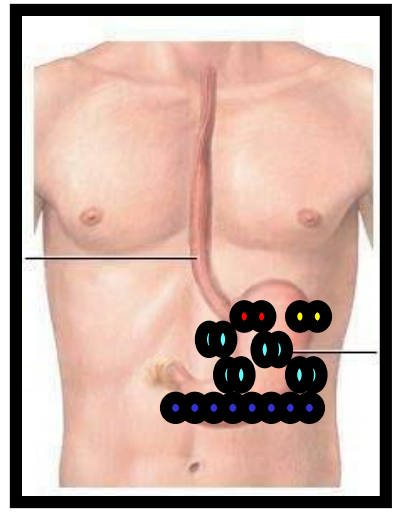
HCl

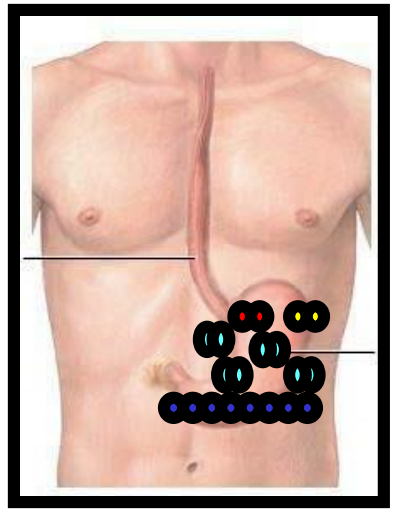
Pepsinogen

Mucous

Step 8: the stomach mashes the food around.

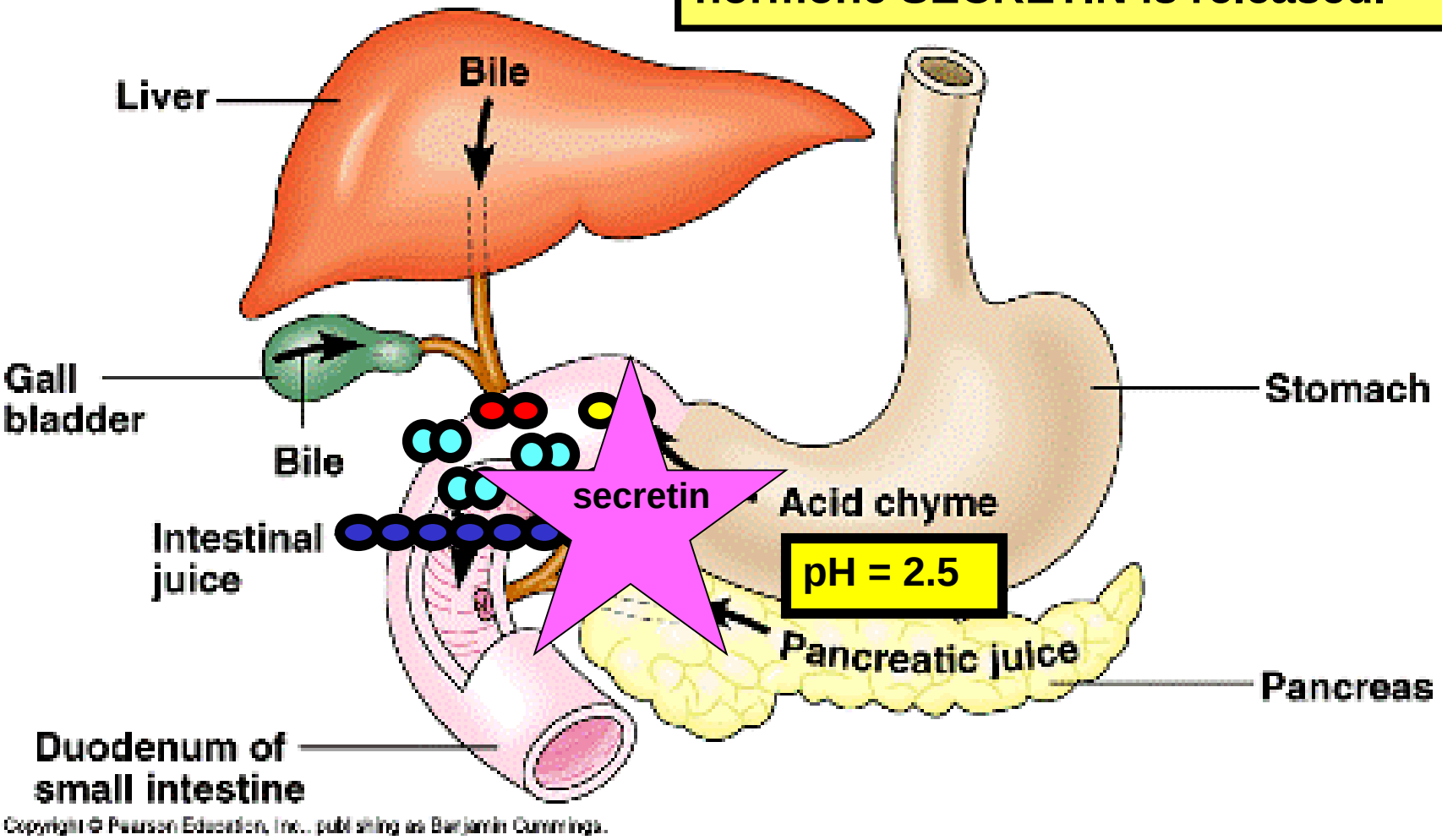




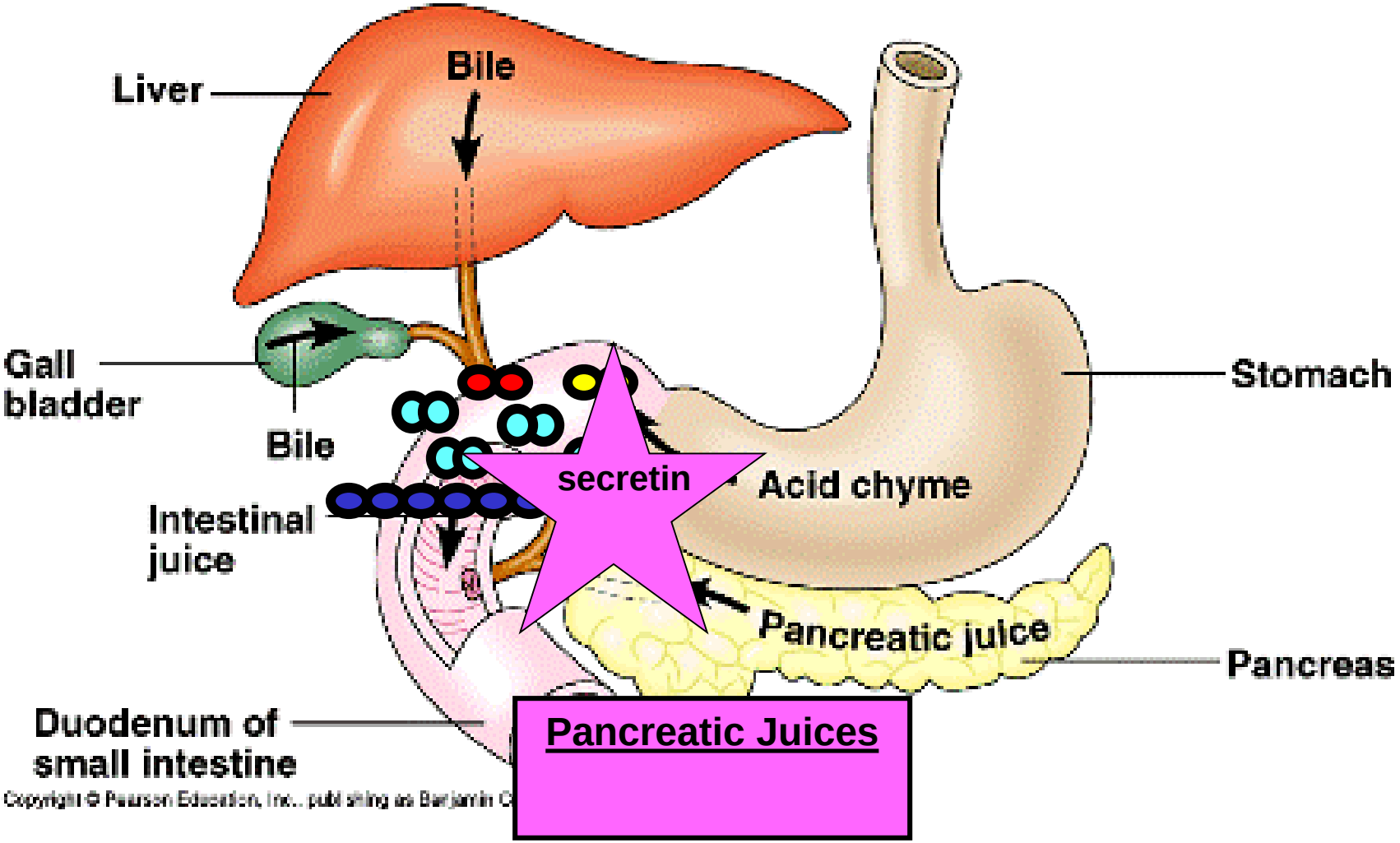


Step 9: the food slowly leaves the stomach through the PYLORIC valve.

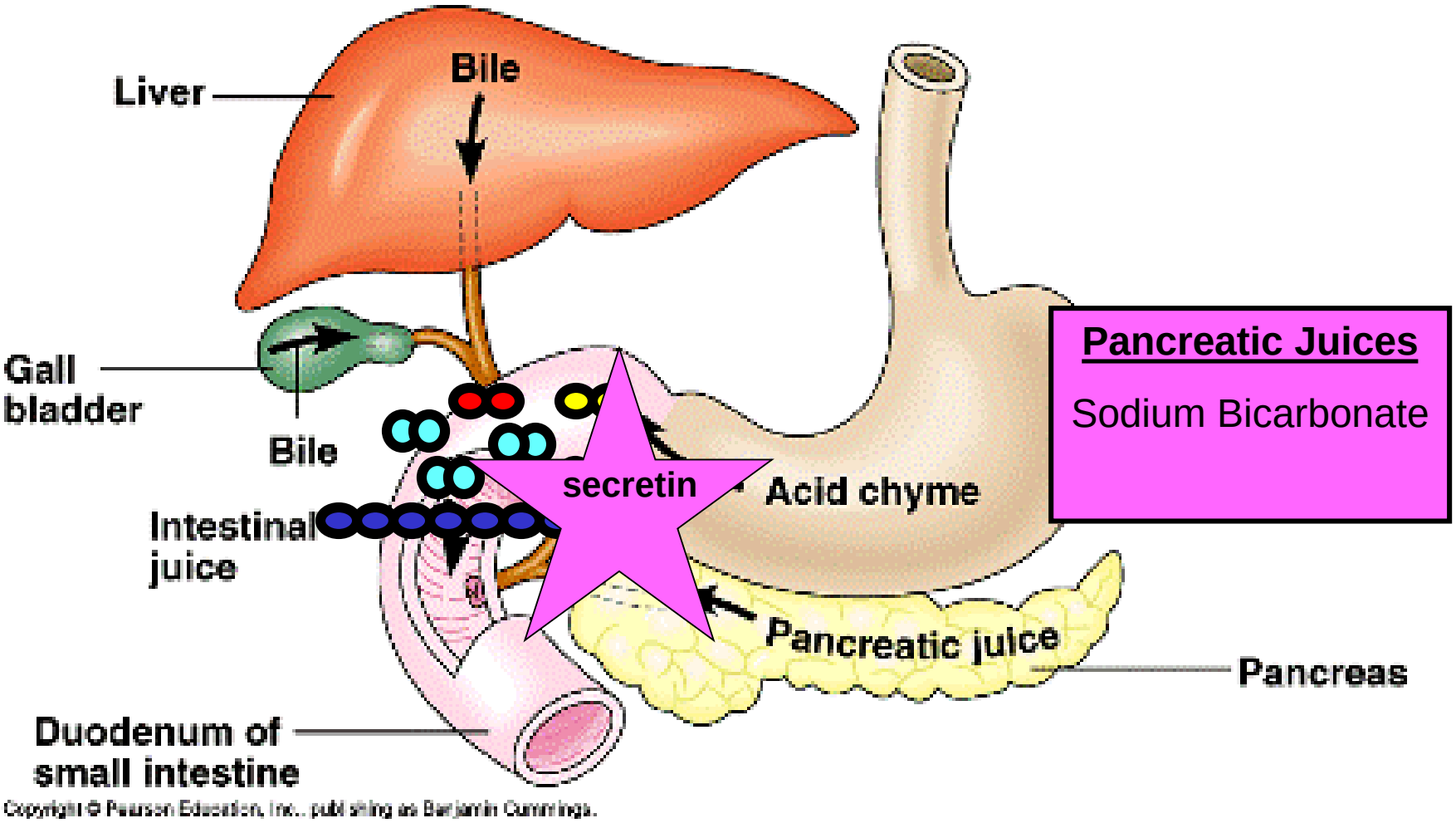
Step 10: when the acid chyme reaches the duodenum, the hormone SECRETIN is released.

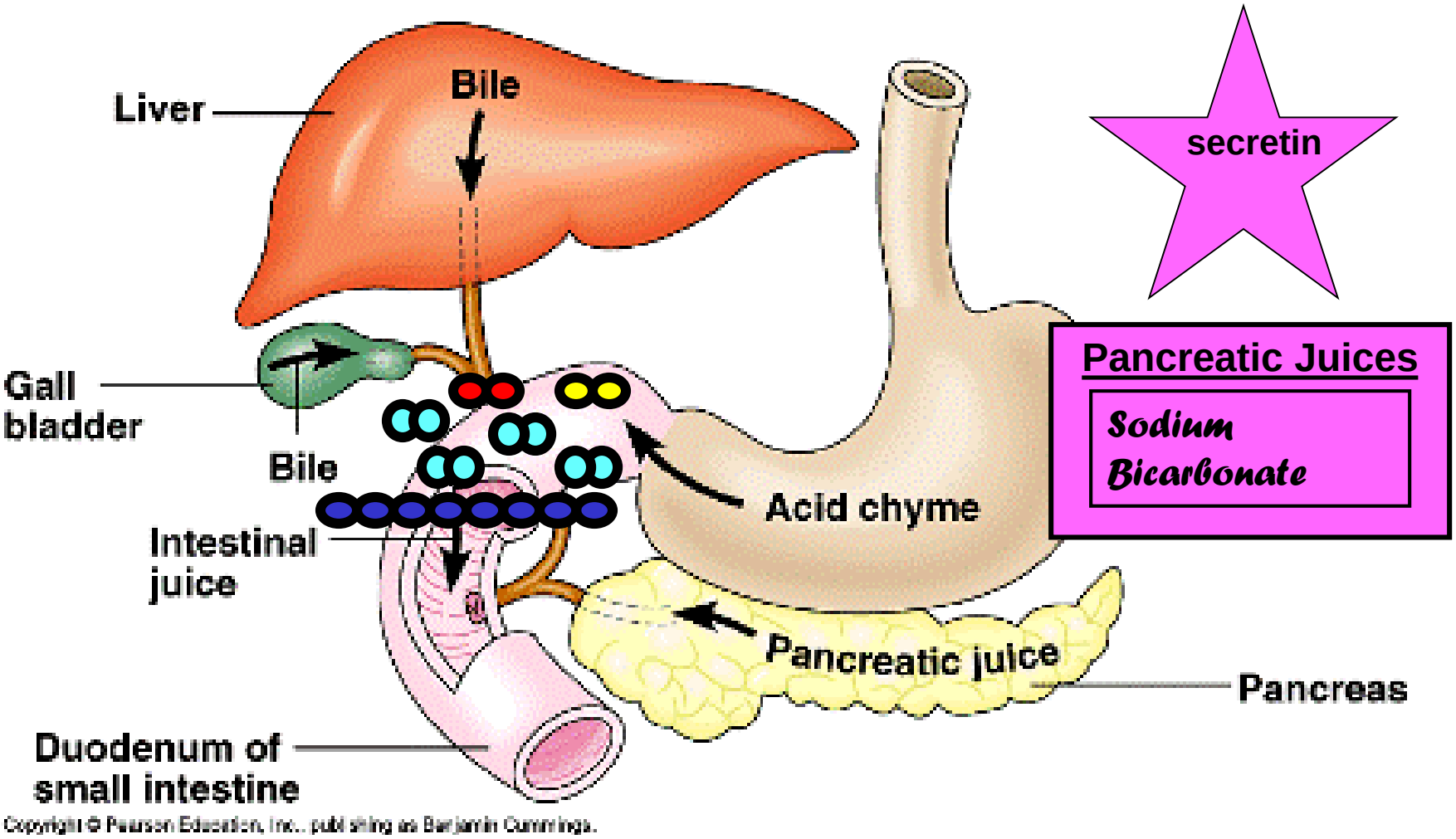


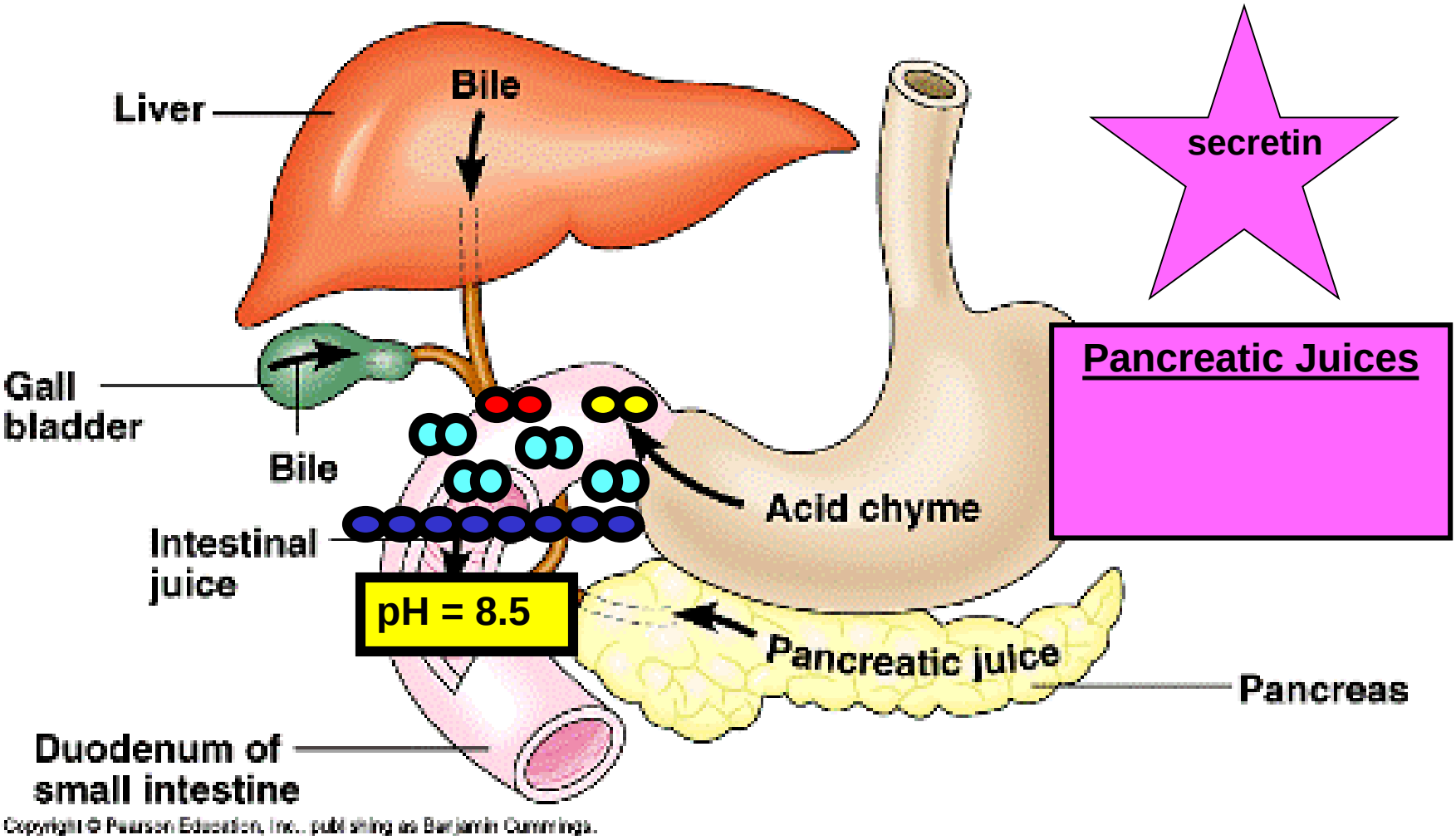
Step 10: Secretin causes the release of all of the pancreatic juices.



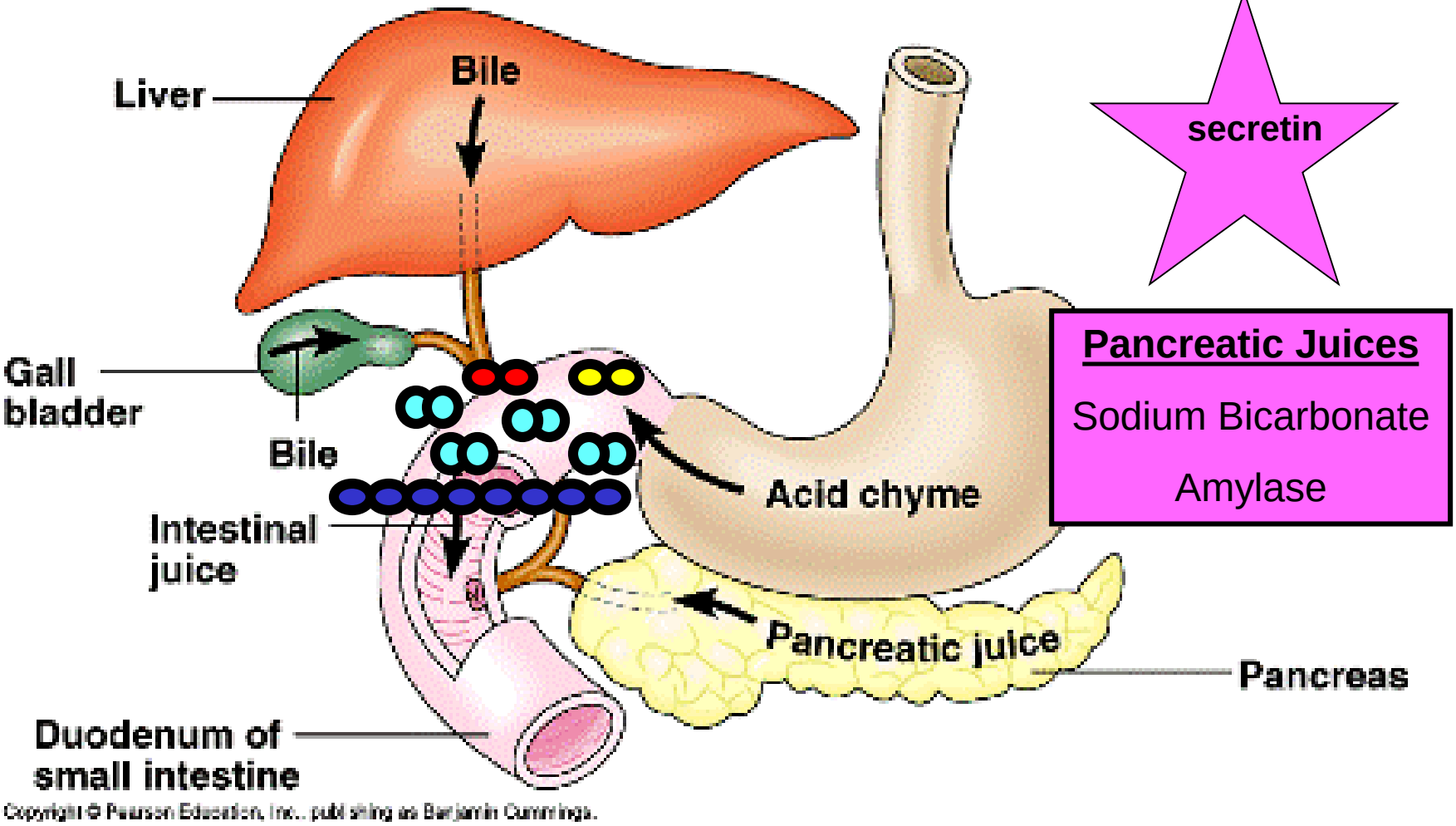
Step 10: sodium bicarbonate increases the pH to 8.5.







Step 11: the enzyme amylase digests the uncooked starch to maltose.

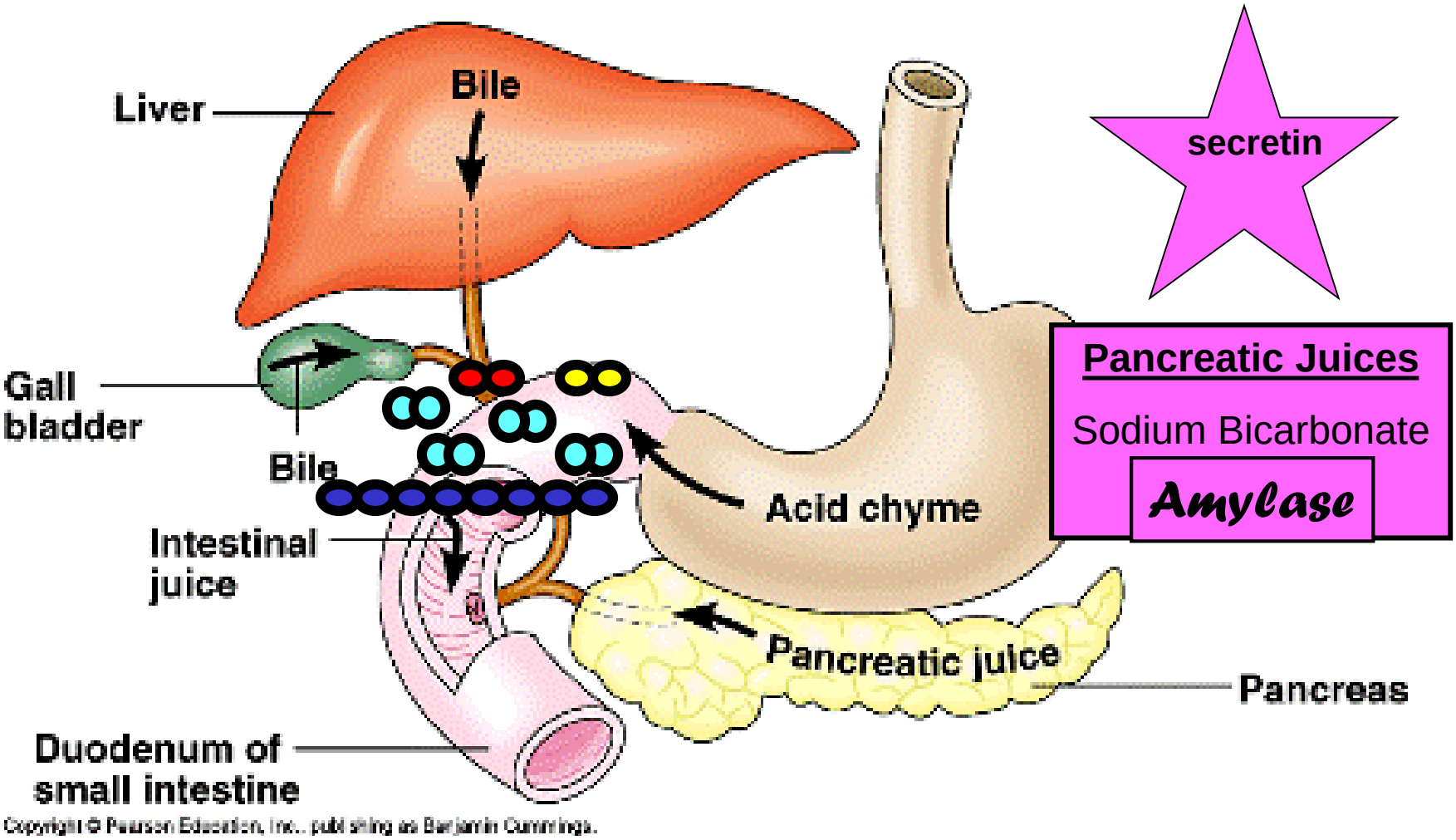


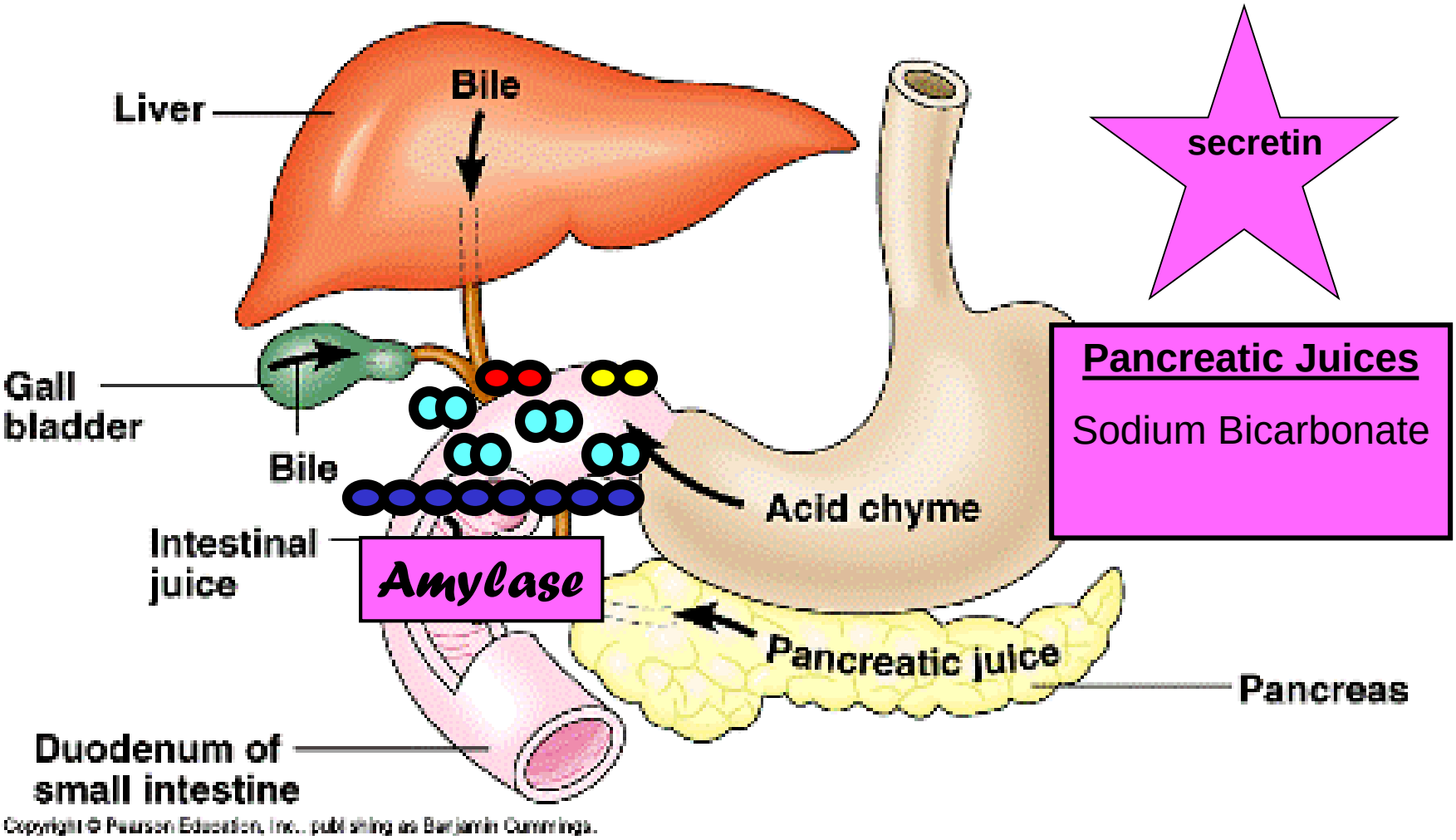
secretin

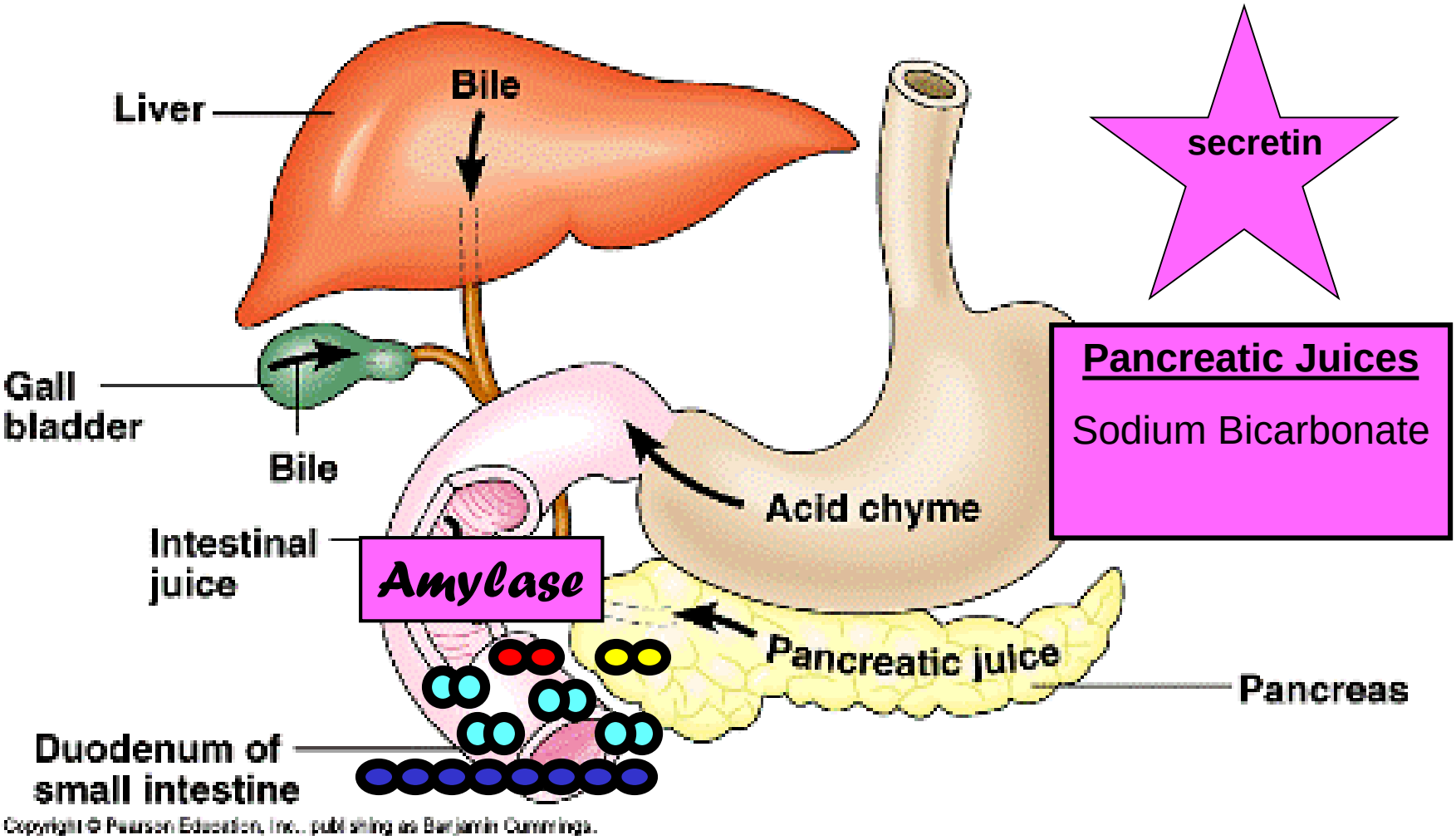
Pancreatic Juices

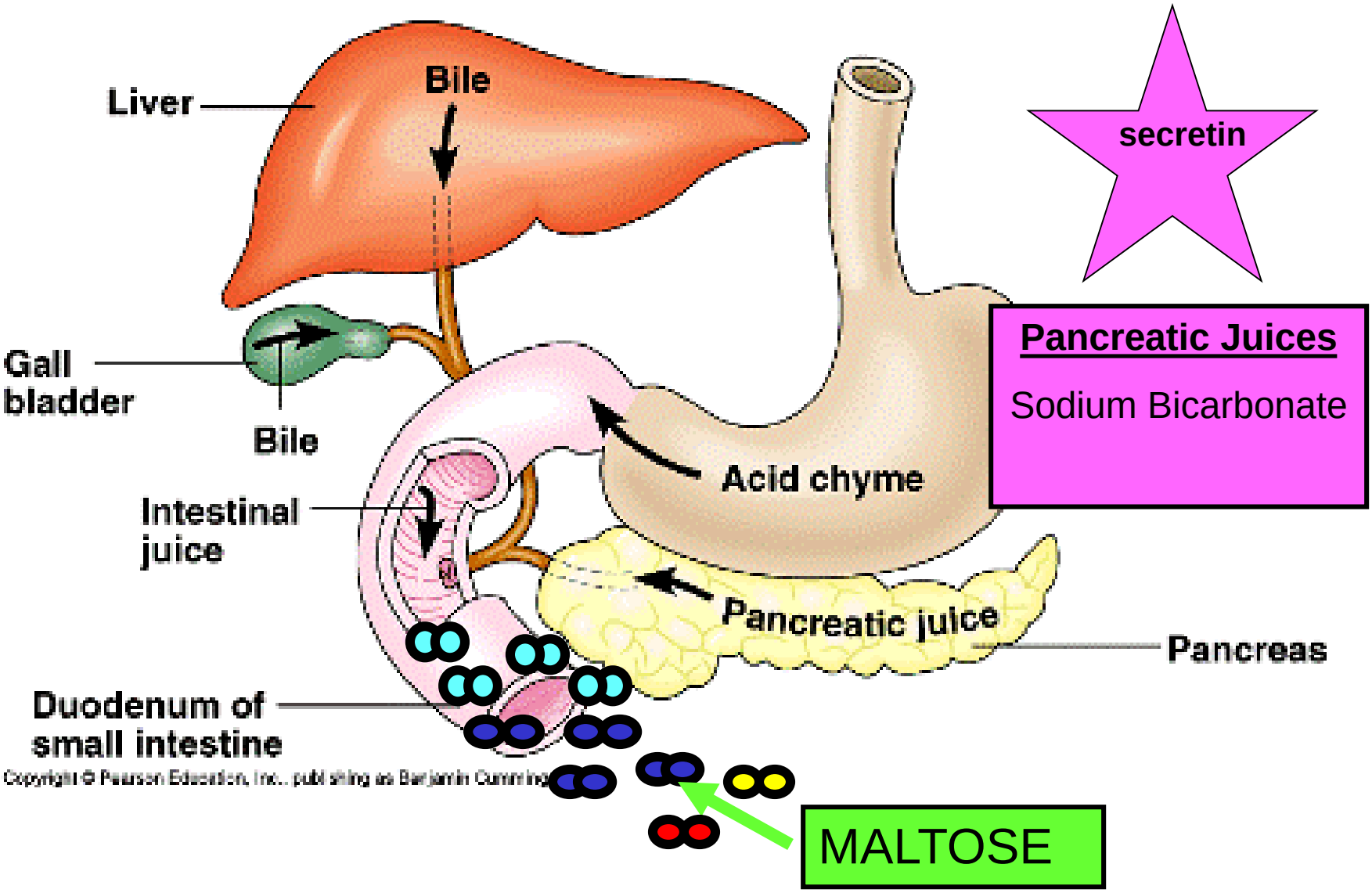
Sodium Bicarbonate

Amylase

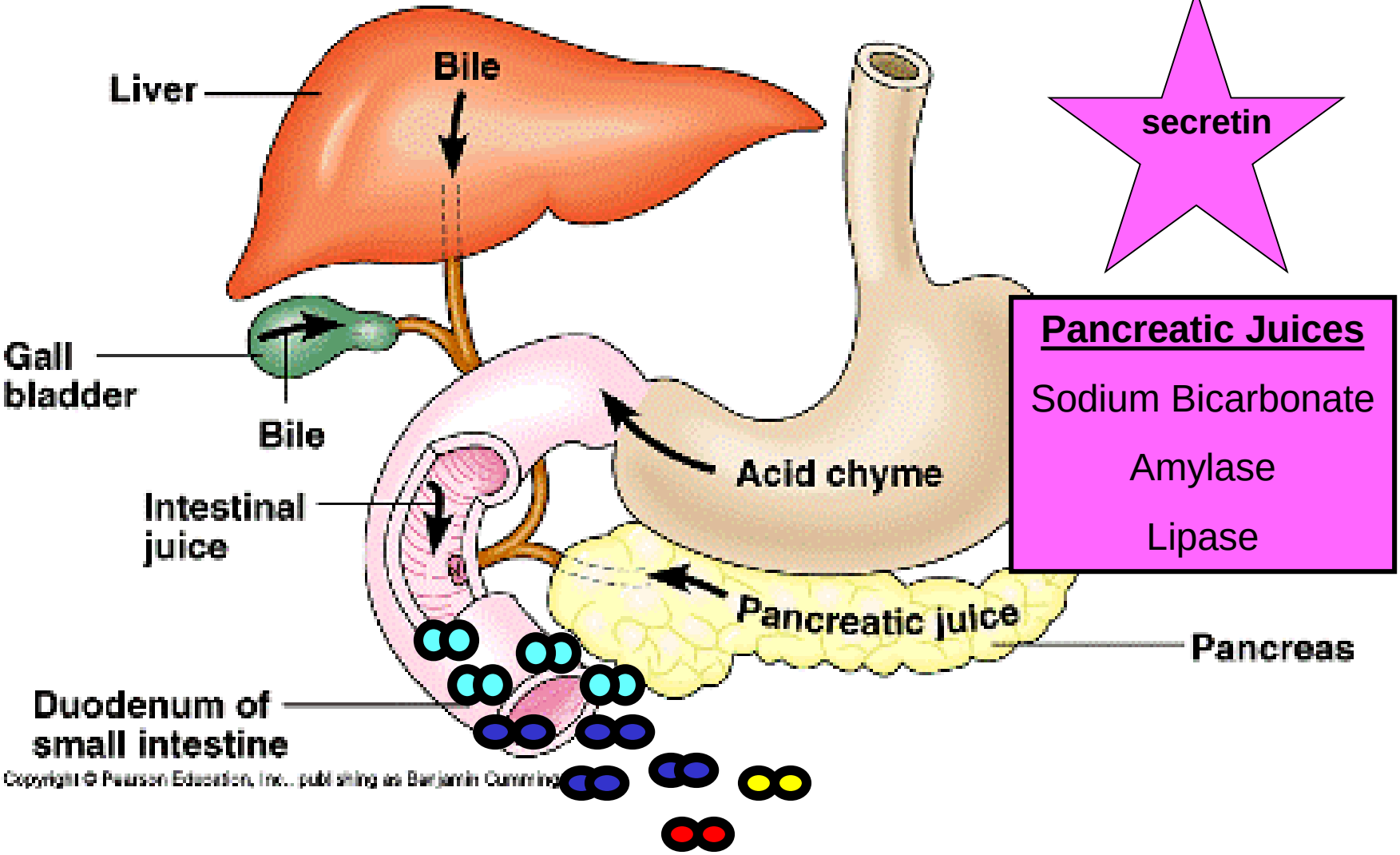


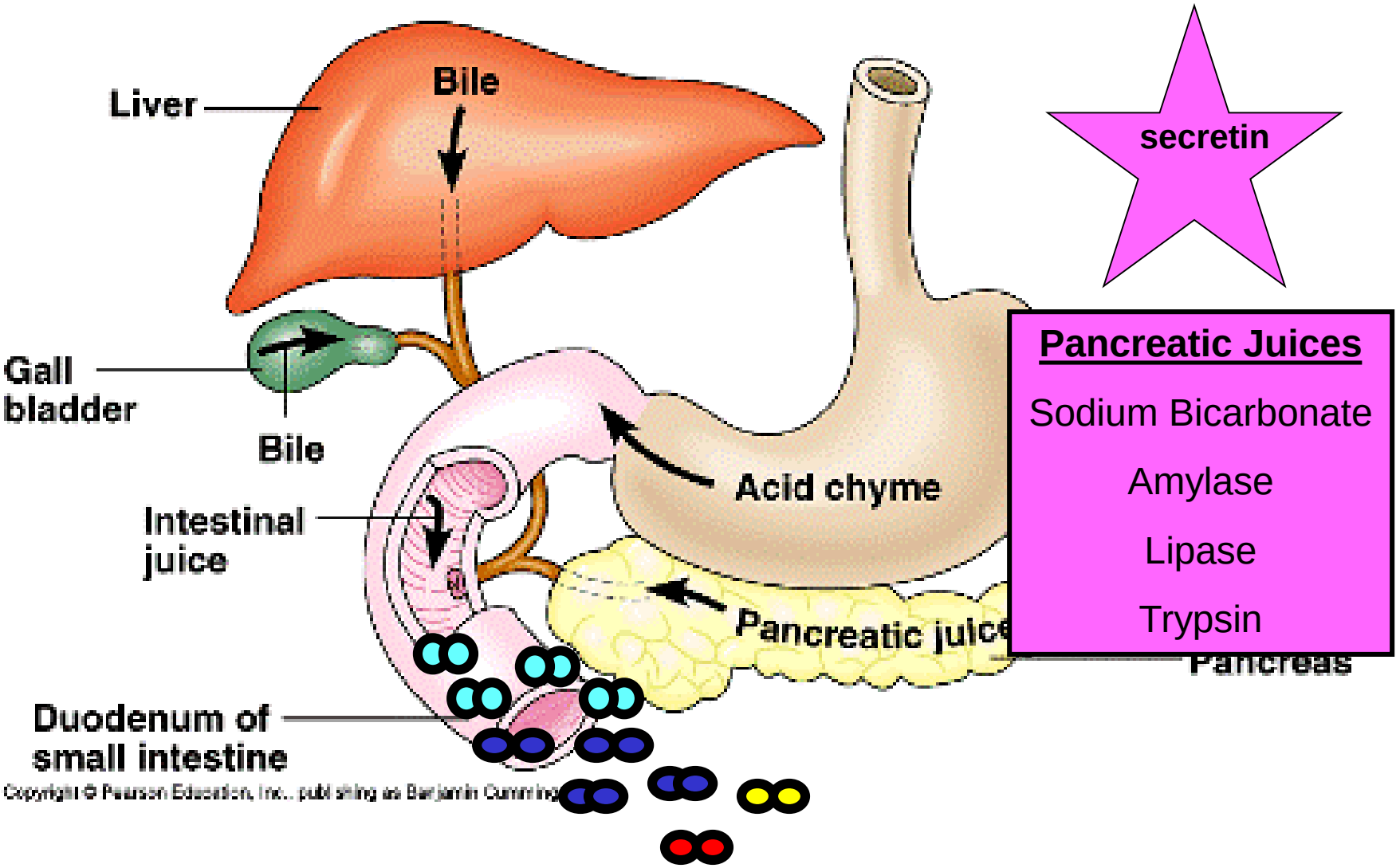


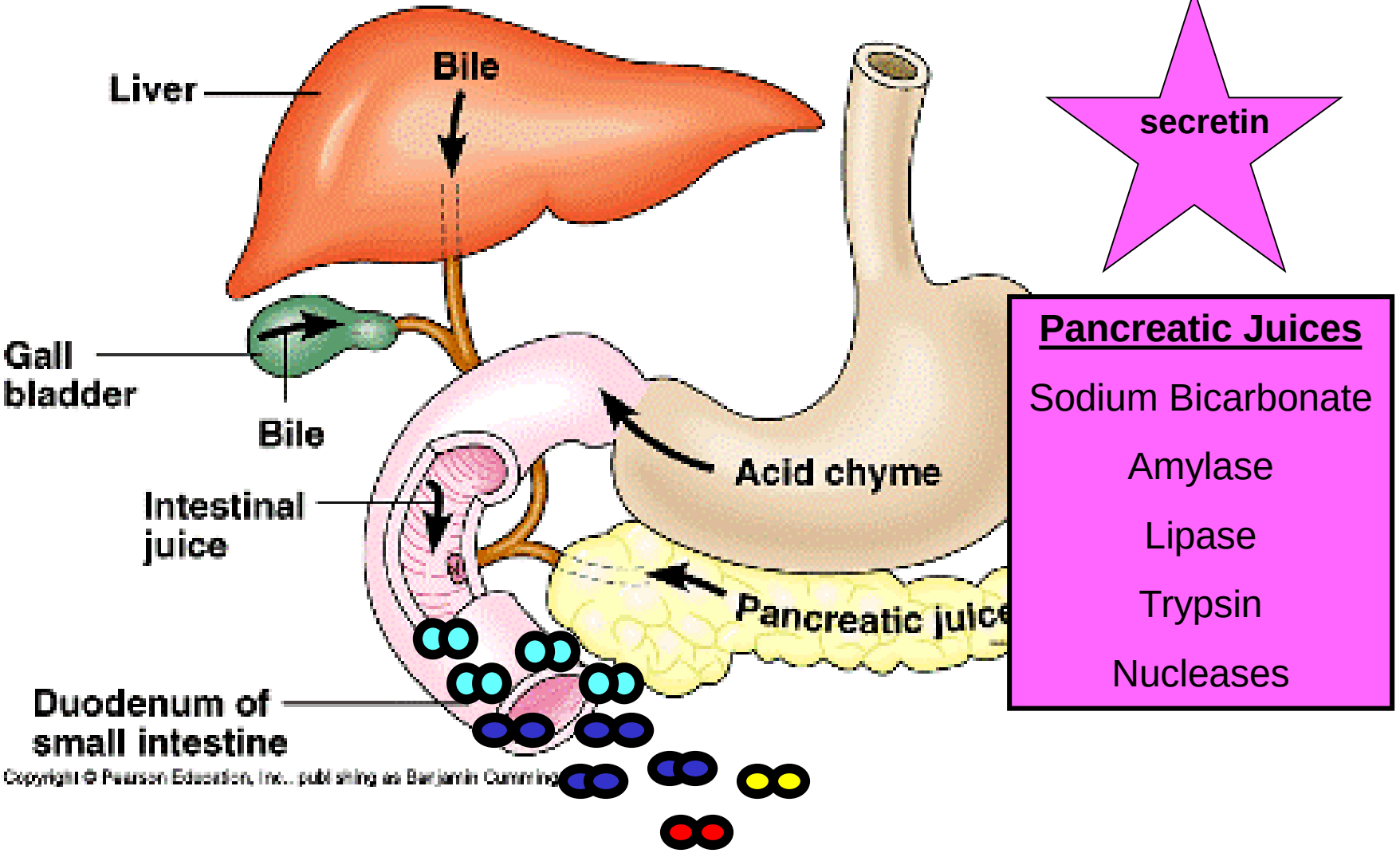




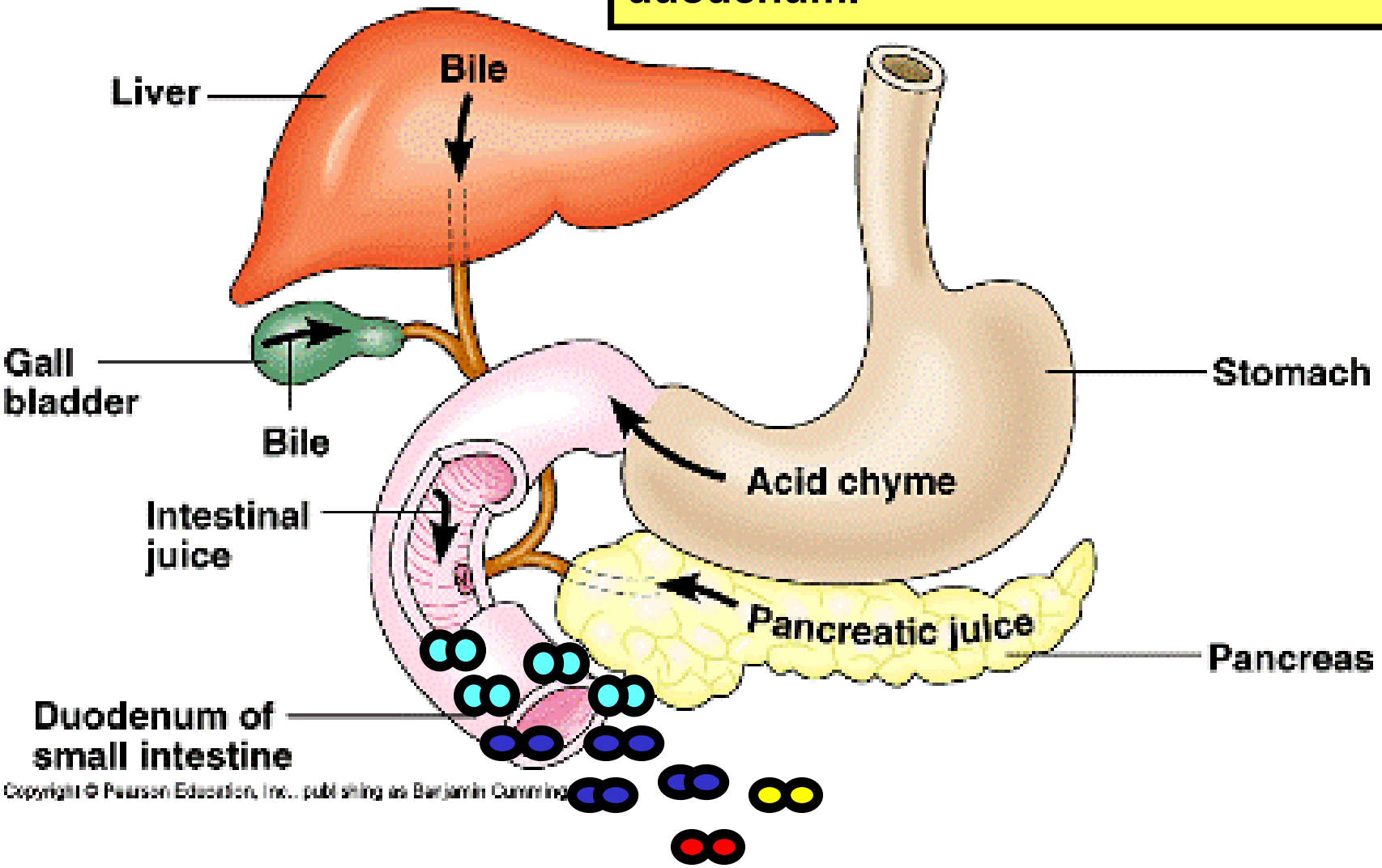
Step 12: the other enzymes have no effect on carbohydrates.

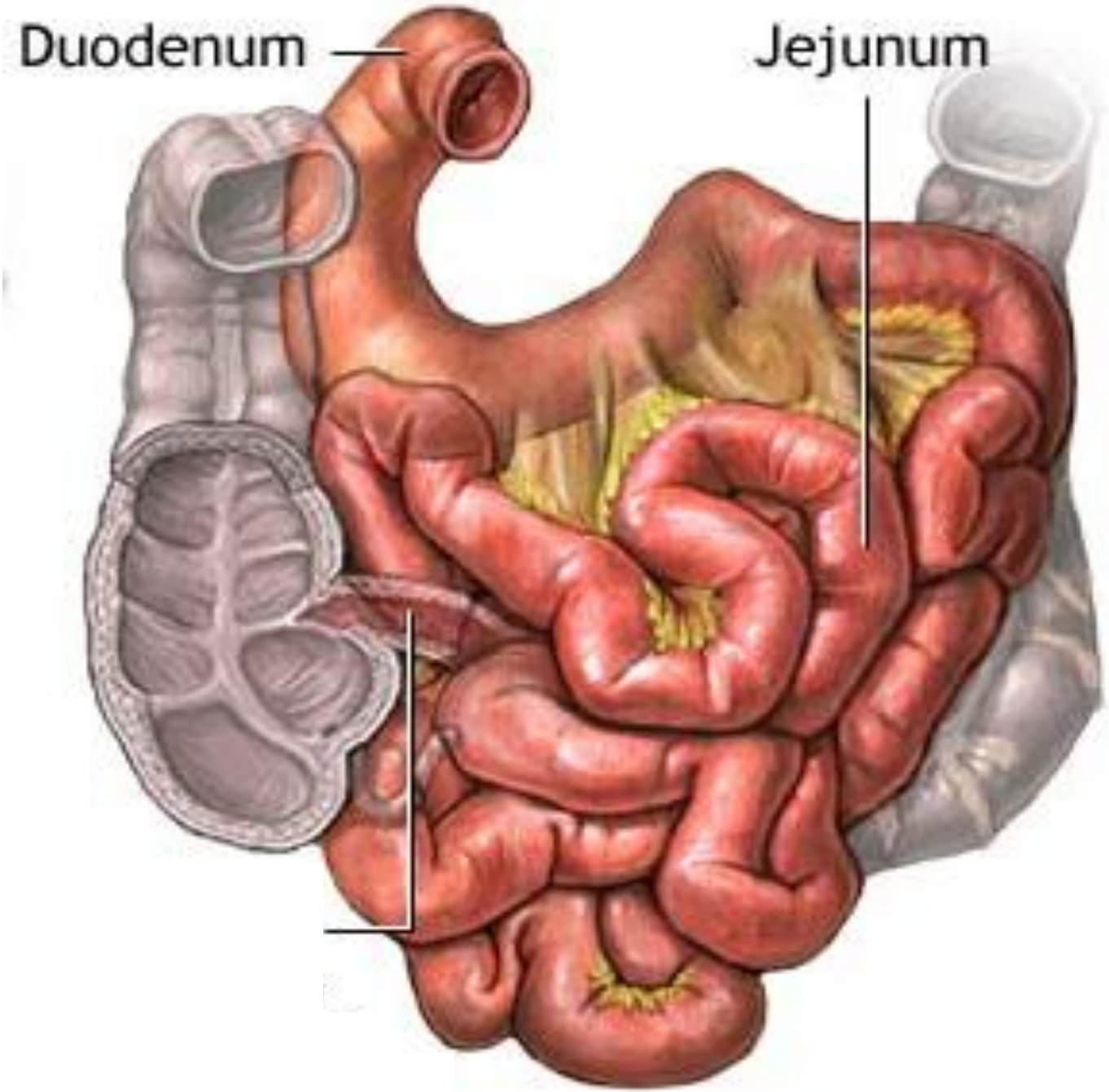


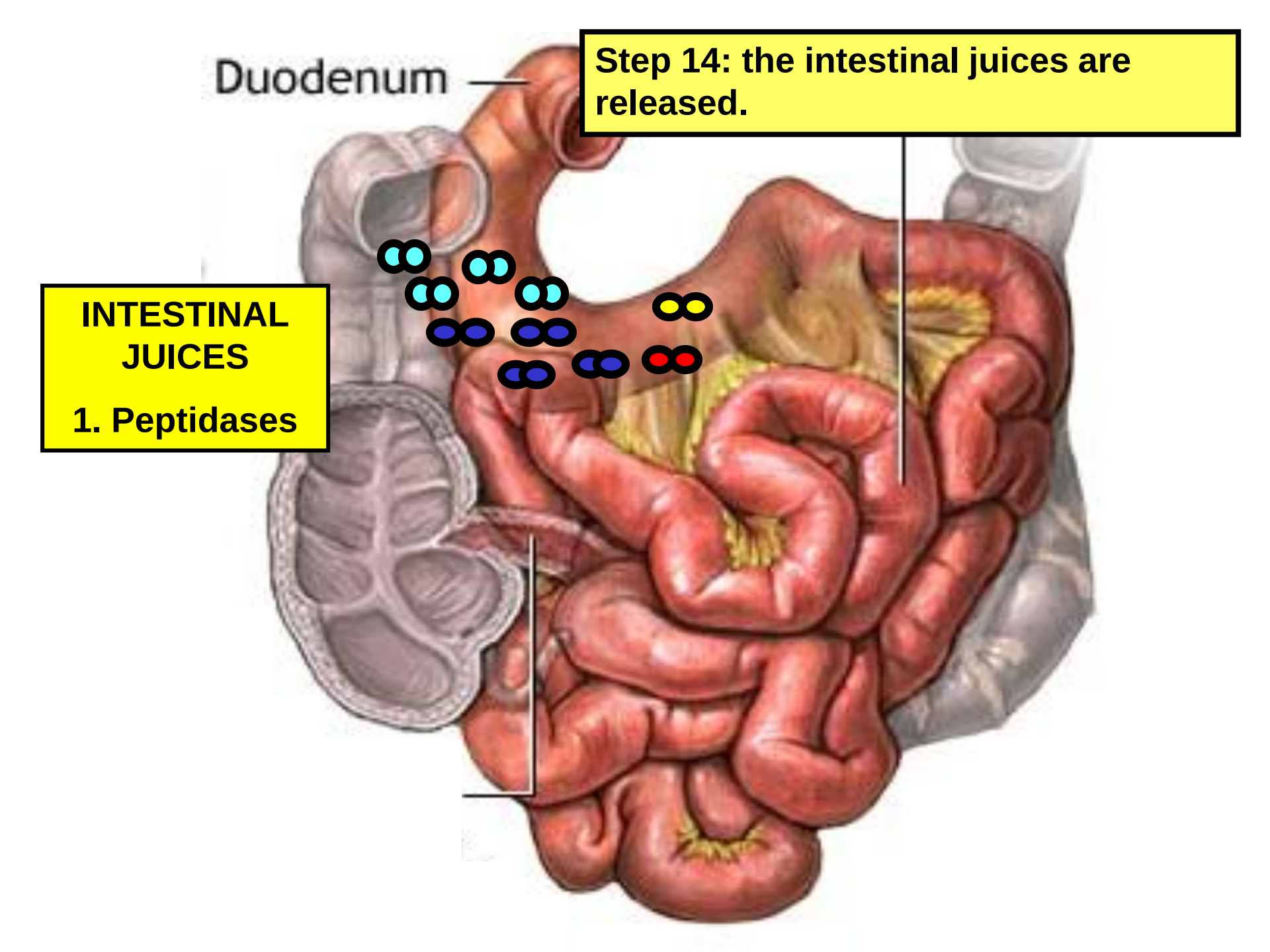


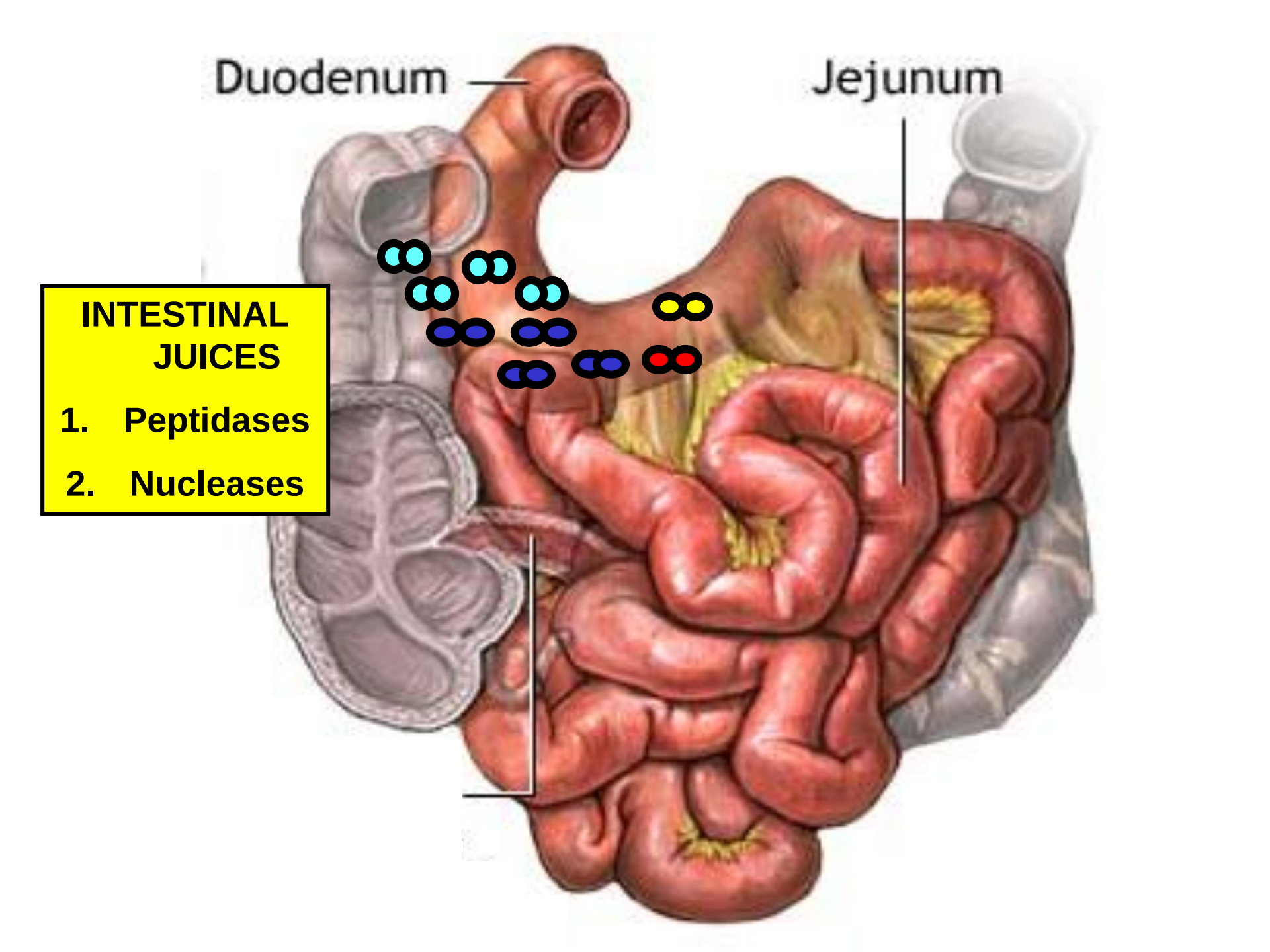


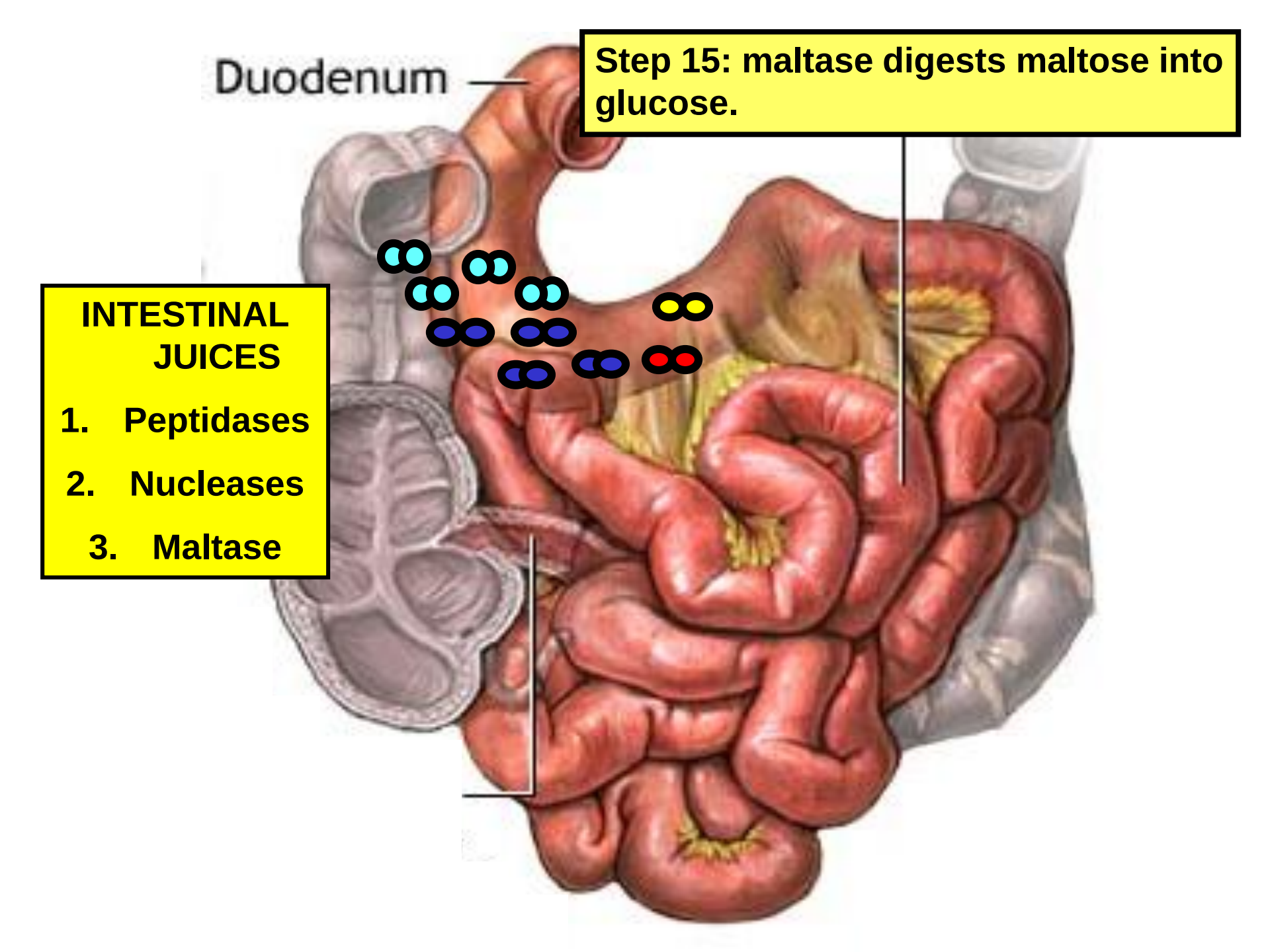
Step 13: maltose, sucrose, and lactose travel further down in the duodenum.

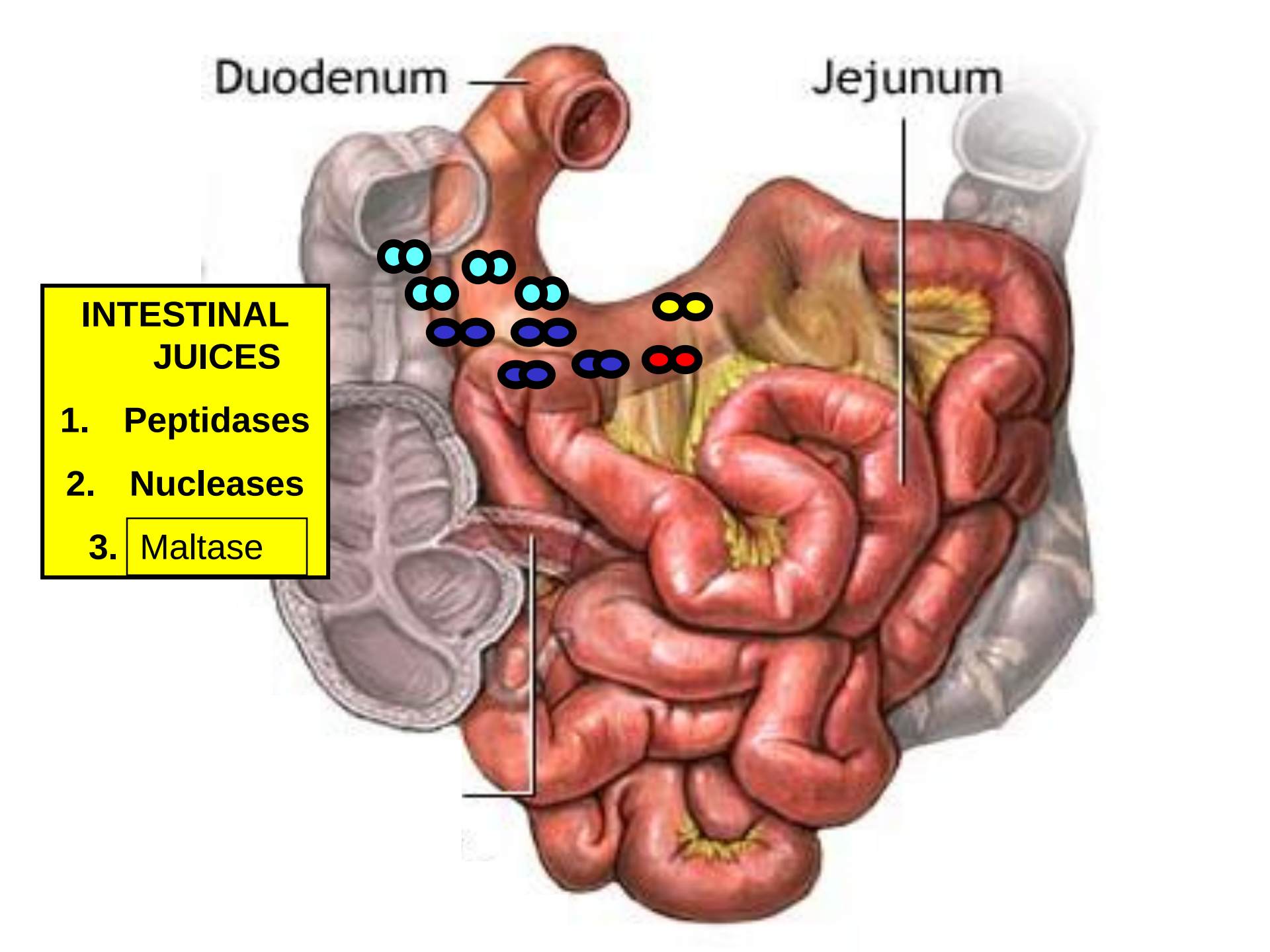


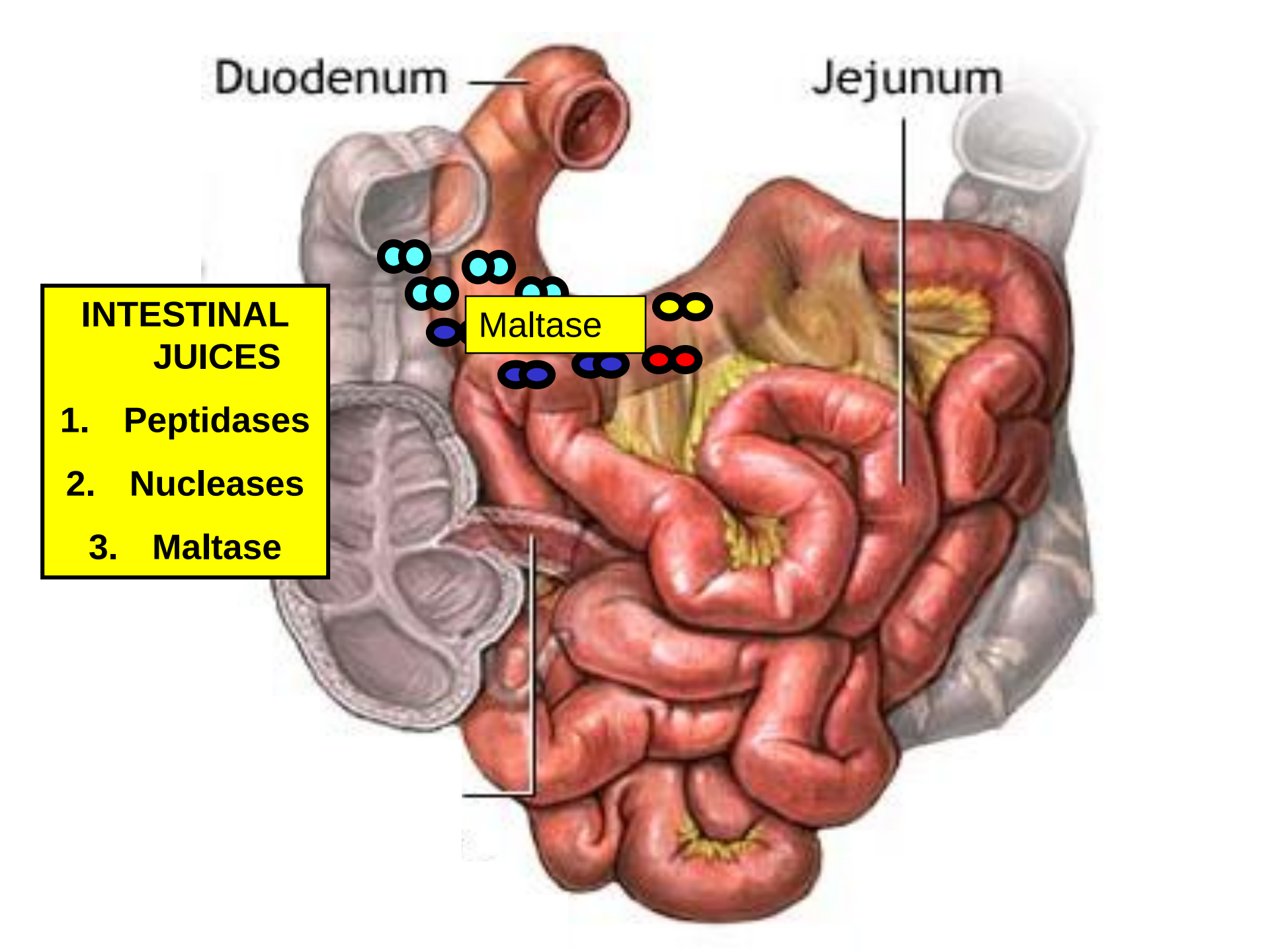

Duodenum
Jejunum


Duodenum
Step 14: the intestinal juices are released.
INTESTINAL JUICES
1. Peptidases


Duodenum
Jejunum
INTESTINAL JUICES
1. Peptidases
2. Nucleases

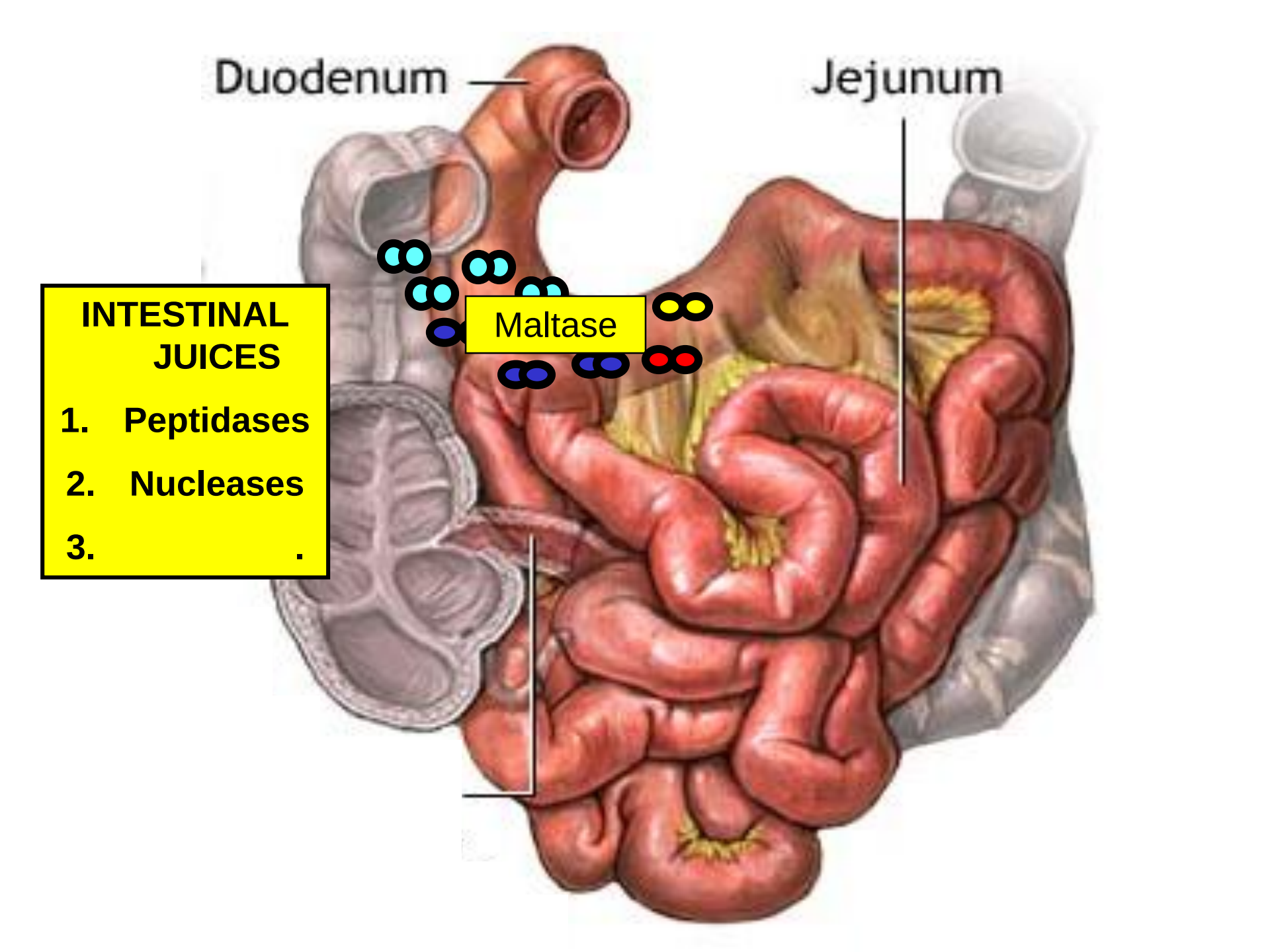

Duodenum
Step 15: maltase digests maltose into glucose.
INTESTINAL JUICES
1. Peptidases
2. Nucleases
3. Maltase


Duodenum
Jejunum
INTESTINAL JUICES
1. Peptidases
2. Nucleases
3. Maltase



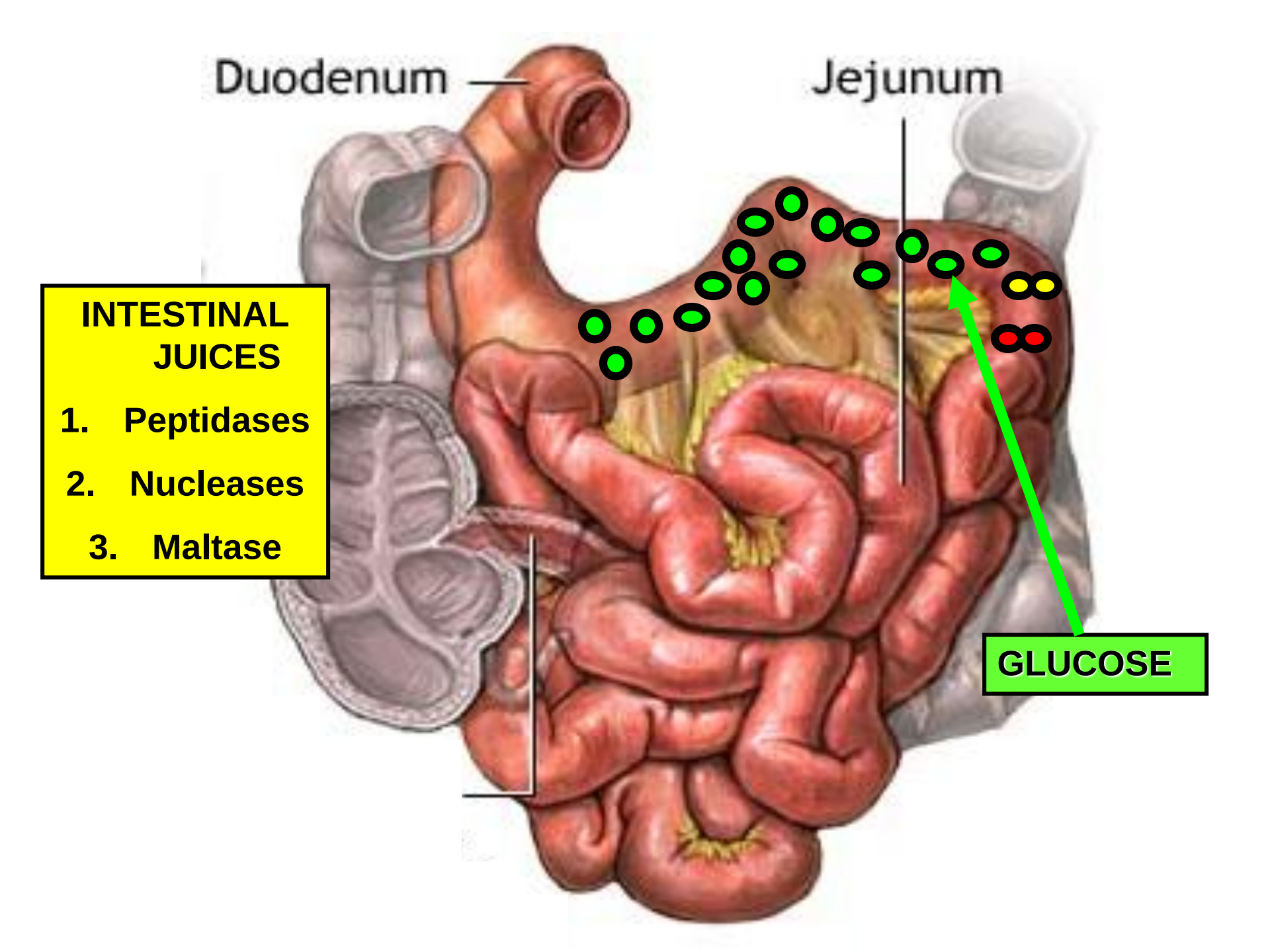
INTESTINAL JUICES

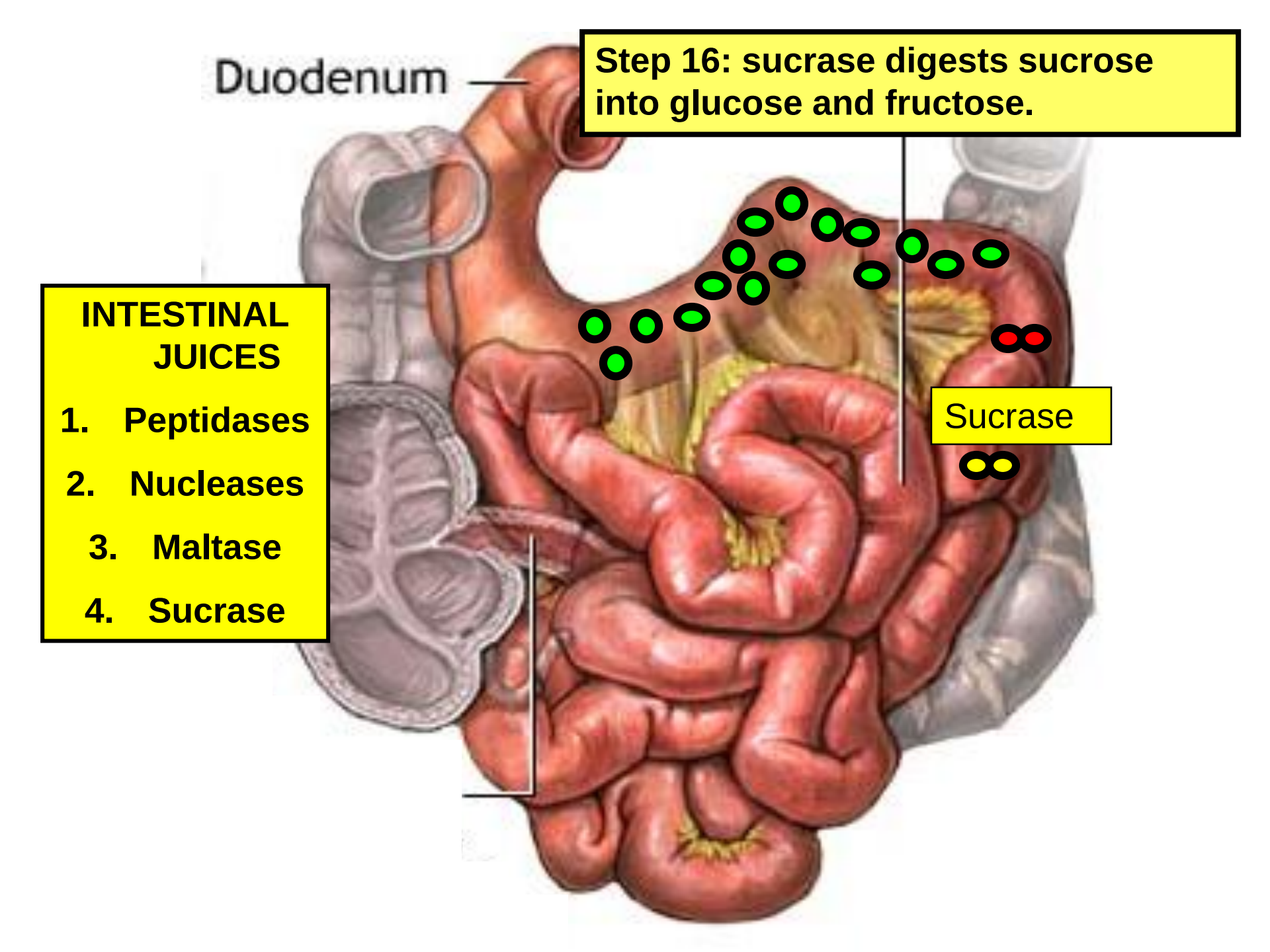
1. **Peptidases**
2. **Nucleases**
3. **Maltase**

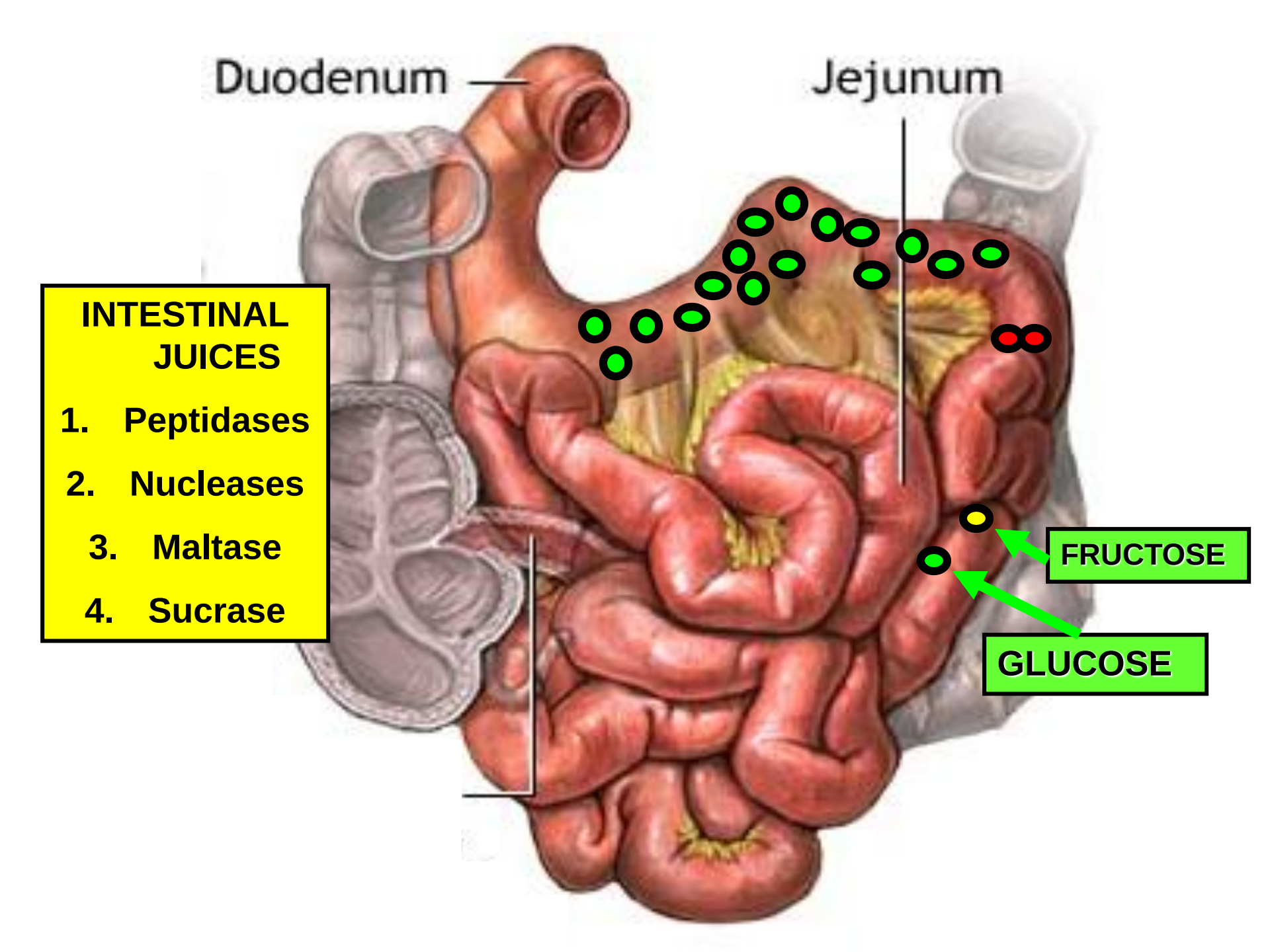


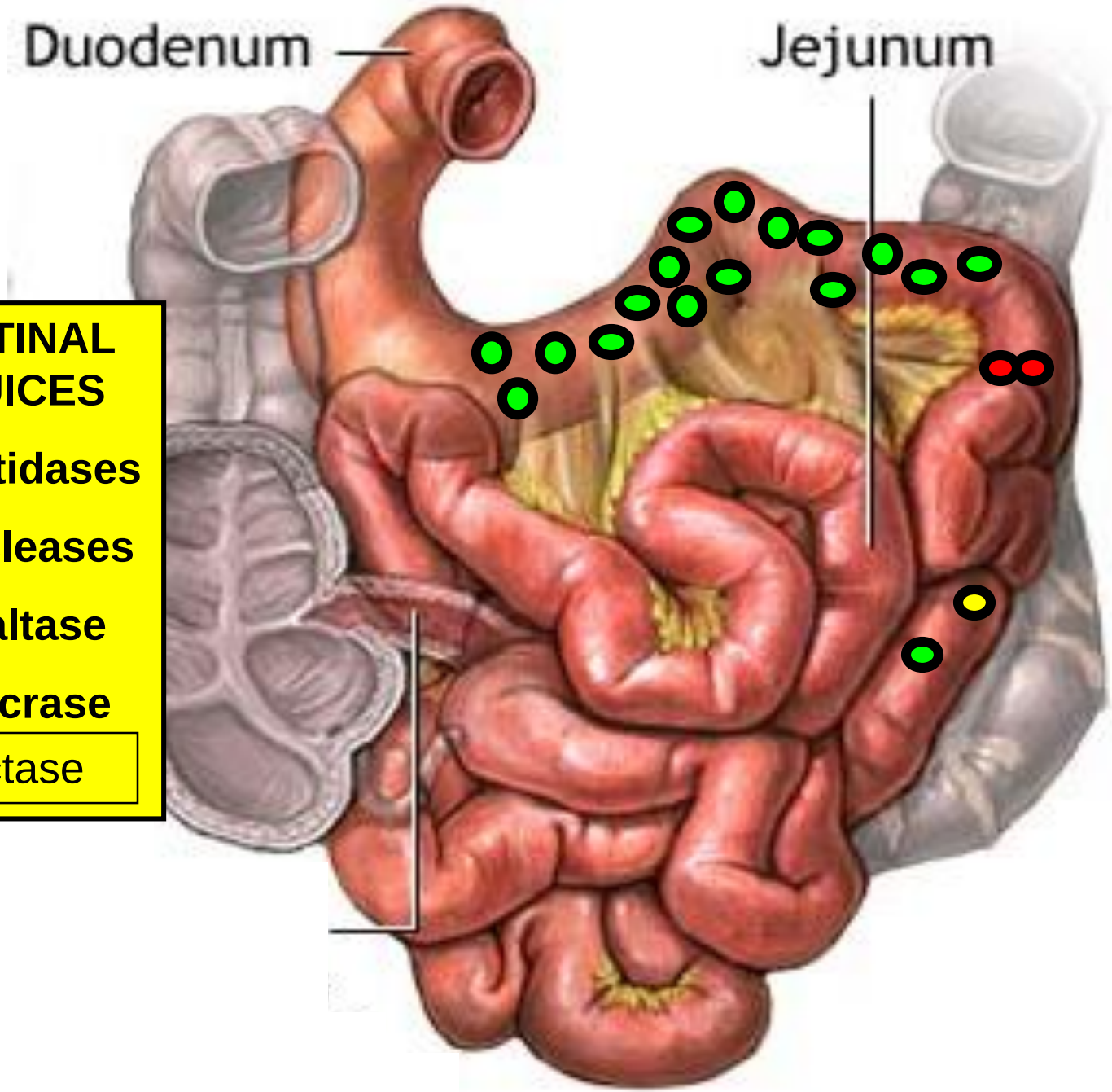
INTESTINAL JUICES

1. **Peptidases**
2. **Nucleases**
3. **.**


Duodenum
Jejunum
INTESTINAL JUICES
1. Peptidases
2. Nucleases
3. Maltase
GLUCOSE

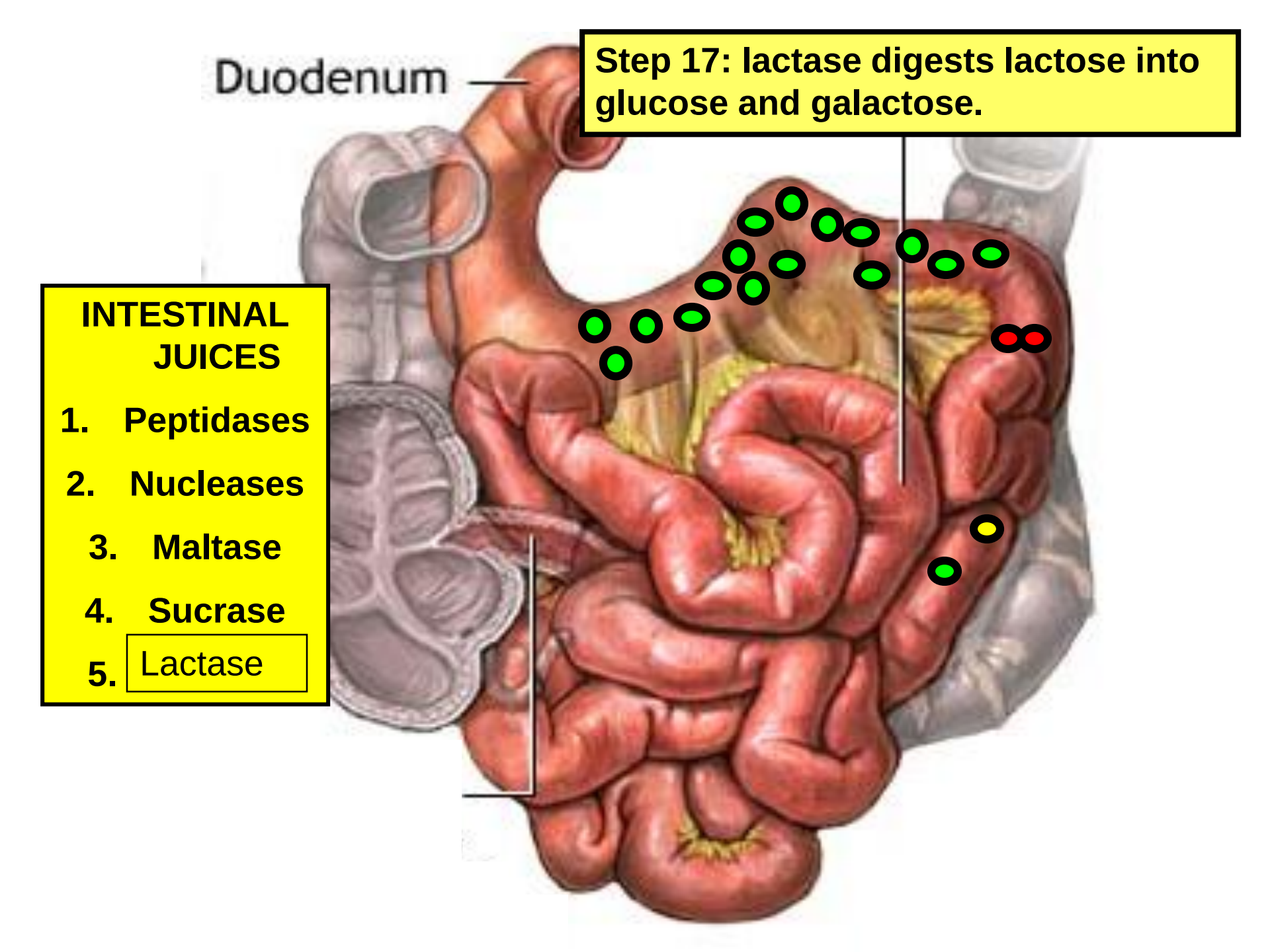

Duodenum
Step 16: sucrase digests sucrose into glucose and fructose.
INTESTINAL JUICES
1. Peptidases
2. Nucleases
3. Maltase
4. Sucrase
Sucrase

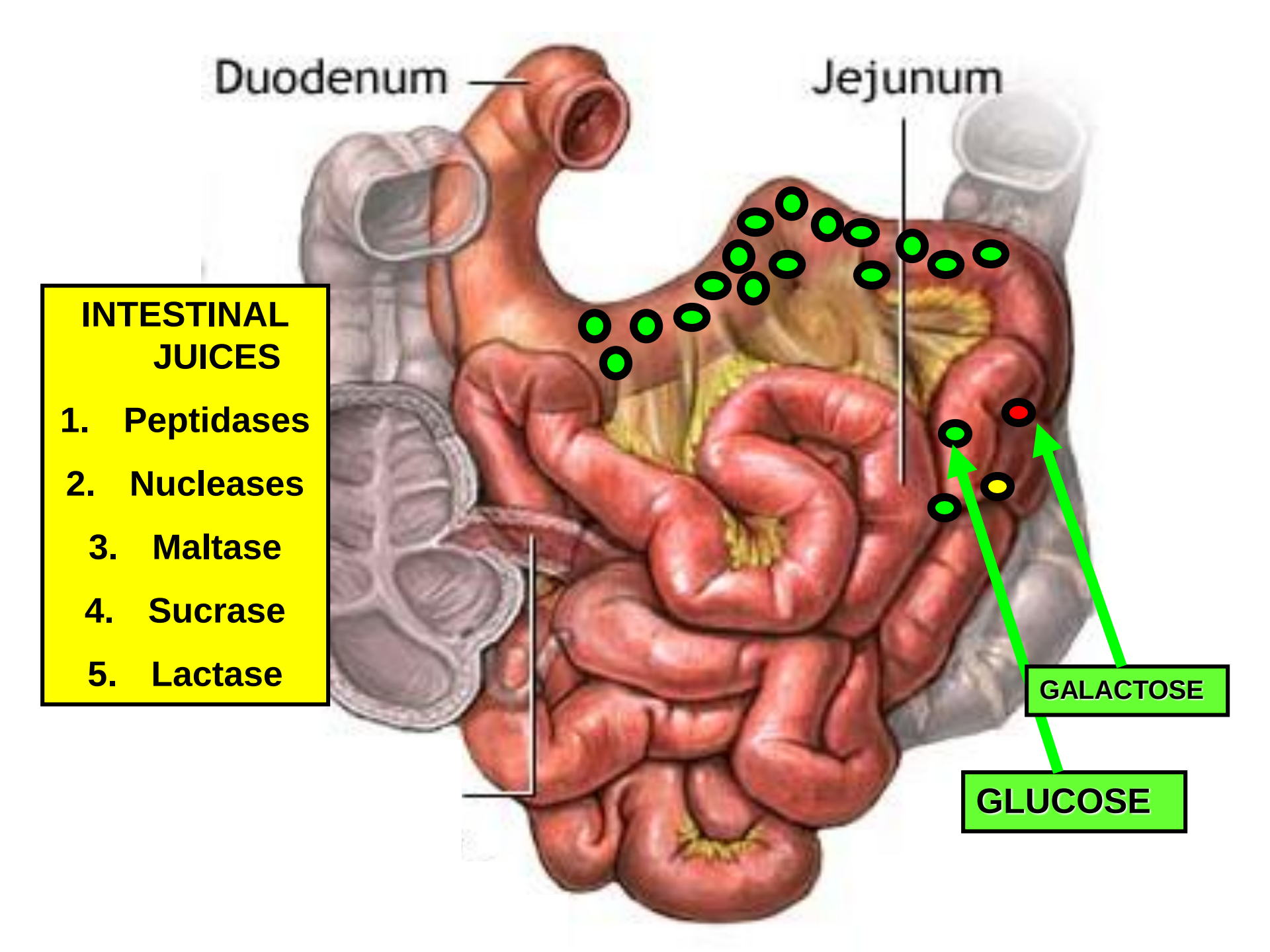

Duodenum
Jejunum
INTESTINAL JUICES
1. Peptidases
2. Nucleases
3. Maltase
4. Sucrase
FRUCTOSE
GLUCOSE

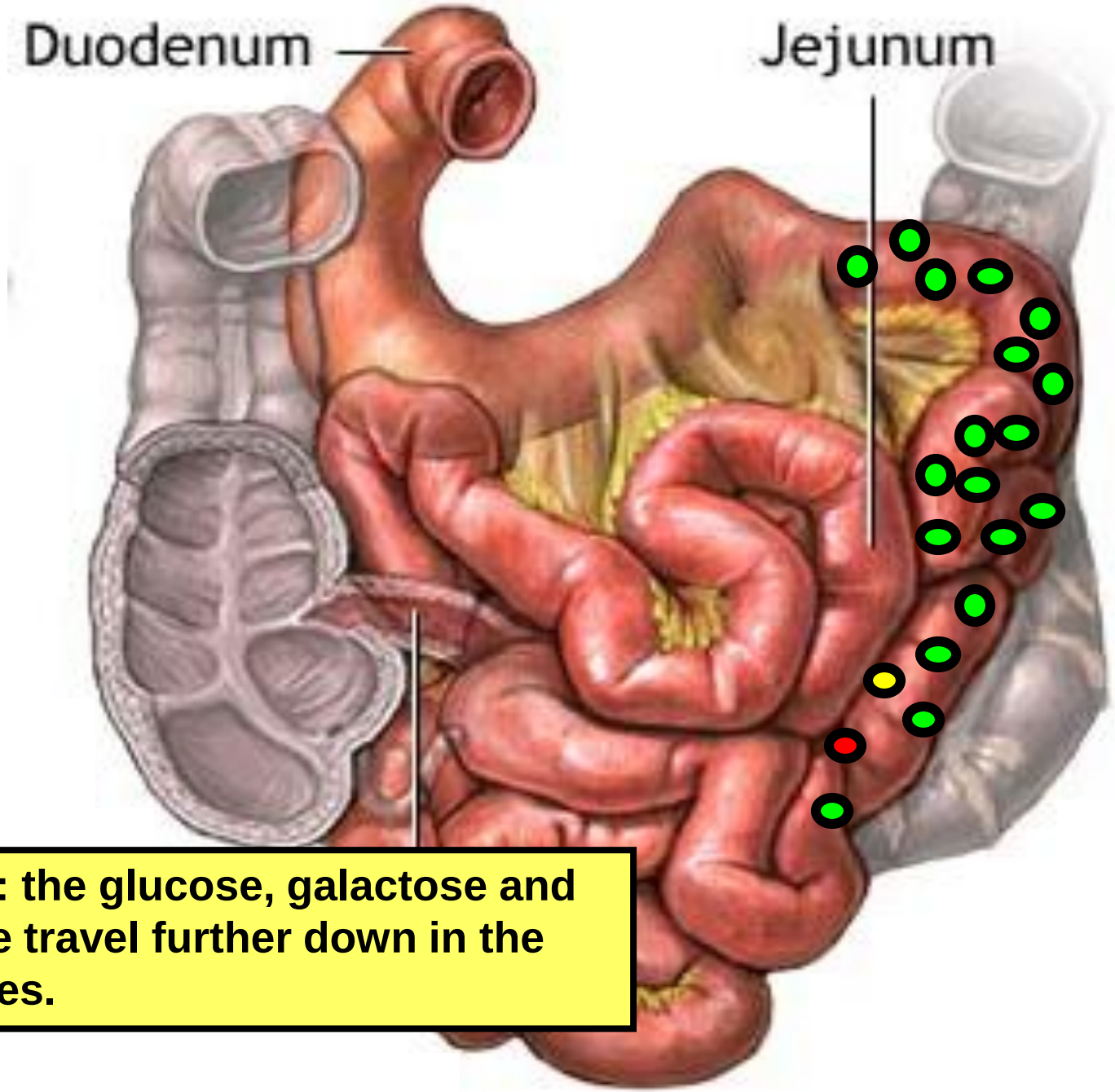


INTESTINAL JUICES

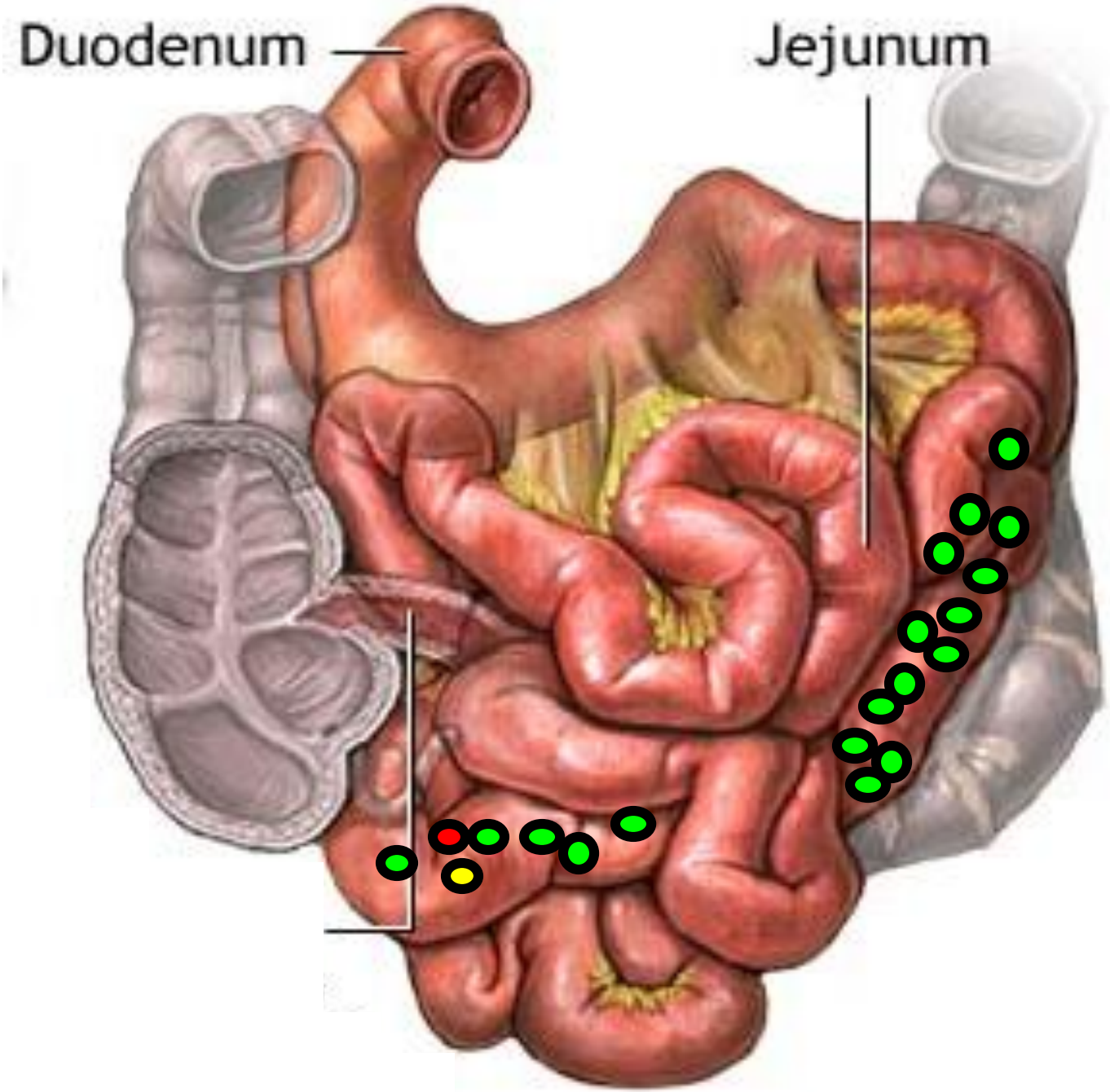
1. **Peptidases**
2. **Nucleases**
3. **Maltase**
4. **Sucrase**
5. Lactase

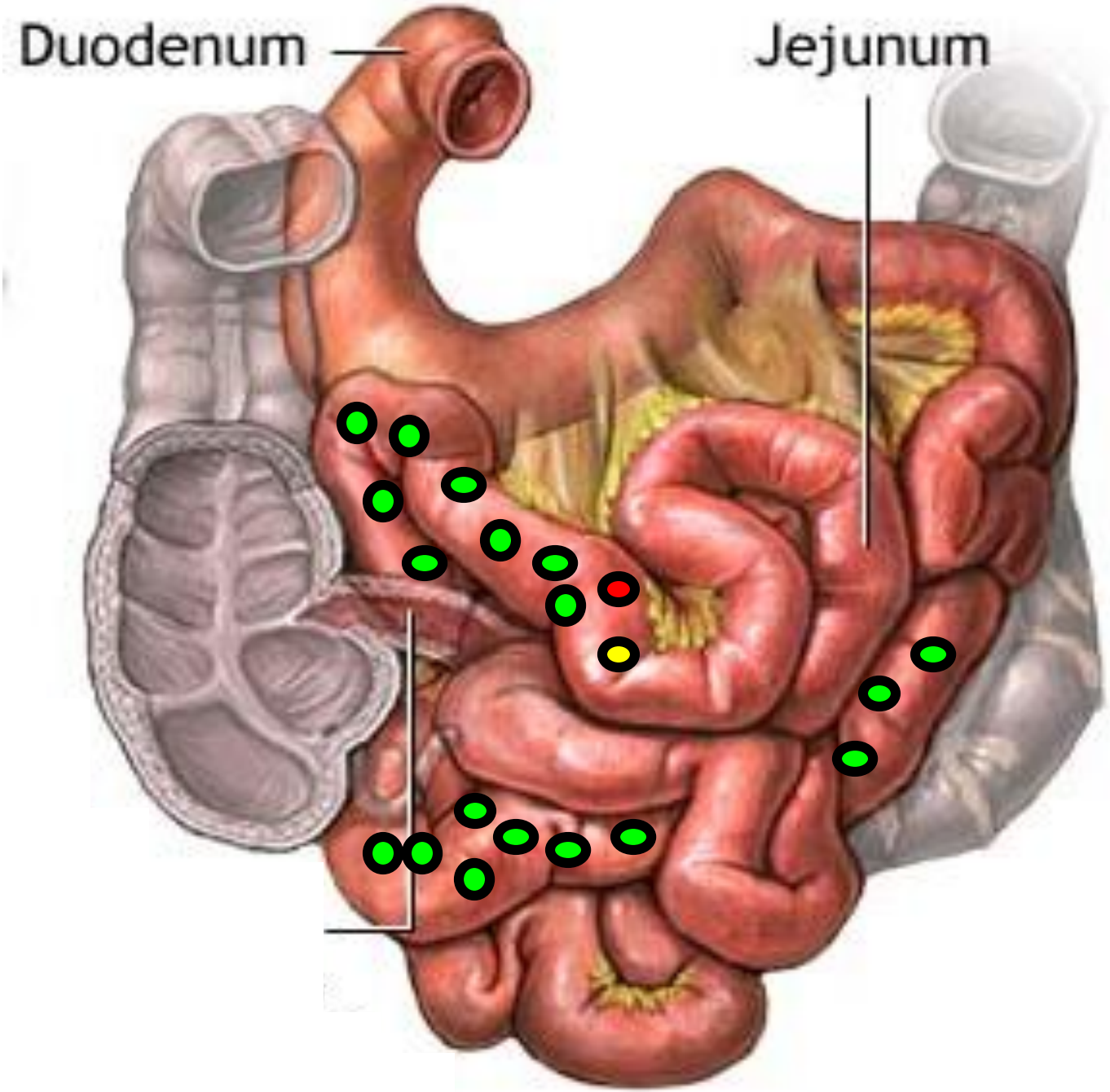

Duodenum
Step 17: lactase digests lactose into glucose and galactose.
INTESTINAL JUICES
1. Peptidases
2. Nucleases
3. Maltase
4. Sucrase
5. Lactase

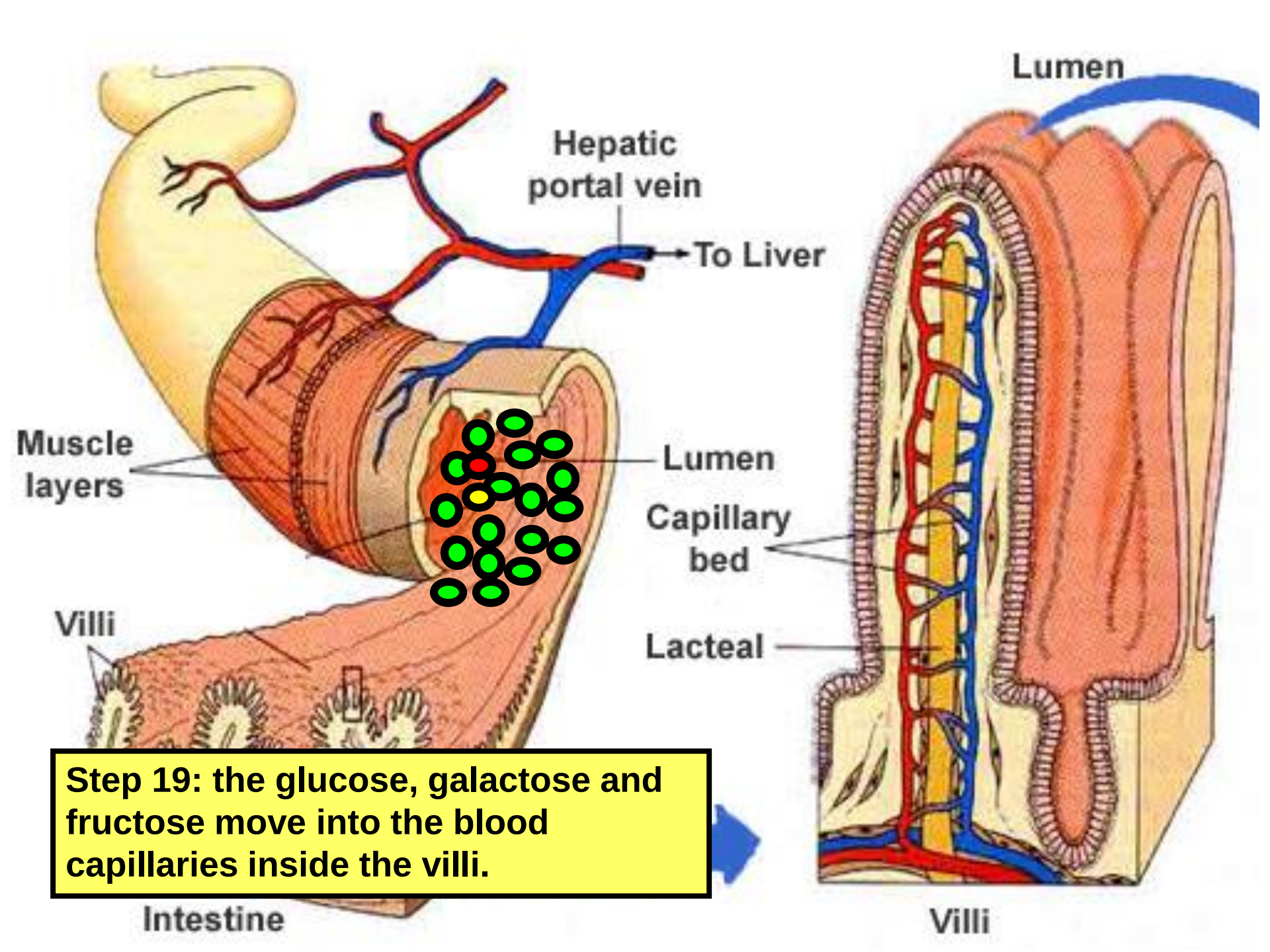

Duodenum
Jejunum
INTESTINAL JUICES
1. Peptidases
2. Nucleases
3. Maltase
4. Sucrase
5. Lactase
GALACTOSE
GLUCOSE



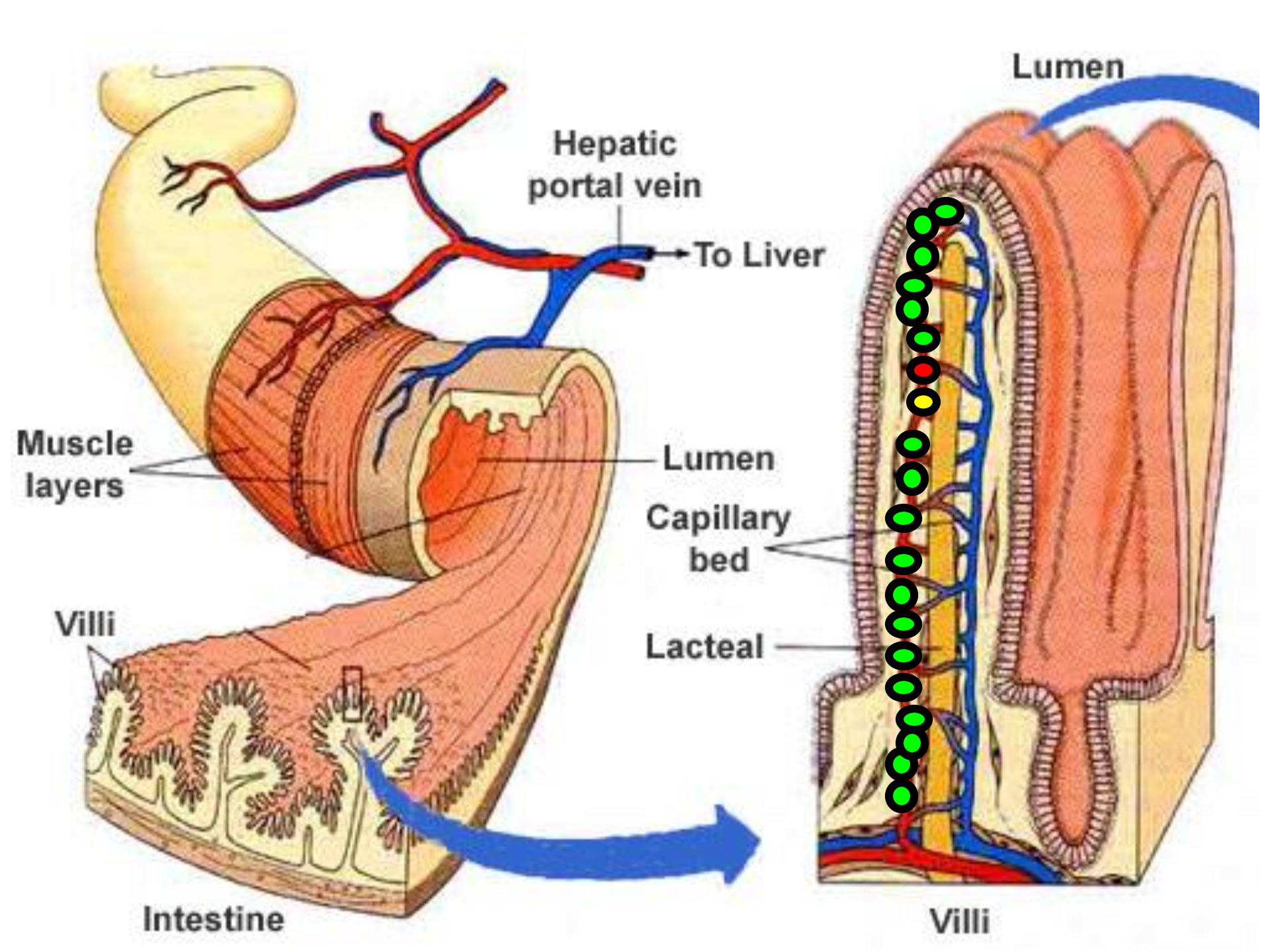
Step 18: the glucose, galactose and fructose travel further down in the intestines.

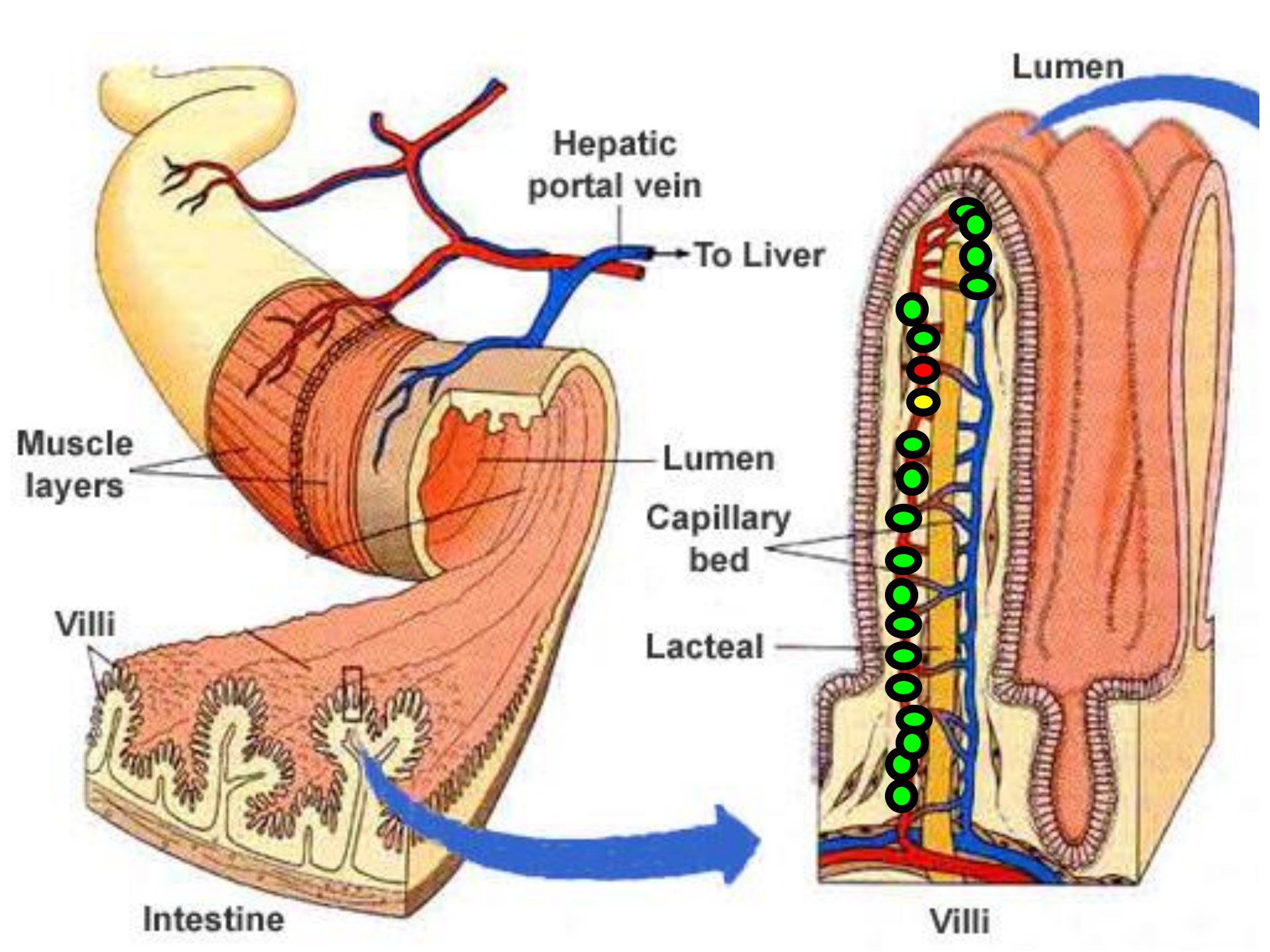

Duodenum
Jejunum

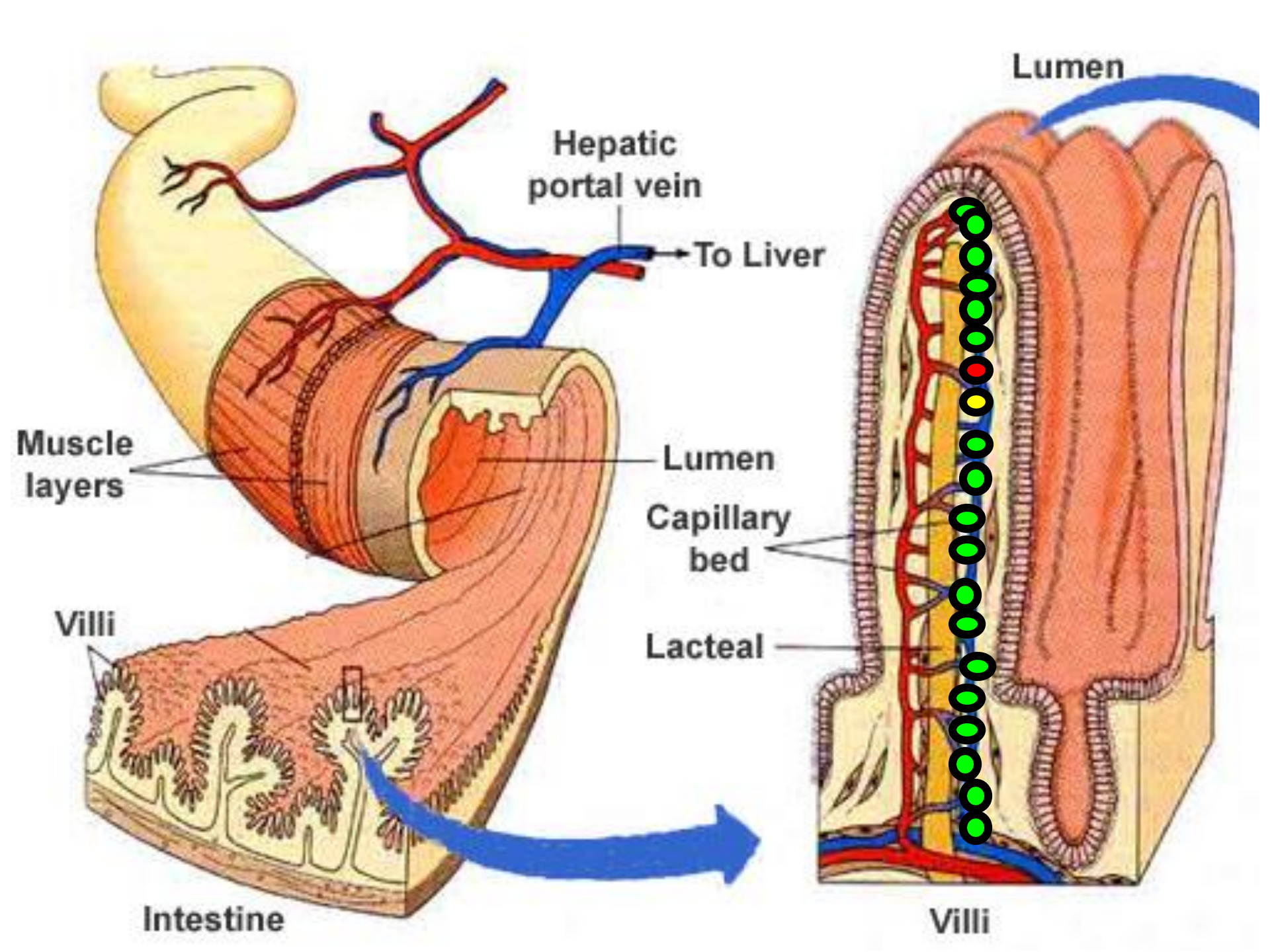

Duodenum
Jejunum

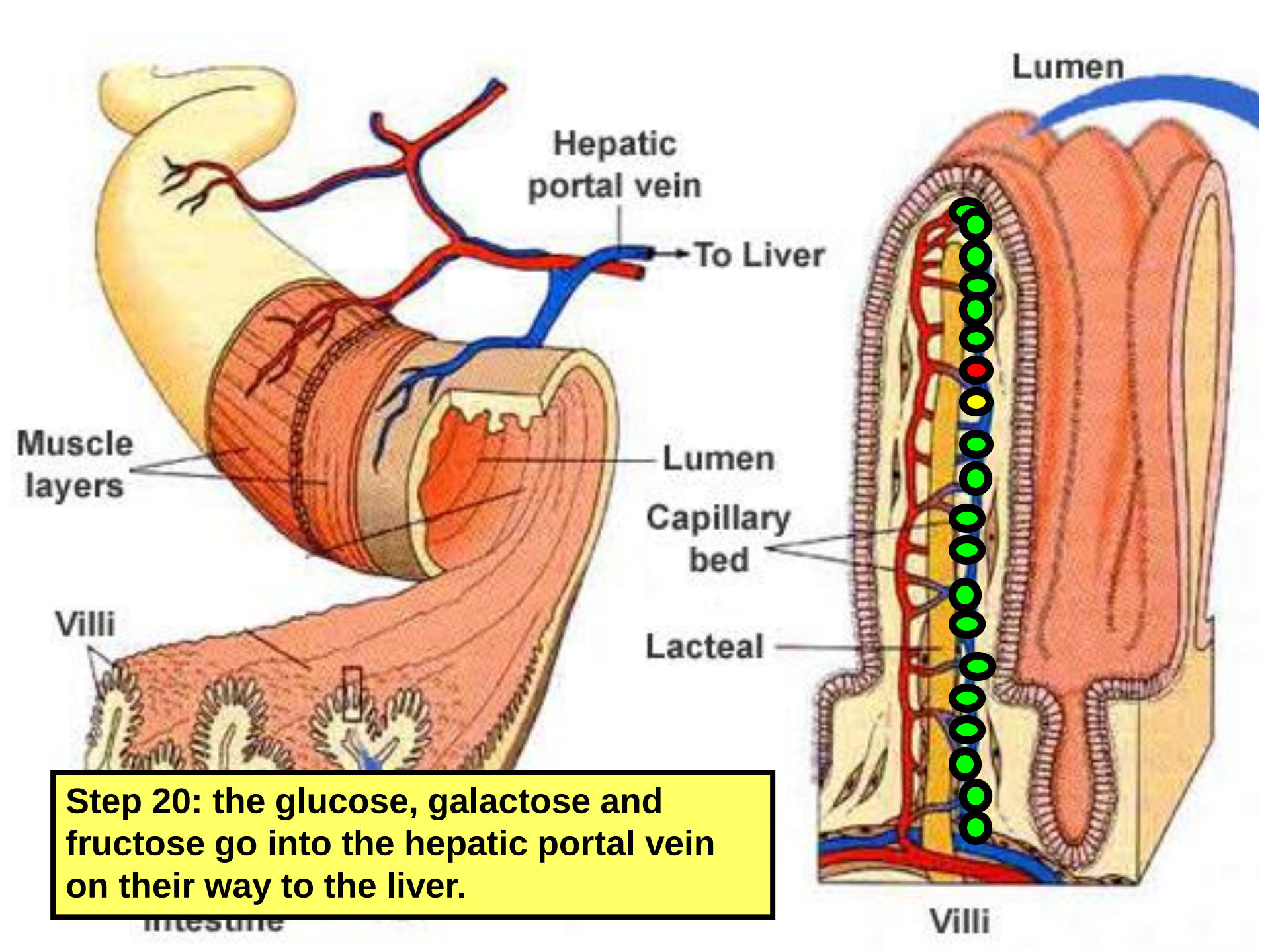


Step 19: the glucose, galactose and fructose move into the blood capillaries inside the villi.


Lumen
Hepatic
portal vein
To Liver
Muscle
layers
Lumen
Capillary
bed
Villi
Lacteal
Intestine
Villi

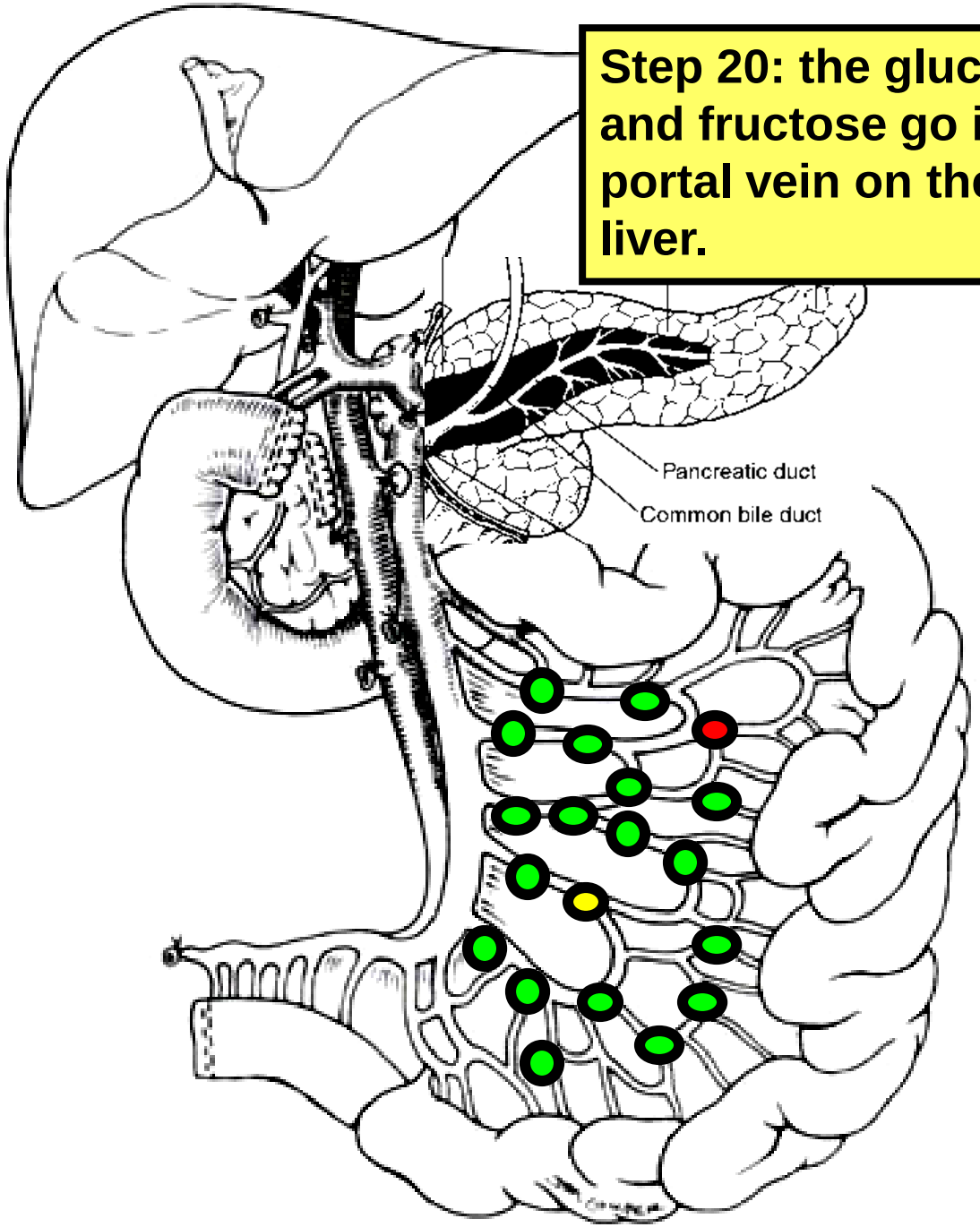

Hepatic
portal vein
To Liver
Muscle
layers
Lumen
Villi
Intestine
Lumen
Capillary
bed
Lacteal
Villi

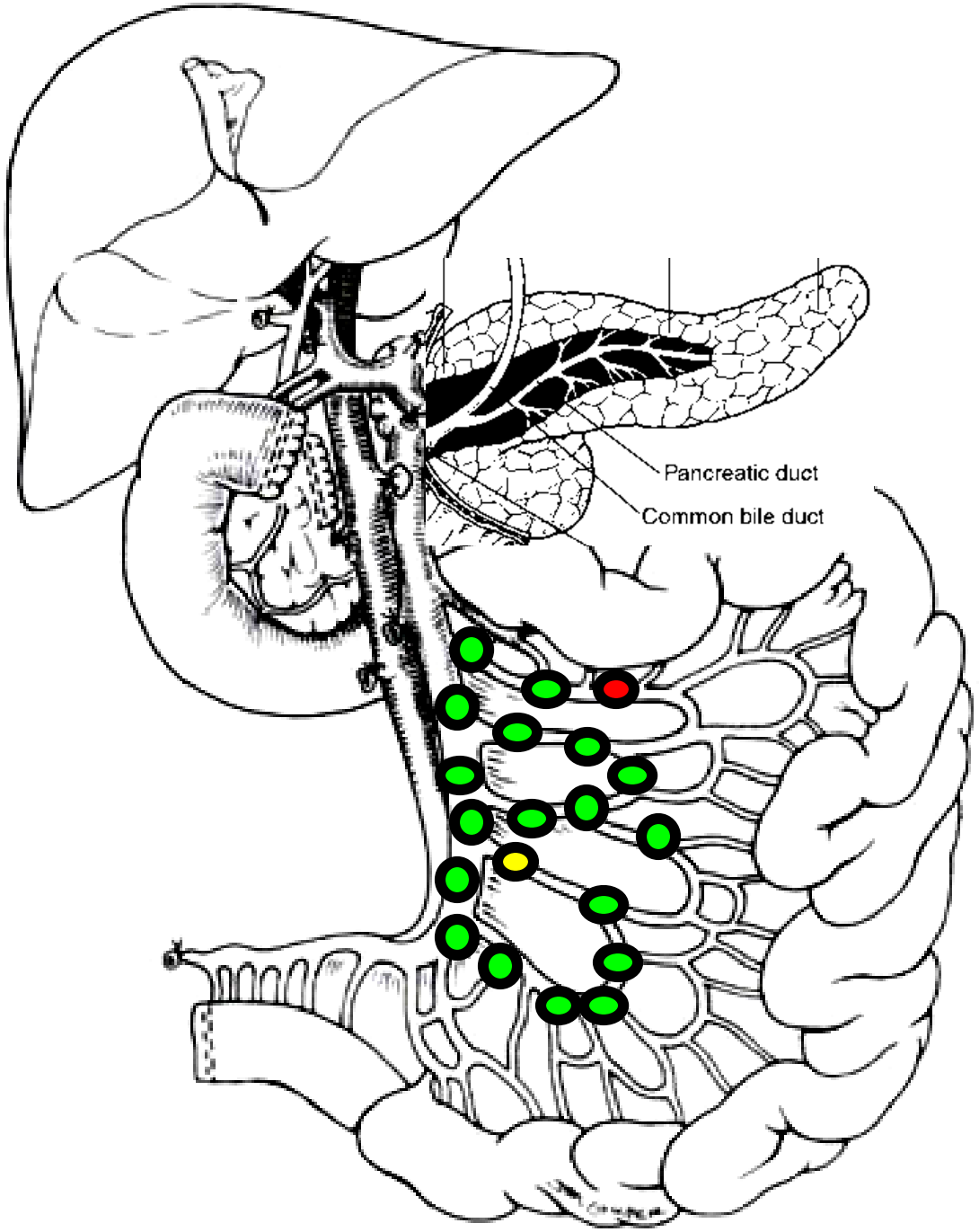

Lumen
Hepatic portal vein
To Liver
Muscle layers
Lumen
Capillary bed
Villi
Lacteal
Intestine
Villi

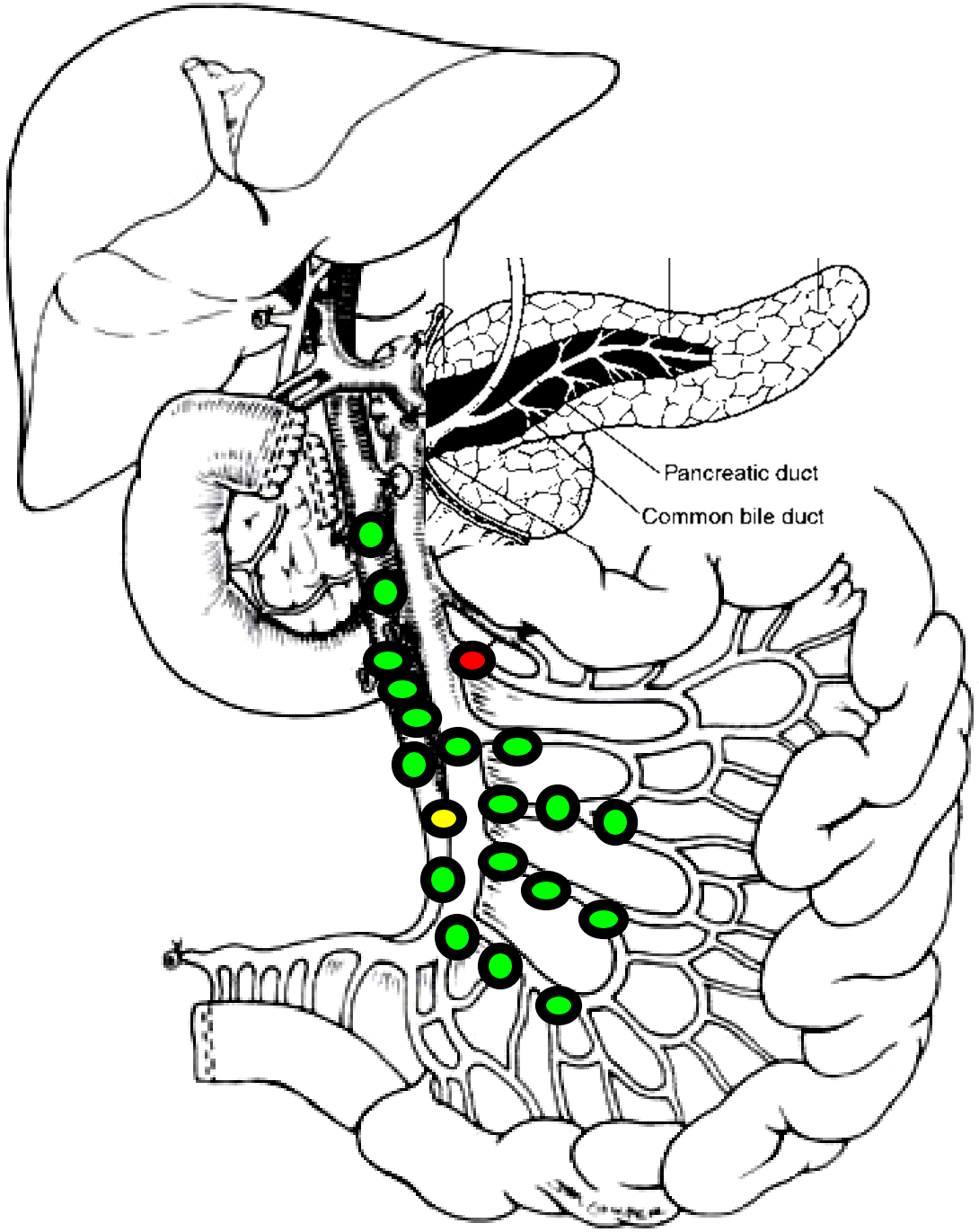


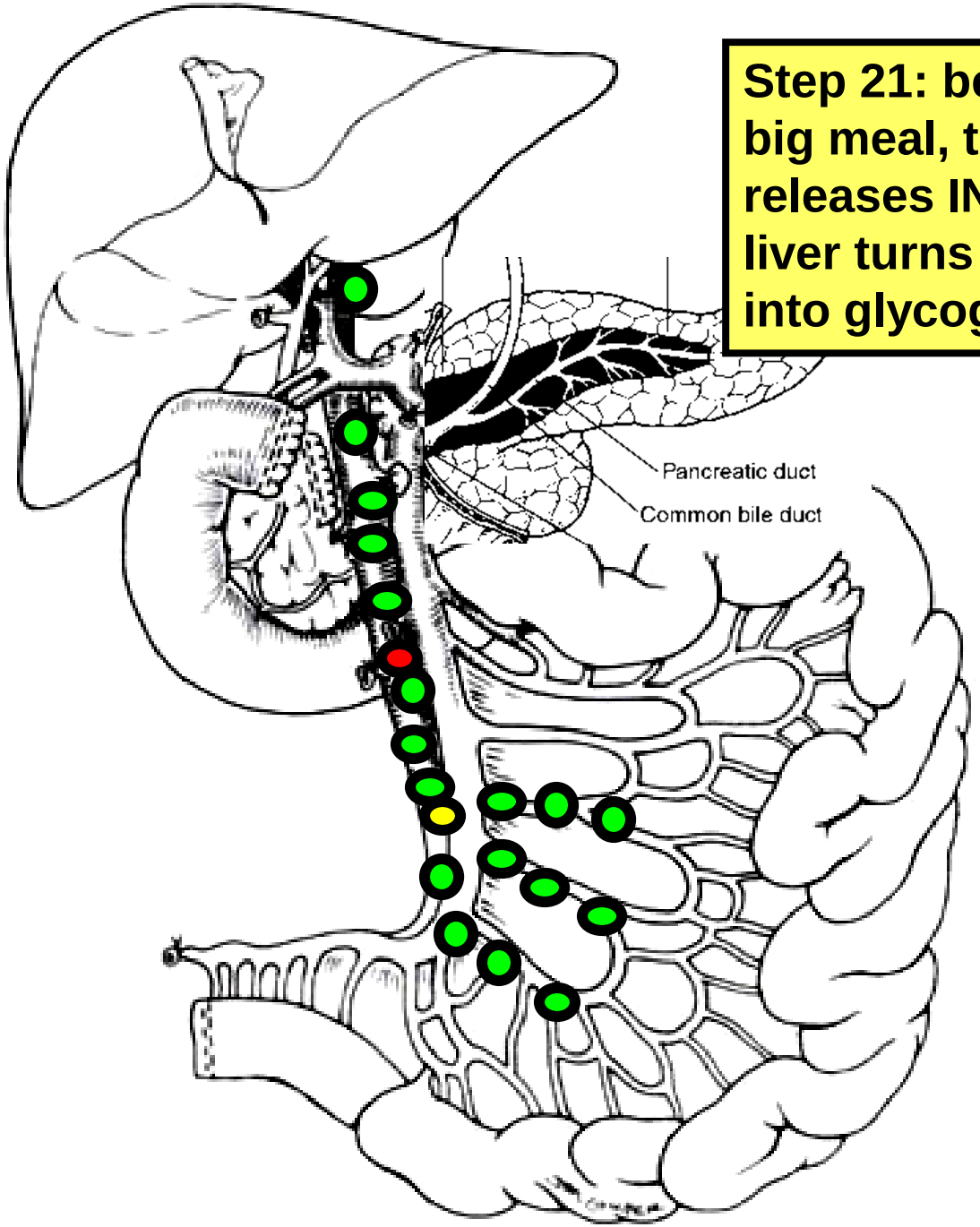
Step 20: the glucose, galactose and fructose go into the hepatic portal vein on their way to the liver.

Step 20: the glucose, galactose and fructose go into the hepatic portal vein on their way to the liver.

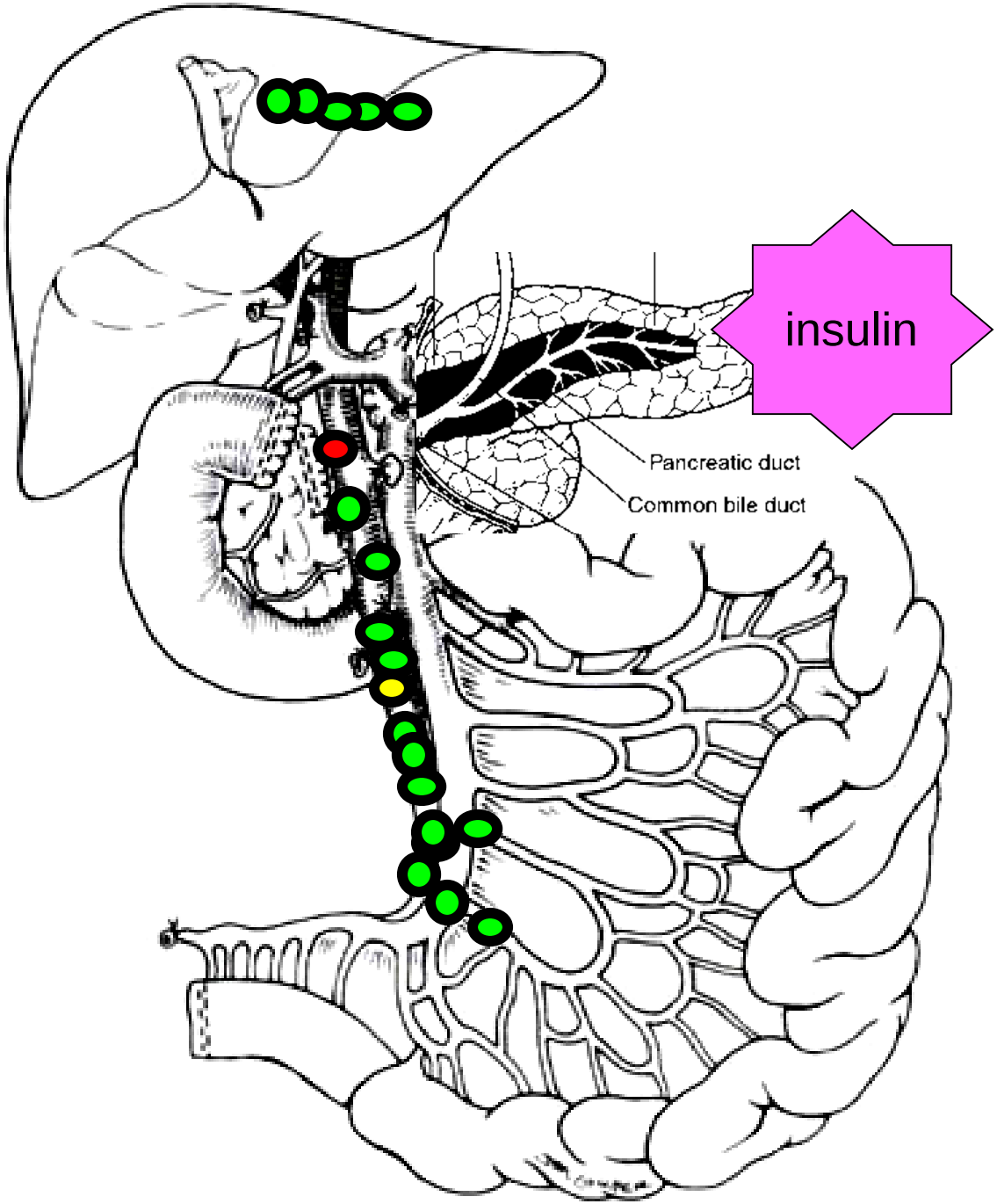


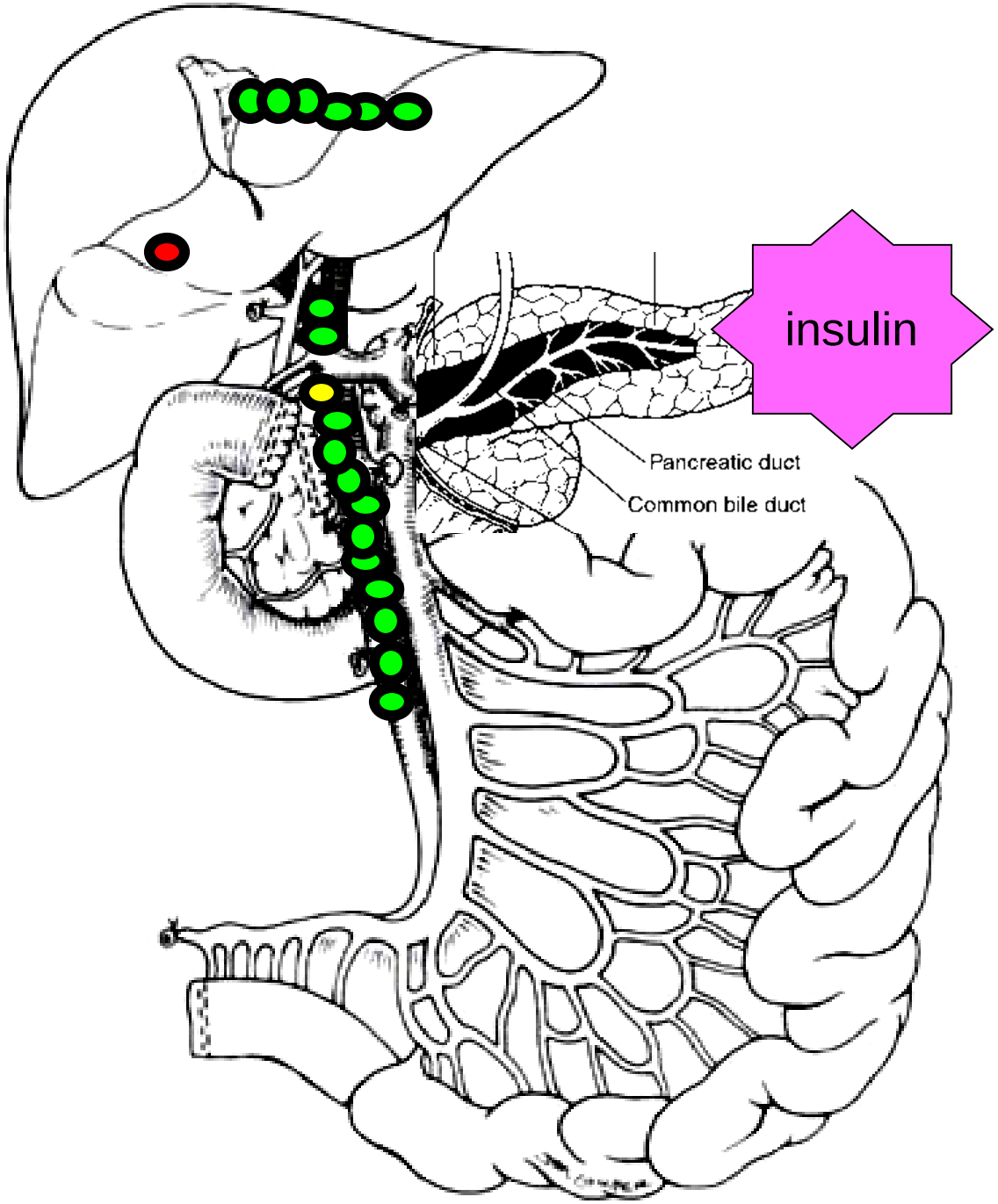

Pancreatic duct
Common bile duct

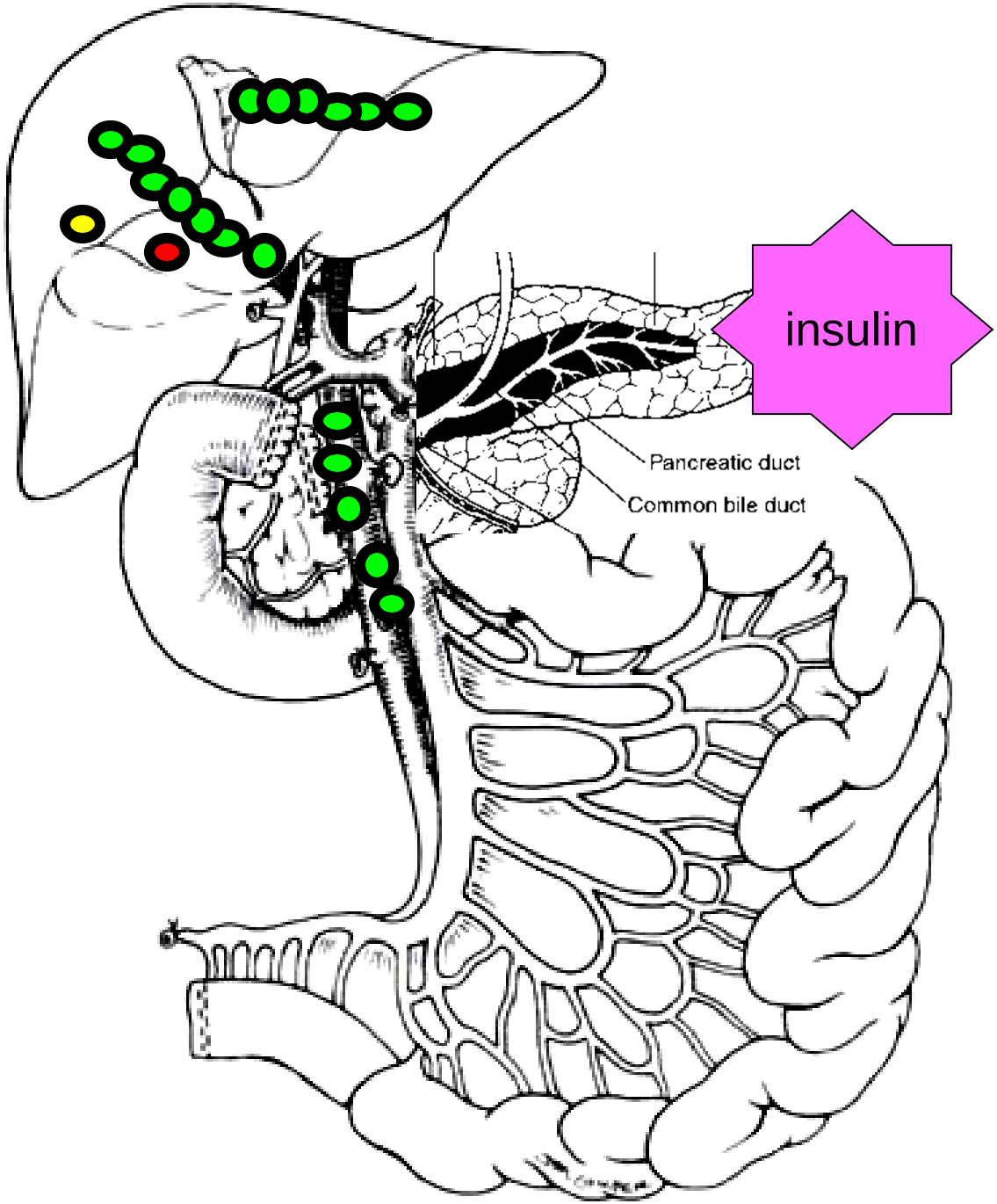

Pancreatic duct
Common bile duct

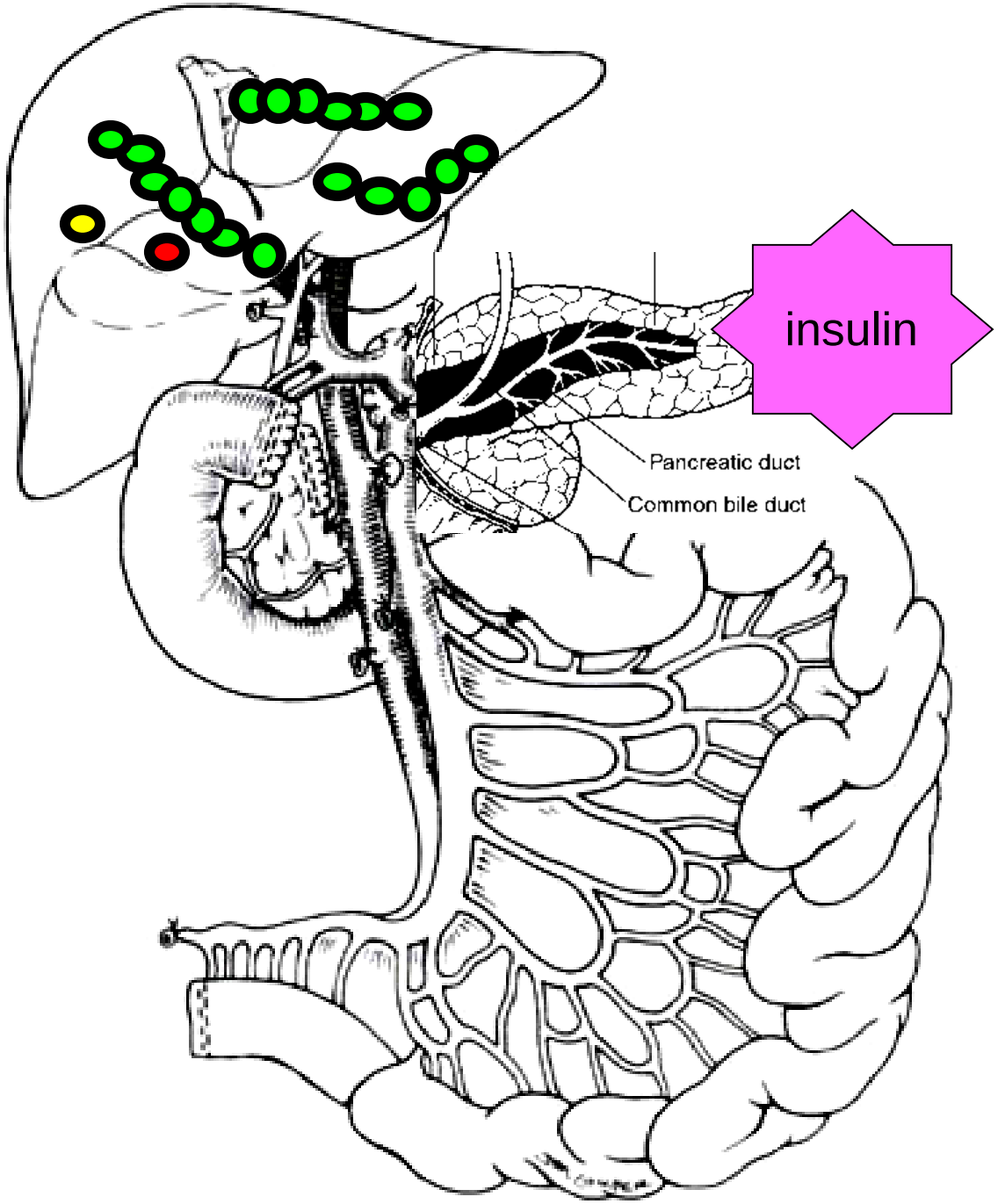


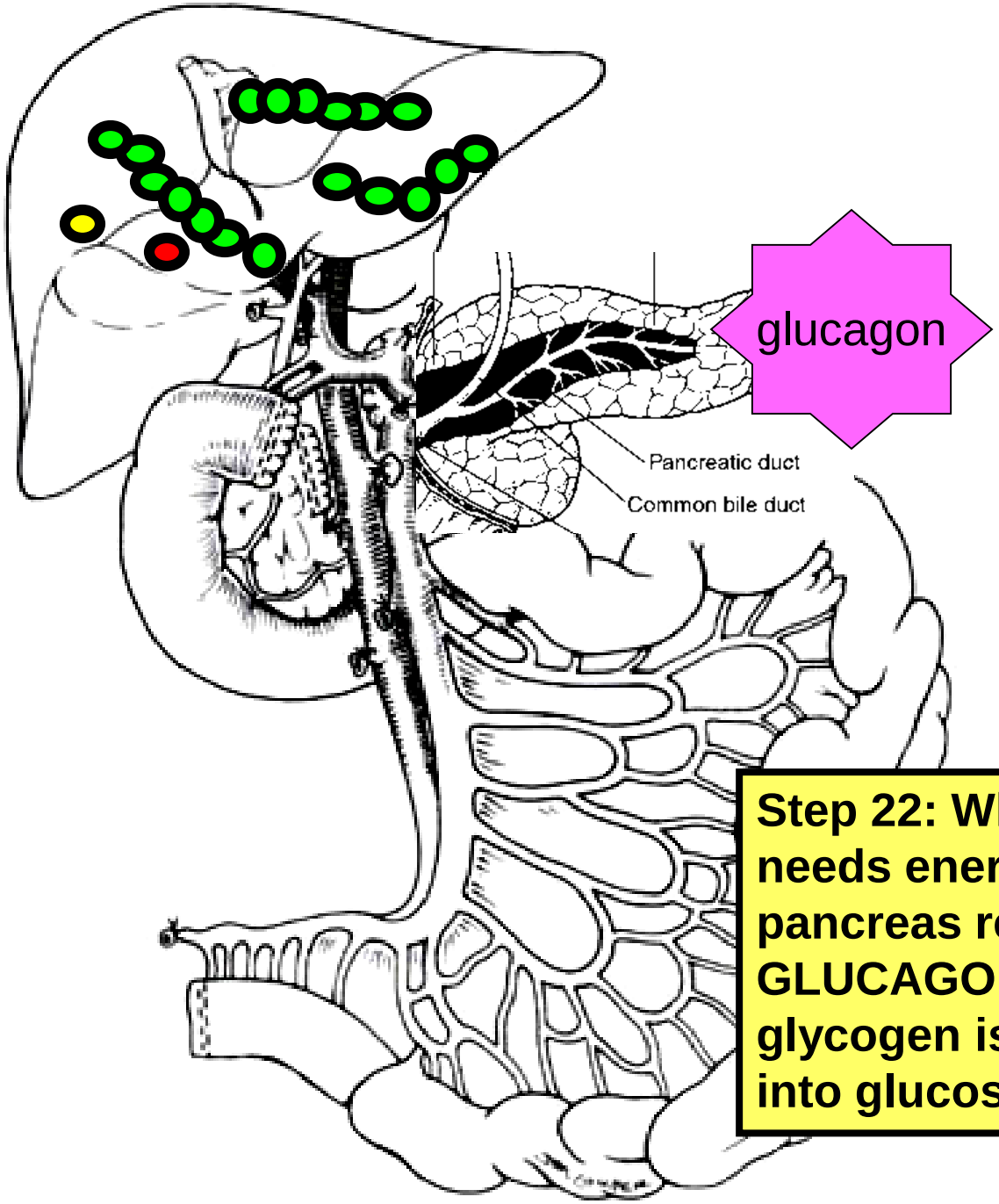
Step 21: because it was a big meal, the pancreas releases INSULIN and the liver turns the glucose into glycogen for storage.


insulin
Pancreatic duct
Common bile duct

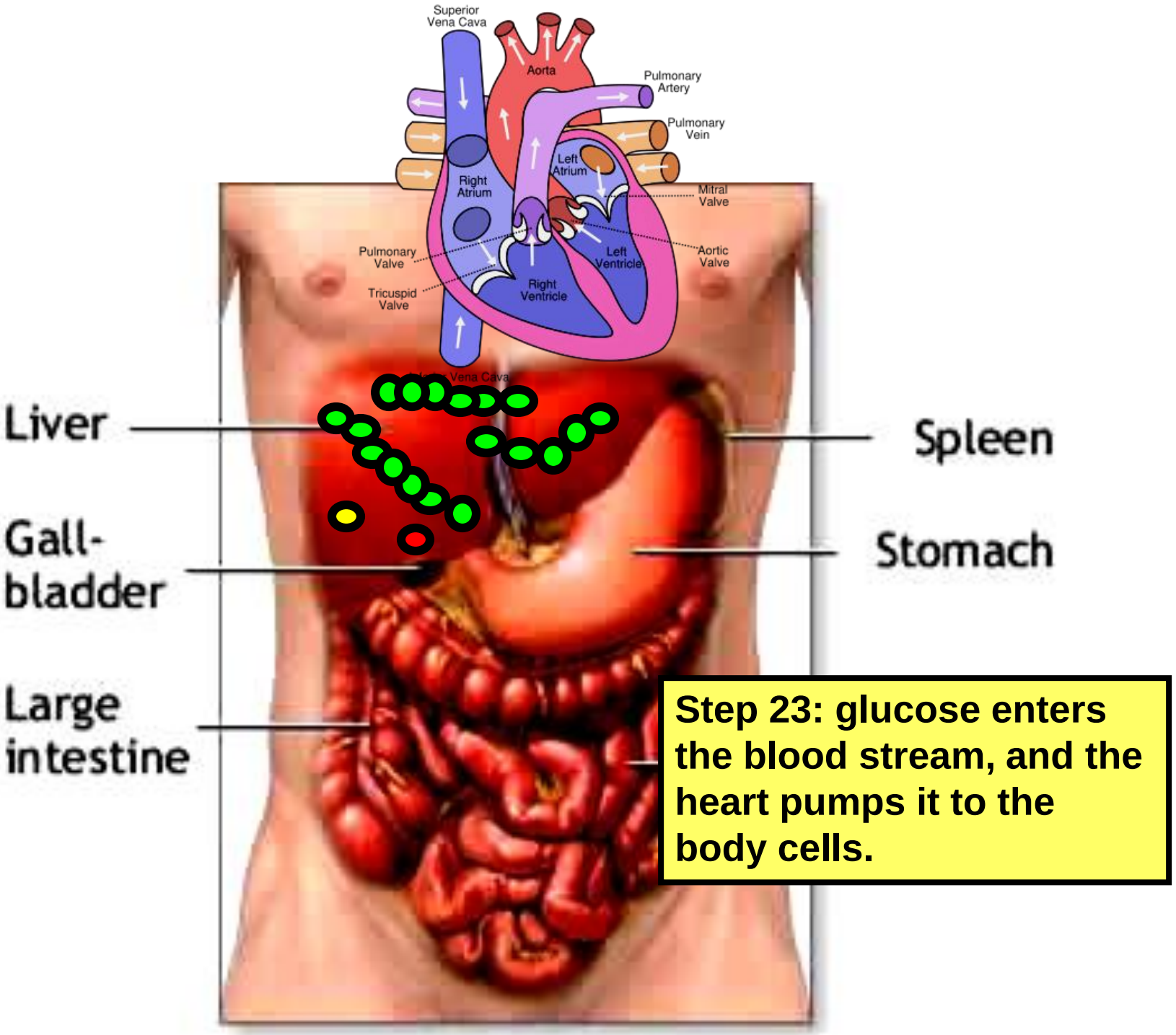

insulin
Pancreatic duct
Common bile duct

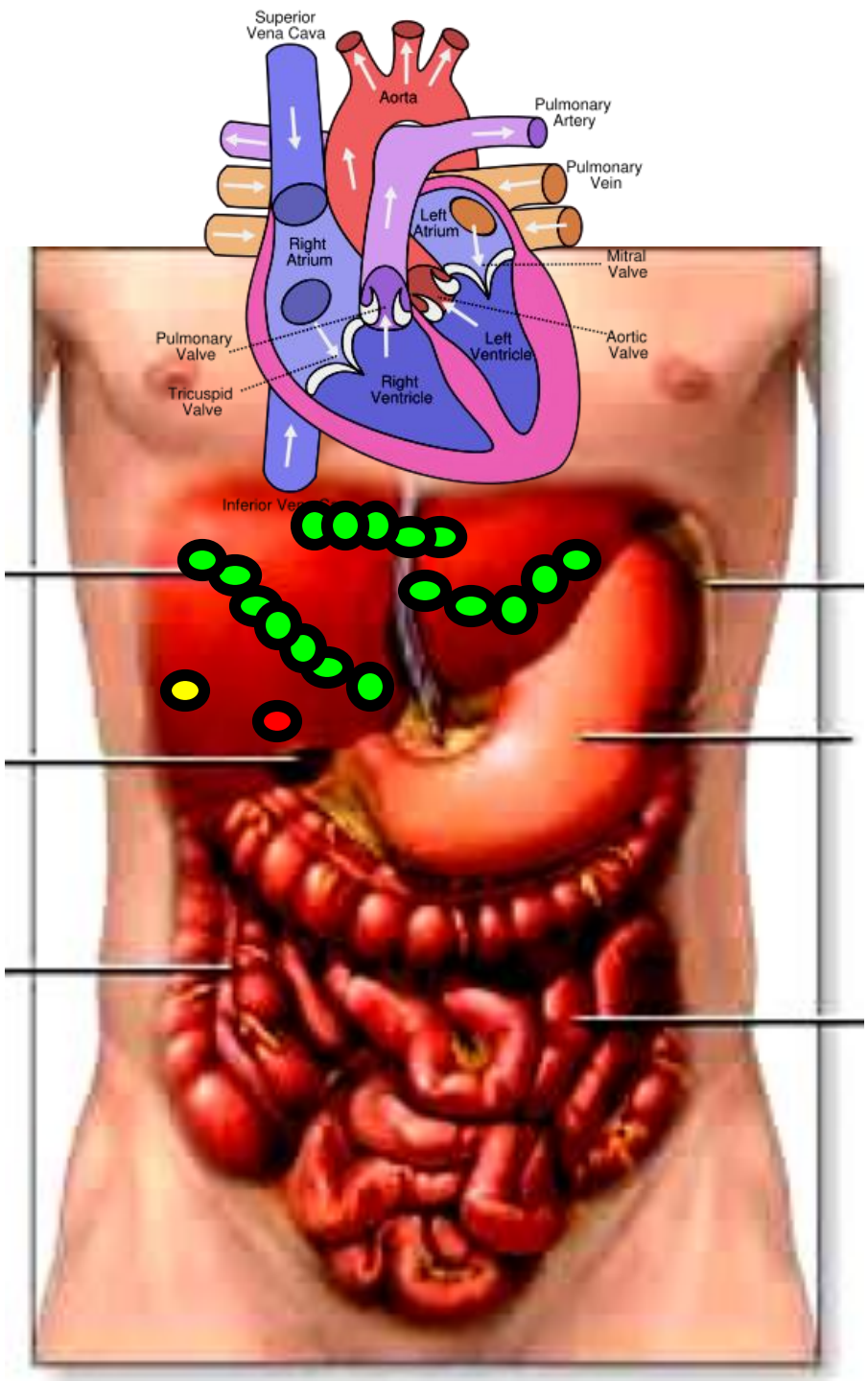

insulin
Pancreatic duct
Common bile duct

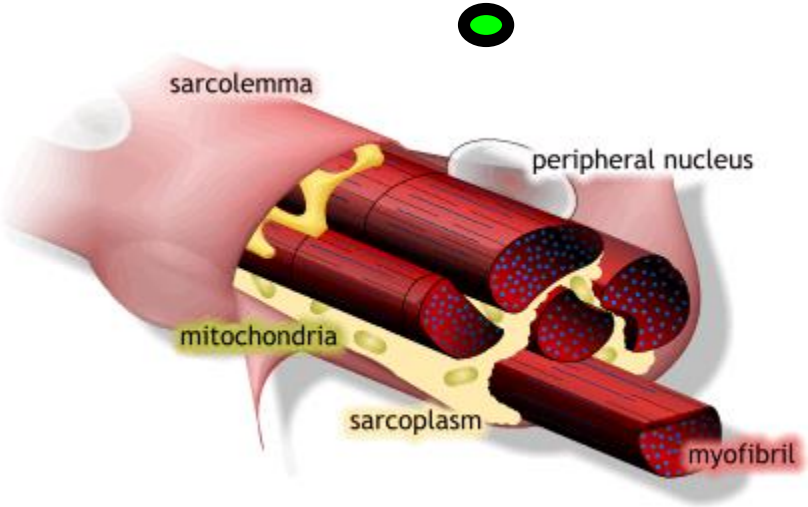

insulin
Pancreatic duct
Common bile duct



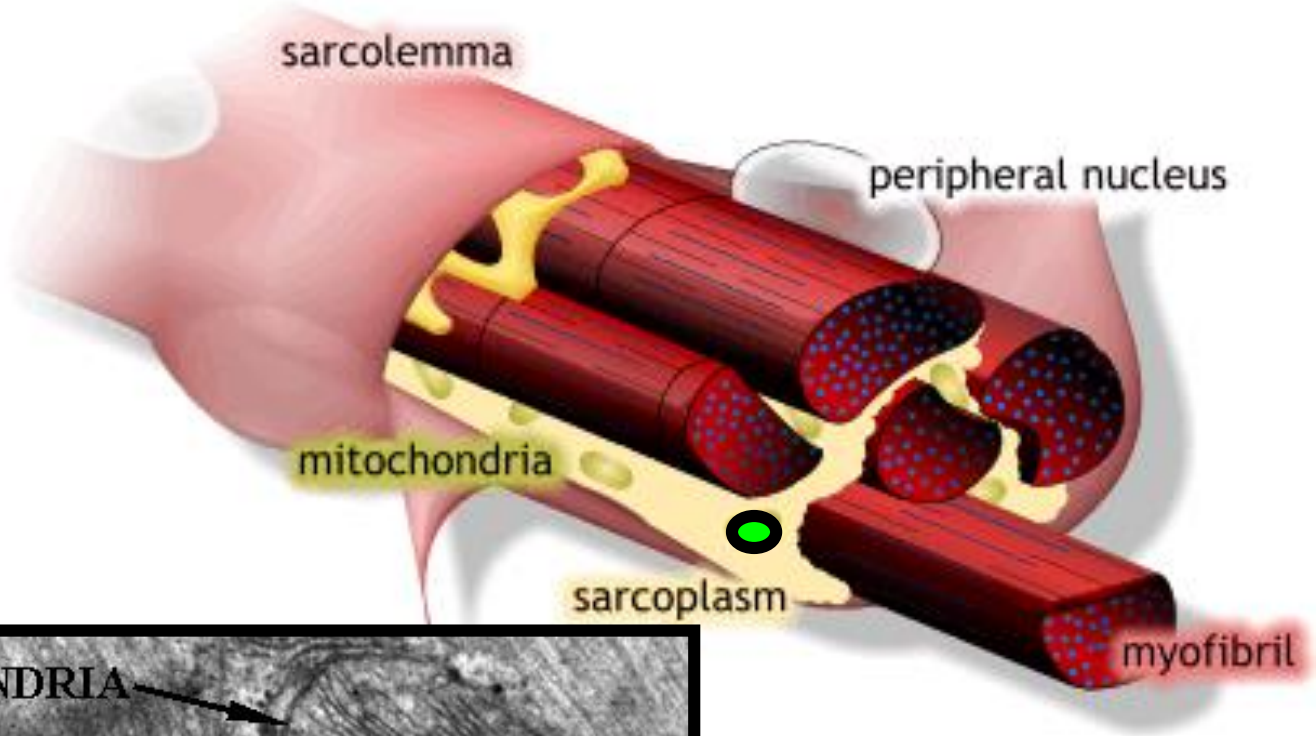
Step 22: When the body needs energy, the pancreas releases GLUCAGON and the glycogen is turned back into glucose.


Superior Vena Cava
Aorta
Pulmonary Artery
Pulmonary Vein
Left Atrium
Right Atrium
Mitral Valve
Pulmonary Valve
Aortic Valve
Left Ventricle
Right Ventricle
Tricuspid Valve
Liver
Spleen
Gall-bladder
Stomach
Large intestine
Step 23: glucose enters the blood stream, and the heart pumps it to the body cells.

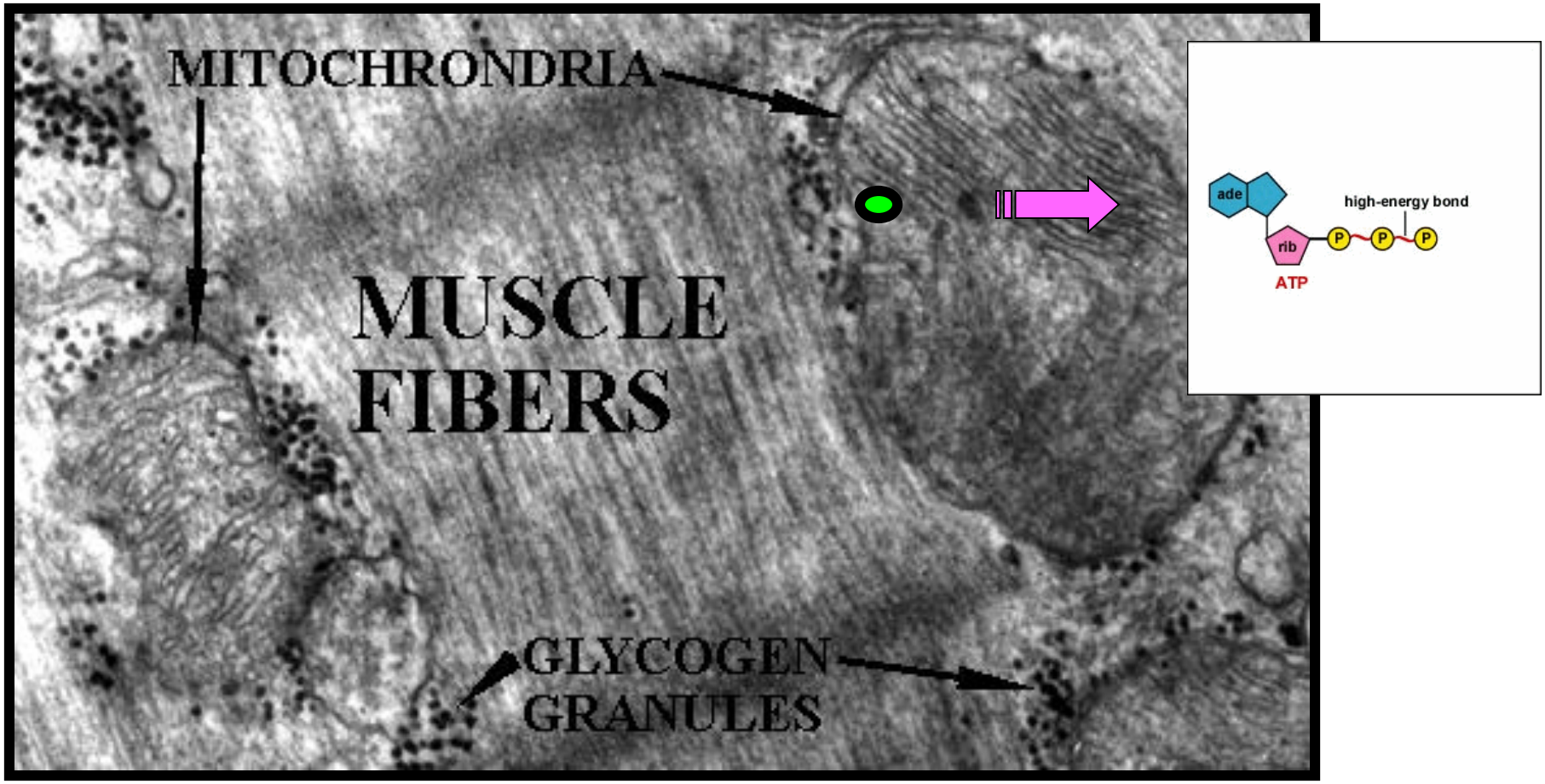


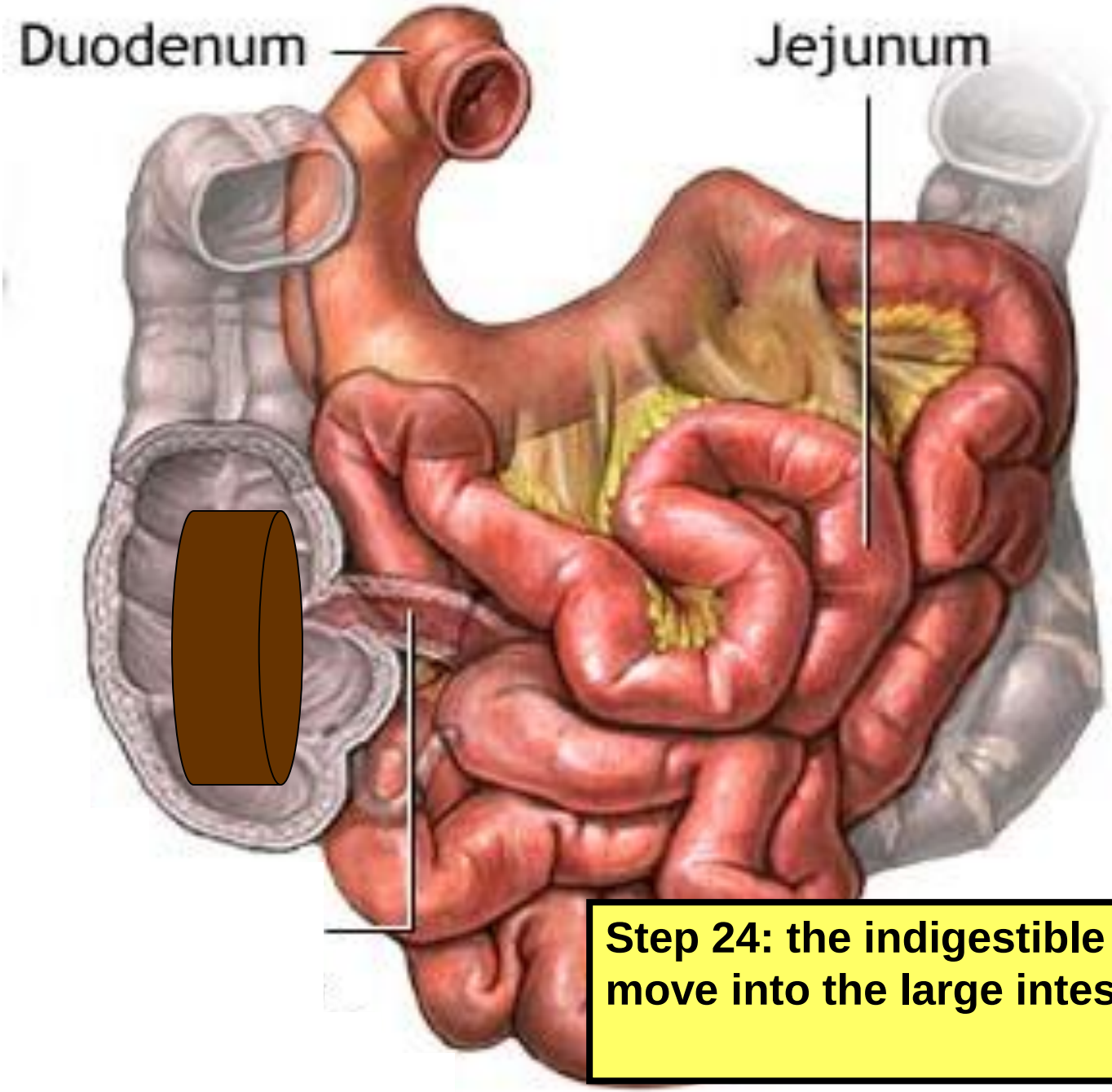


Step 23: glucose enters the body cells and goes into the mitochondria.

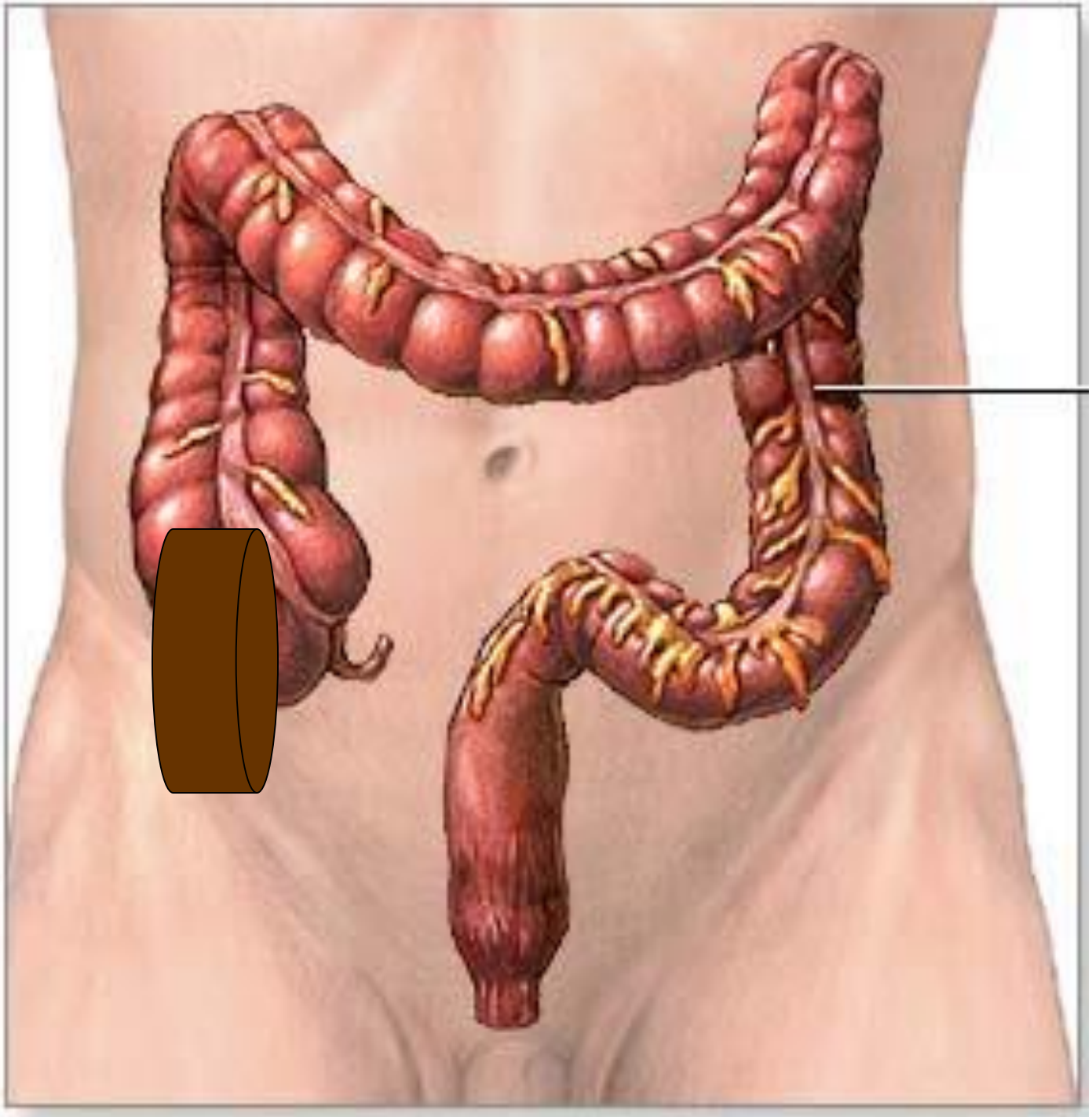


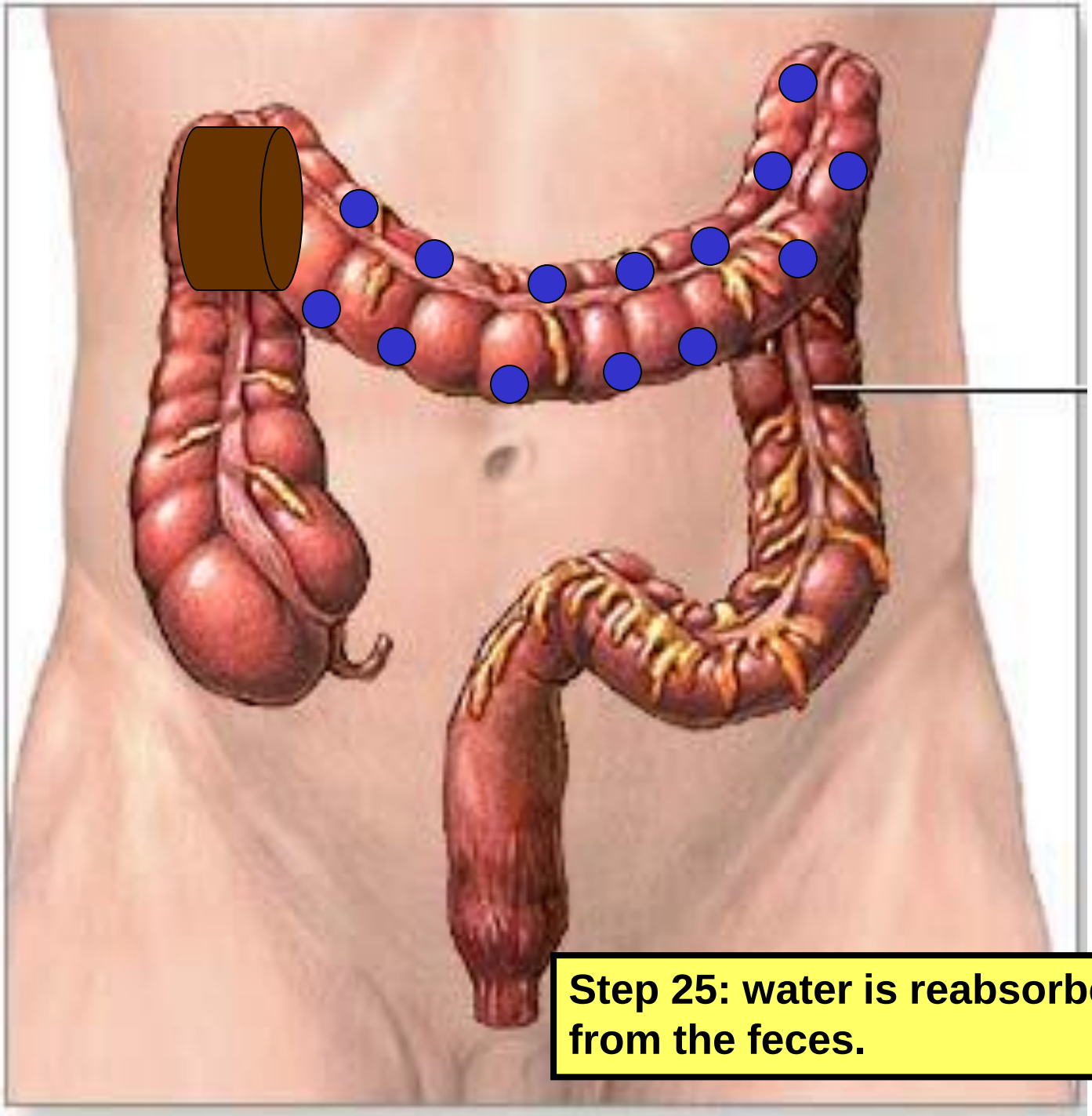
Step 23: the mitochondria turns the glucose into ATP via cellular respiration.


MITOCHRONDRIA
MUSCLE FIBERS
GLYCOGEN GRANULES
ade
high-energy bond
rib
P
P
P
ATP

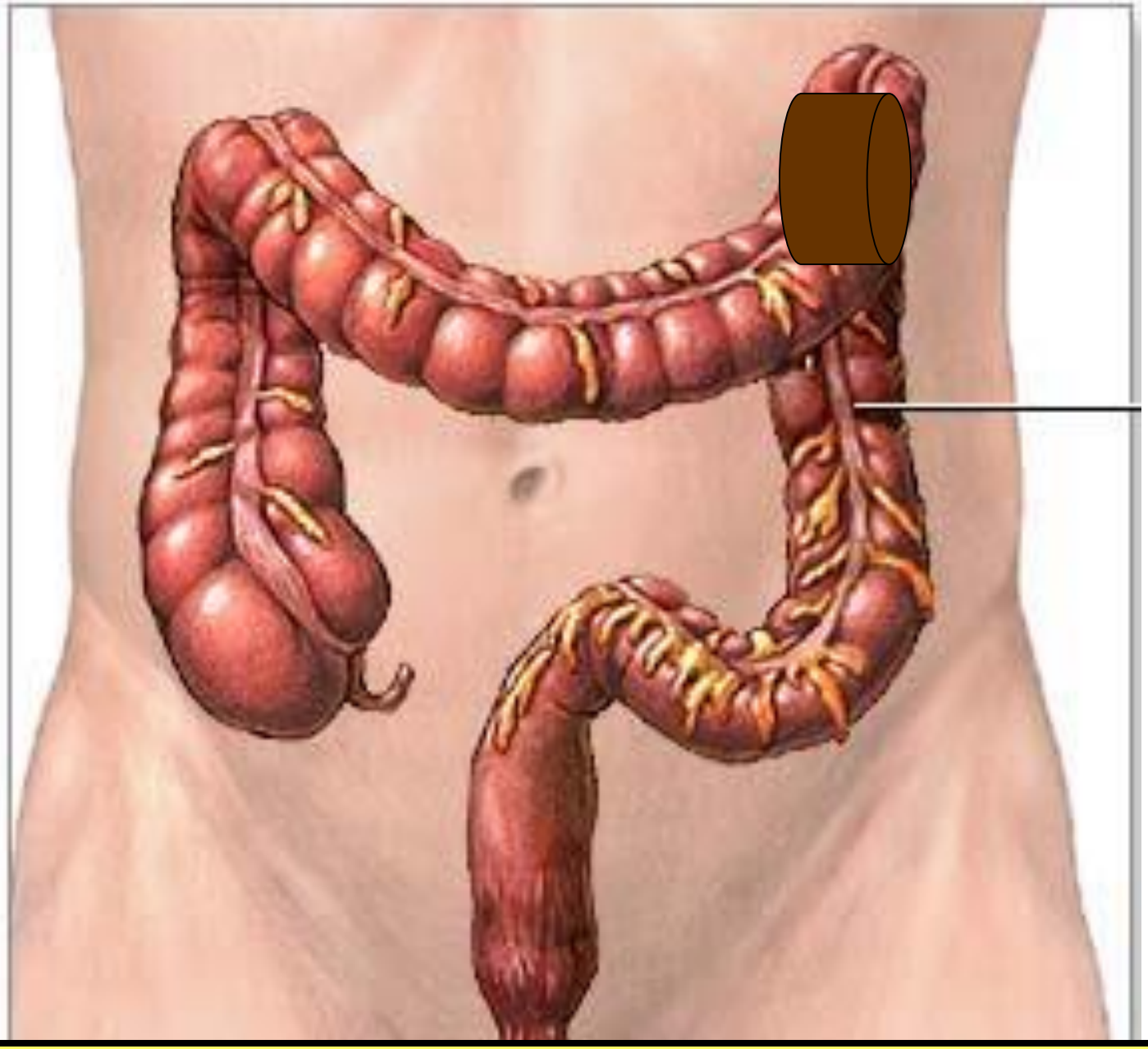


Step 24: the indigestible wastes move into the large intestines.





Step 25: water is reabsorbed from the feces.



Step 26: the feces continue until the sphincter relaxes and they are released from the body.

Let's Put It All Together

LIPIDS

1. Eat lipids and chew them with our mouth.
2. Saliva is released with salivary amylase and mucous.
3. The bolus goes the to back of the throat and we swallow it.
4. The esophagus takes the bolus to the stomach via peristalsis.
5. When food reaches the stomach, GASTRIN is released.
6. Gastrin causes the release of the gastric juices (HCl, mucous, pepsinogen)
7. HCl kills the bacteria in the food and creates a pH of 2.5.
8. The stomach mixes the food around.
9. The acid chyme is slowly released in to the duodenum through the pyloric sphincter.
10. When the FATS reach the duodenum two hormones are released.

Let's Put It All Together

LIPIDS

11. SECRETIN causes the release of the pancreatic juices.
12. CCK causes the release of bile from the gall bladder and an additional release of the pancreatic juices.
13. Sodium bicarbonate neutralizes the pH to 8.5 so all the enzymes can work at their optimum pH.
14. Bile emulsifies the fats into small droplets.
15. Lipase breaks the small fat droplets into fatty acids and glycerol.
16. Fatty acids and glycerol move into the lactaels of the villi.
17. The lactaels are connected to the lymphatic system and take the fatty acids and glycerol to the subclavien vein (in the shoulder).
18. The fatty acids and glycerol move through the subclavien vein, into the vena cava, and into the heart.

Let's Put It All Together

LIPIDS

19. The heart pumps the fatty acids around the body to be used for…

    Insulation

    Protection of the organs

    Energy storage in fat cells

20. The remainder of the indigestible food continues into the large intestines.

21. Water is reabsorbed from the feces.

22. The feces continue on until the anal sphincter is relaxed and the feces leave the body.

Let's Put It All Together

PROTEINS

1. Eat proteins and chew them with our mouth.
2. Saliva is released with salivary amylase and mucous.
3. The bolus goes the to back of the throat and we swallow it.
4. The esophagus takes the bolus to the stomach via peristalsis.
5. When food reaches the stomach, GASTRIN is released.
6. Gastrin causes the release of the gastric juices (HCl, mucous, pepsinogen)
7. HCl kills the bacteria in the food and creates a pH of 2.5.
8. HCl also activates the pepsinogen and turns it into the active form PEPSIN.
9. Pepsin digests proteins into smaller polypeptides.
10. The stomach mixes the food around.
11. The acid chyme is slowly released in to the duodenum through the pyloric sphincter.
12. When the PROTEINS reach the duodenum two hormones are released.
13. SECRETIN causes the release of the pancreatic juices.
14. CCK causes the release of bile from the gall bladder and an additional release of the pancreatic juices.

Let's Put It All Together
PROTEINS

15. Sodium bicarbonate neutralizes the pH to 8.5 so all the enzymes can work at their optimum pH.
16. Trypsin digests the smaller polypeptides into di and tri-peptides.
17. The di and tri-peptides move further down into the small intestines.
18. The glands in the small intestine release intestinal juices: peptidases, nucleases, maltase, sucrase and lactase.
19. the peptidases digest the di and tri-peptides into amino acids.
20. The amino acids move into the capillaries of the villi.
21. The capillaries are attached to the hepatic portal vein which takes the amino acids to the liver.
22. The liver may turn the amino acids into glucose if the body needs energy.
23. Otherwise, the liver sends the amino acids to the heart where they are pumped to the body cells.
24. The body cells use proteins to:
    build new cells and grow and repair
25. The indigestible wastes continue into the large intestines, where water is reabsorbed and the feces are released from the body when the anal sphincter relaxes.

Let's Put It All Together

NUCLEIC ACIDS

1. Eat nucleic acids (DNA and RNA) and chew them with our mouth.
2. Saliva is released with salivary amylase and mucous.
3. The bolus goes the to back of the throat and we swallow it.
4. The esophagus takes the bolus to the stomach via peristalsis.
5. When food reaches the stomach, GASTRIN is released.
6. Gastrin causes the release of the gastric juices (HCl, mucous, pepsinogen)
7. HCl kills the bacteria in the food and creates a pH of 2.5.
8. The stomach mixes the food around.
9. The acid chyme is slowly released in to the duodenum through the pyloric sphincter.
10. When the NUCLEIC ACIDS reach the duodenum, SECRETIN is released.
11. Sodium bicarbonate neutralizes the pH to 8.5 so all the enzymes can work at their optimum pH.
12. Nucleases digest the nucleic acids into nucleotides.
13. The nucleotides move further down into the small intestines.

Let's Put It All Together

NUCLEIC ACIDS

14. The glands in the small intestine release intestinal juices: peptidases, nucleases, maltase, sucrase and lactase.
15. The nucleases further digest the nucleic acids into nucleotides.
16. The nucleotides move into the capillaries of the villi.
17. The capillaries are attached to the hepatic portal vein which takes the nucleotides to the liver.
18. The liver will send the nucleotides to the heart where they are pumped to the body cells.
19. The body cells use nucleotides to make new DNA during DNA replication, and RNA during transcription.
20. The indigestible wastes continue into the large intestines, where water is reabsorbed and the feces are released from the body when the anal sphincter relaxes.

Virtual Body Guided Tour

http://www.kitses.com/animindex.html

http://mediaspace.evergreen.edu/Egallery/animationgallery/gallery/animation/Digestion.html