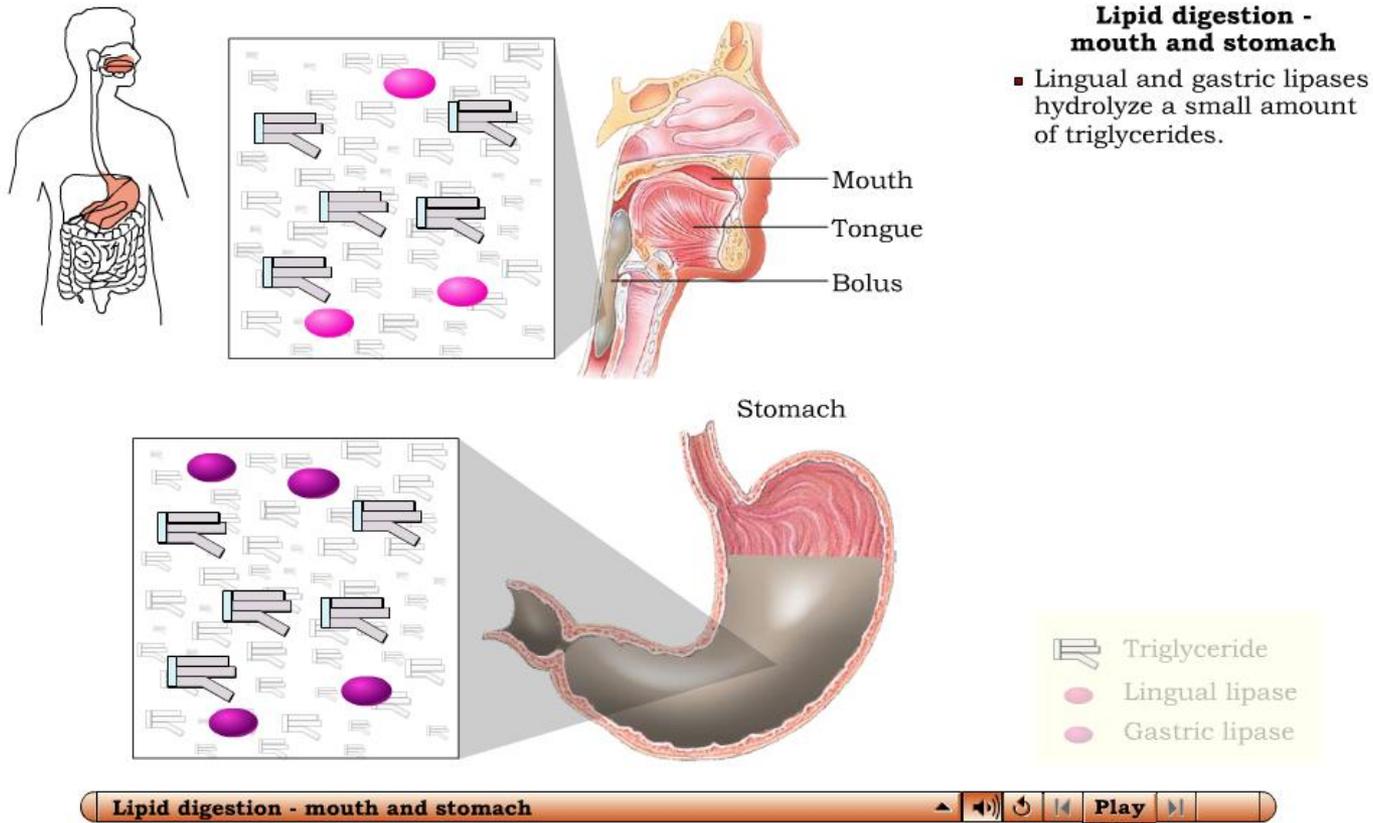


# The Stomach

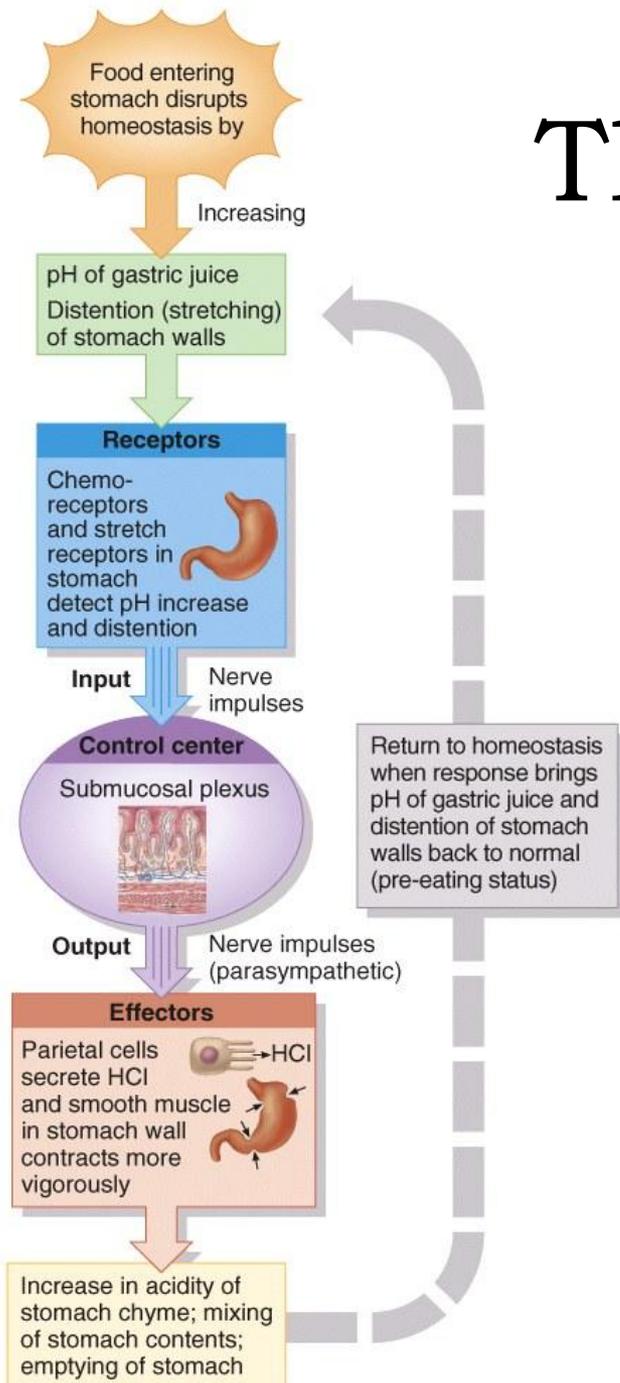
*(Interactions Animation)*

## Lipid Digestion in the Stomach



**You must be connected to the internet to run this animation**

# The Stomach



# The Stomach

- Although digestion is a major function of the stomach, its epithelial cells are impermeable to most materials, and very little absorption takes place.
- Within 2 to 4 hours after eating a meal, the stomach has emptied its contents into the duodenum.
  - Foods rich in carbohydrate spend the least time.
  - High-protein foods remain somewhat longer.
  - Emptying is slowest after a fat-laden meal containing large amounts of triglycerides.

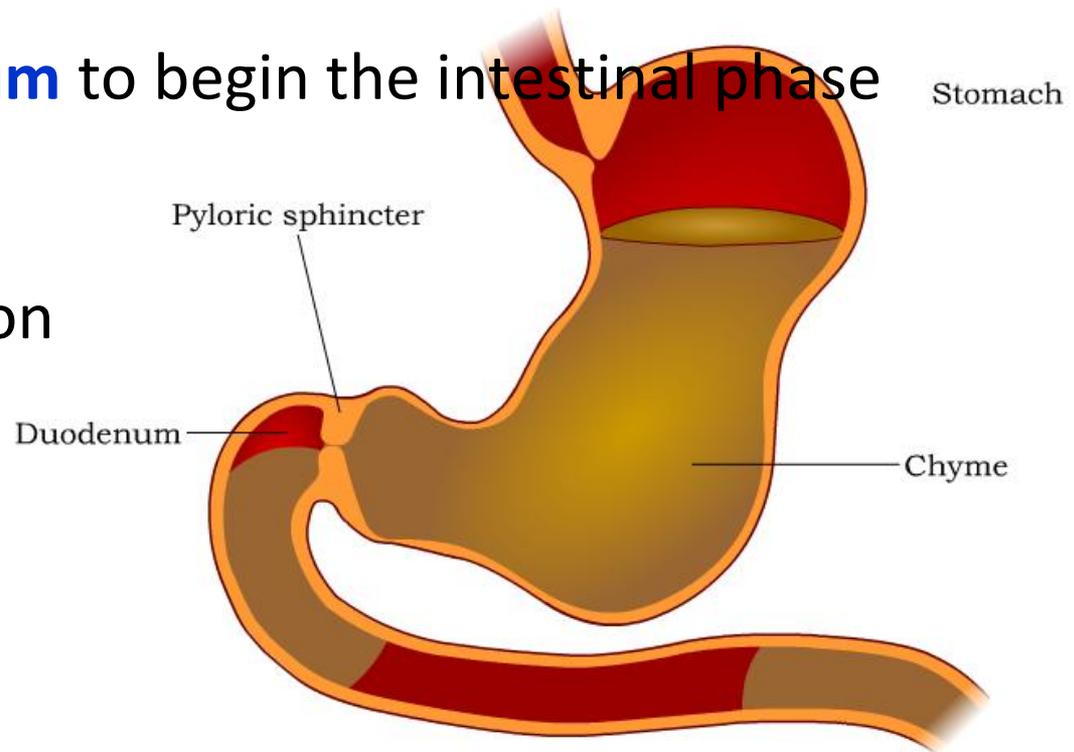
# The Stomach

At appropriate intervals, the stomach allows a small amount of chyme to pass through the pyloric sphincter

and enter the **duodenum** to begin the intestinal phase of digestion.

■ Completion of digestion

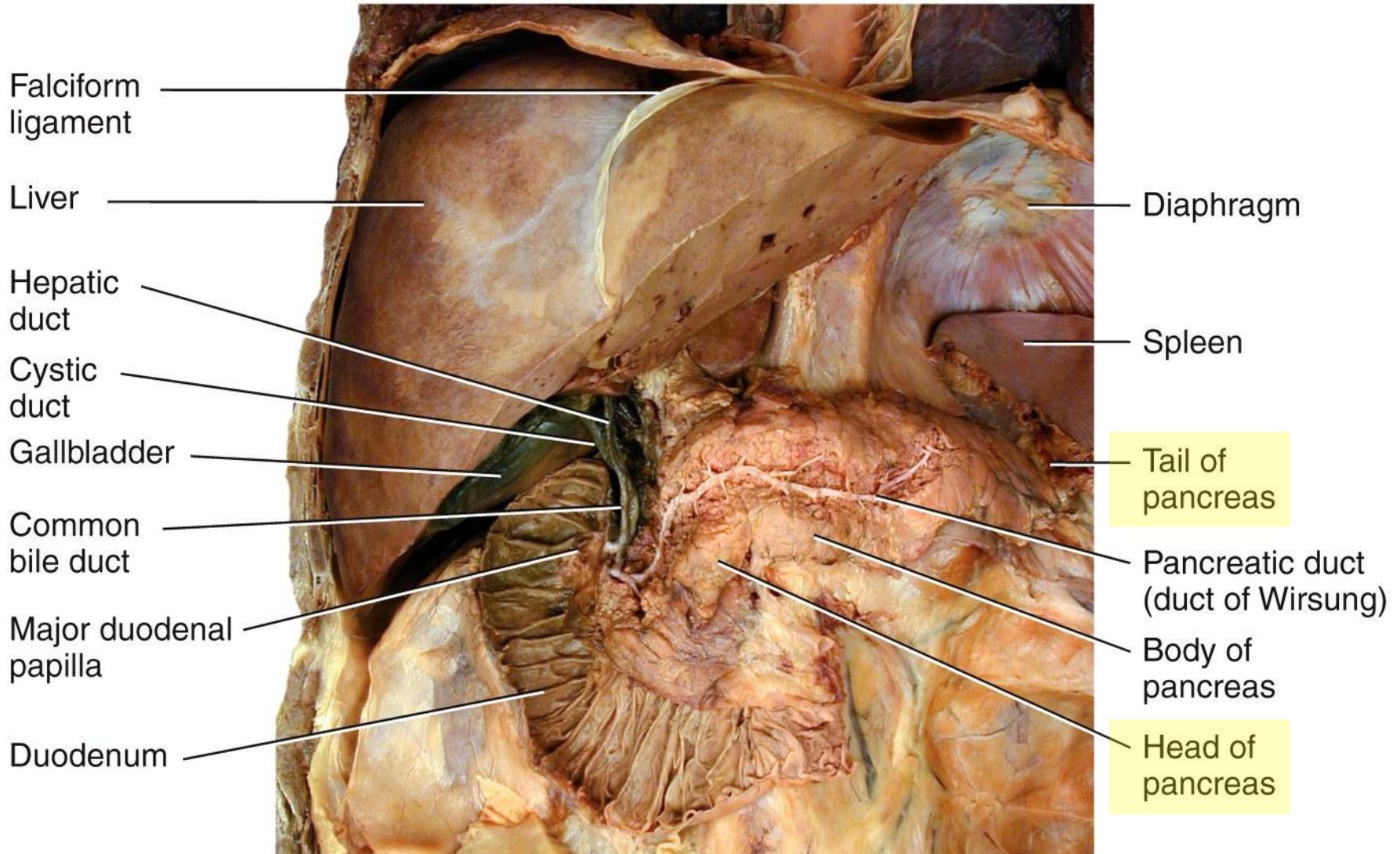
is a collective effort of pancreatic juice, bile, and intestinal juice in the small intestine.



# The Pancreas

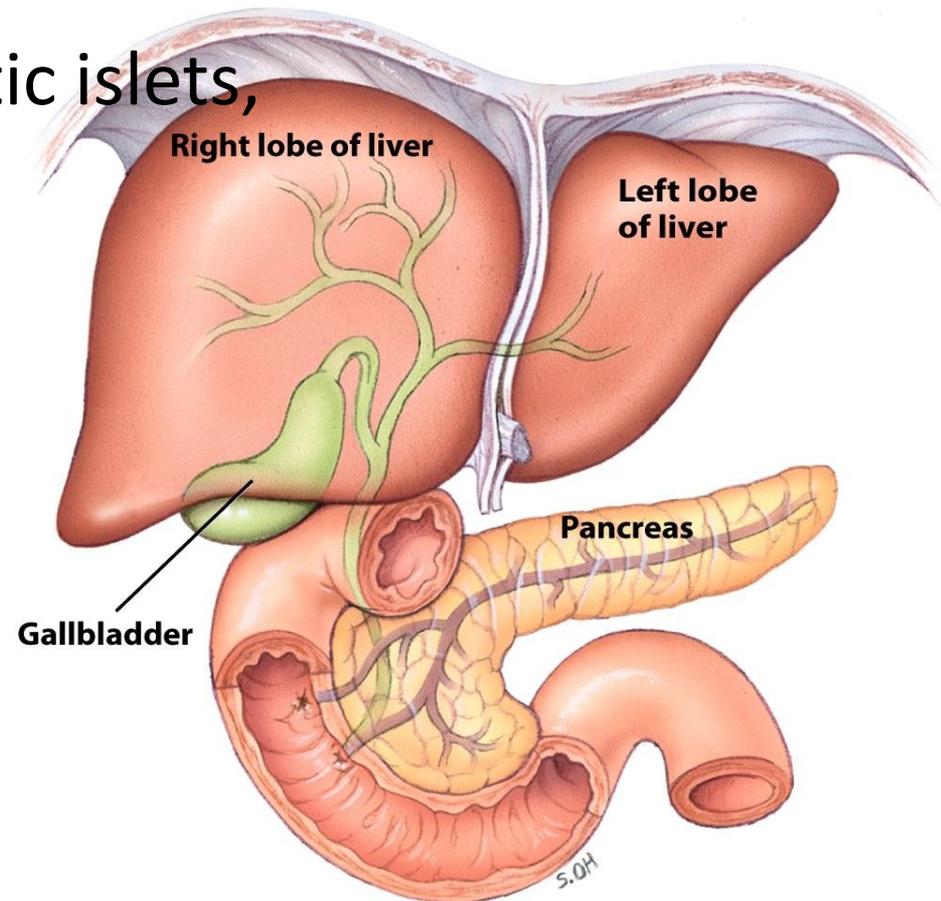
- Digestion and absorption in the small intestine depend heavily on secretions from the pancreas and gallbladder (liver).
  - The **pancreas** is an oblong gland located posterior to the stomach in the retroperitoneal space.
    - It is connected to the duodenum by the hepatopancreatic ampulla and accessory ducts.
    - It secretes enzymes, which digest food in the small intestine, and sodium bicarbonate, which buffers the acidic pH of chyme.

# The Pancreas



# The Pancreas

● About 99% of pancreatic **acini** (glandular clusters) participate in exocrine secretion – only 1% of the clusters, called pancreatic islets, form the endocrine portion of the gland (secreting the hormones glucagon, insulin, and somatostatin and pancreatic polypeptide).



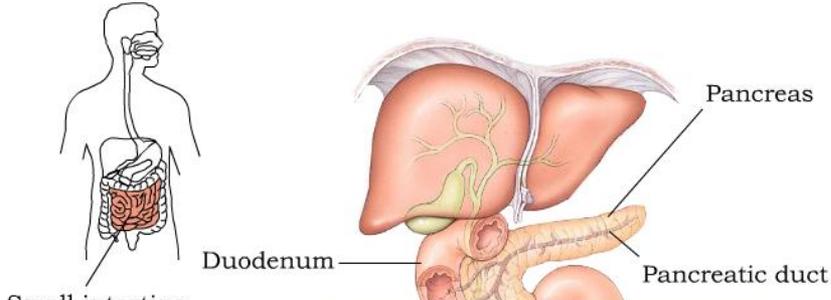
# The Pancreas

- About 1-1.5 liters of alkaline **pancreatic juice** is secreted into the duodenum each day. It creates the proper pH for the following digestive enzymes in the small intestine:
  - A starch digesting enzyme called **pancreatic amylase**
  - Several enzymes that cleave polypeptides into dipeptides and single amino acids: **trypsin, chymotrypsin, carboxypeptidase, and elastase**
  - **Pancreatic lipase**, the major triglyceride (fat) digesting enzyme in adults

# The Pancreas

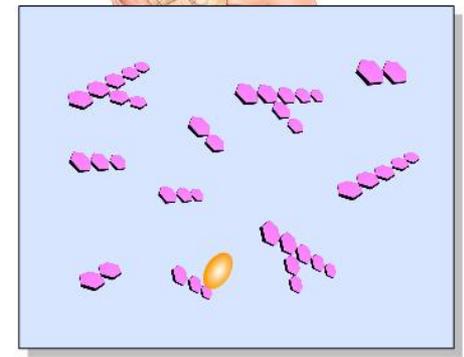
## *(Interactions Animation)*

### Carbohydrate Digestion – The Pancreas



**Carbohydrate digestion-pancreas and small intestine**

- The pancreas secretes amylase into the duodenum.
- In the small intestine, bicarbonate ions from pancreatic juice neutralize gastric acid.



	Pancreatic amylase
	Starch
	Glycogen
	Maltose
	Maltotriose
	Alpha-dextrins
	Bicarbonate ion

Carbohydrate digestion - pancreas and small intestine

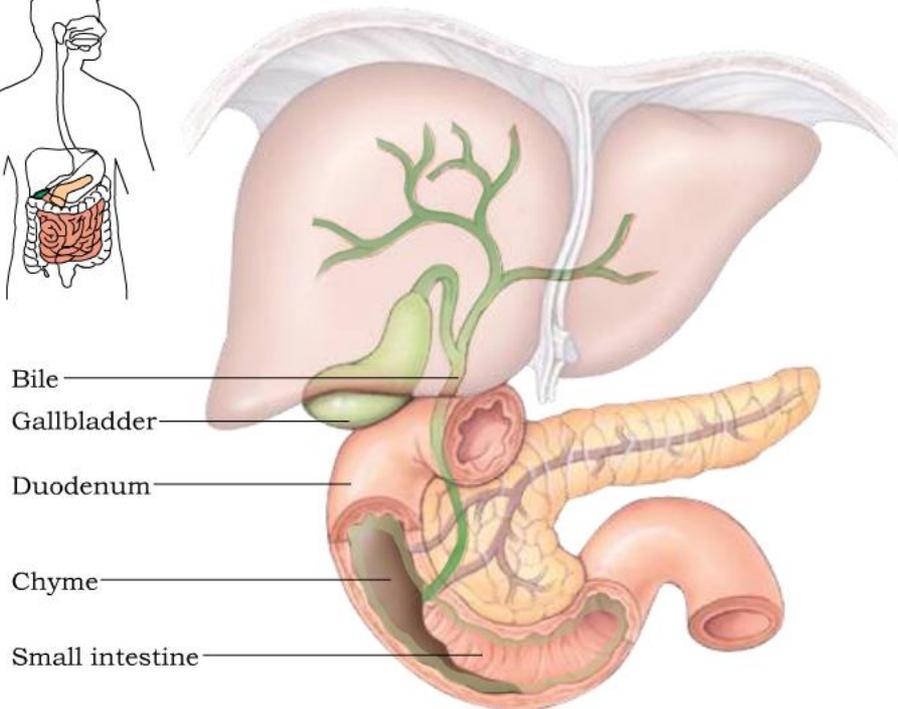
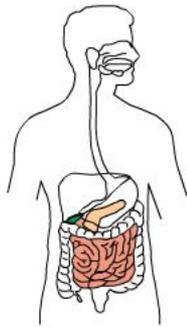
**You must be connected to the internet to run this animation**

# The Pancreas

*(Interactions Animation)*

## Lipid Digestion - Bile Salts and Pancreatic

### Lipase



#### **Lipid digestion - small intestine**

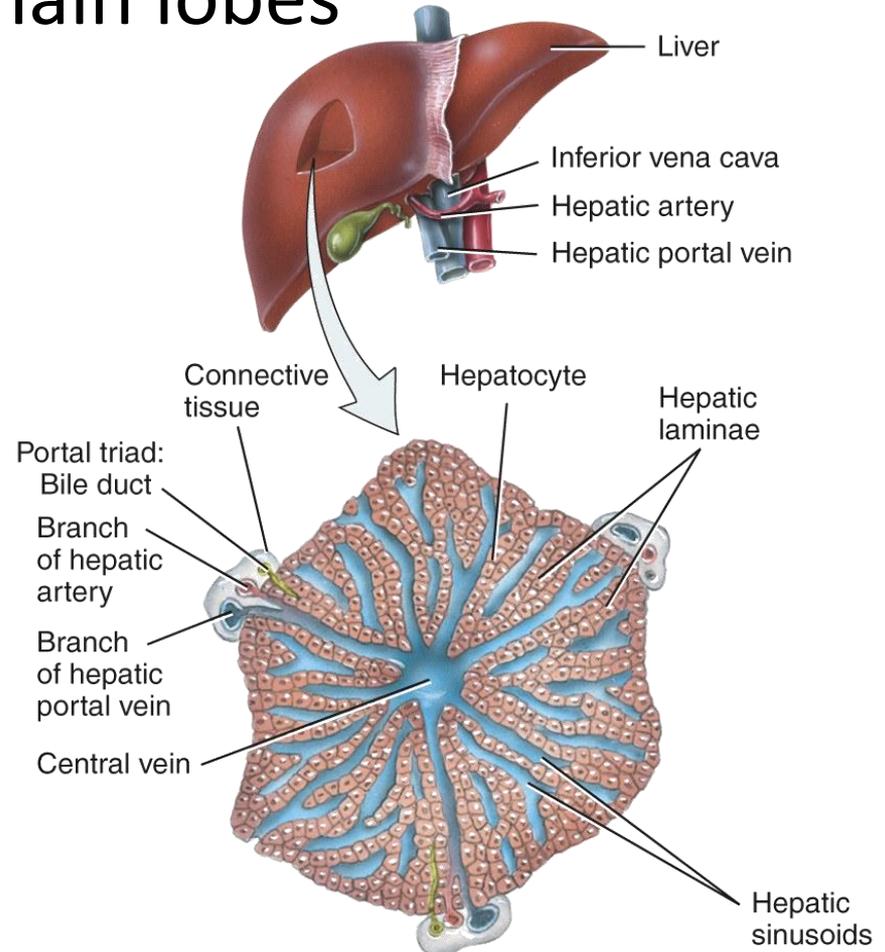
- In the duodenum, triglycerides interact with bile salts and pancreatic juice.

Lipid digestion - small intestine 

**You must be connected to the internet to run this animation**

# The Liver and Gallbladder

- The liver is the body's largest gland and second largest organ. It has 2 main lobes (right and left – divided by the falciform ligament) and is covered by visceral peritoneum.
- The liver is made up of repeating functional units called **liver lobules**.

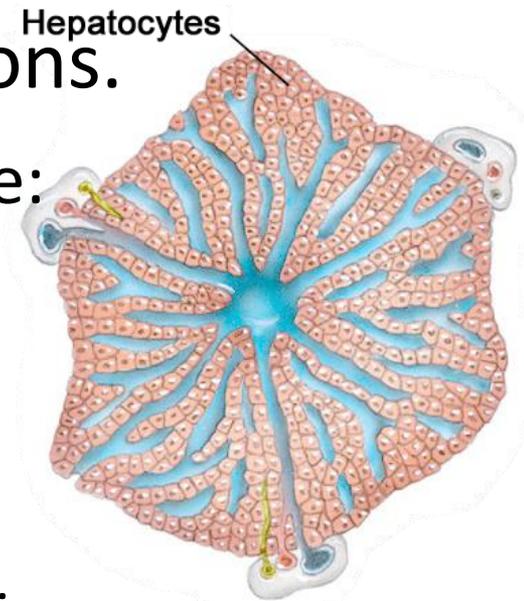


(a) Overview of histological components of liver

# The Liver and Gallbladder

🌿 **Hepatocytes** are the major functional cells of the liver. As the body's "chemical factories", their metabolic versatility is truly remarkable. Hepatocytes participate in a number of digestive and non-digestive functions.

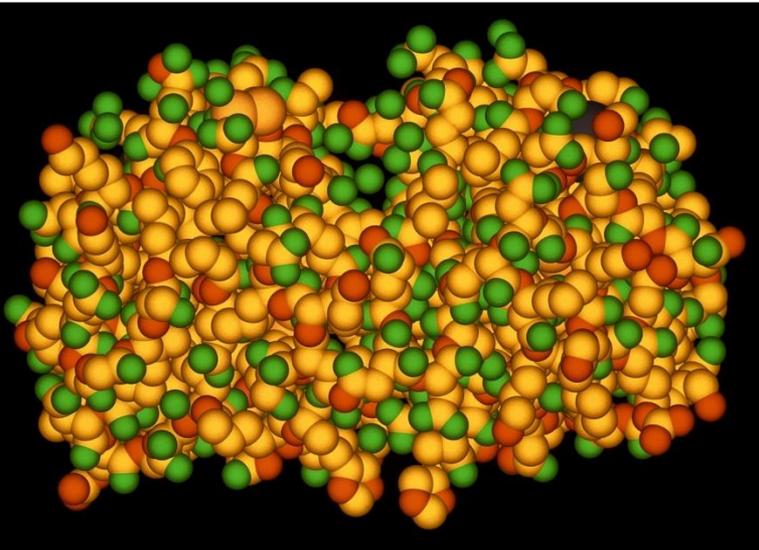
- Important digestive functions include:
  - the synthesis, transformation, and storage of proteins, carbohydrates, and fats
  - detoxification, modification, and excretion of a variety of exogenous and endogenous substances



# The Liver and Gallbladder

🌿 **Non-digestive liver functions** include:

- Phagocytosis of old or worn-out cells
- Making heparin (anticoagulant) and other plasma proteins (prothrombin, fibrinogen, and albumin)
- Modifying vitamin D to its active form

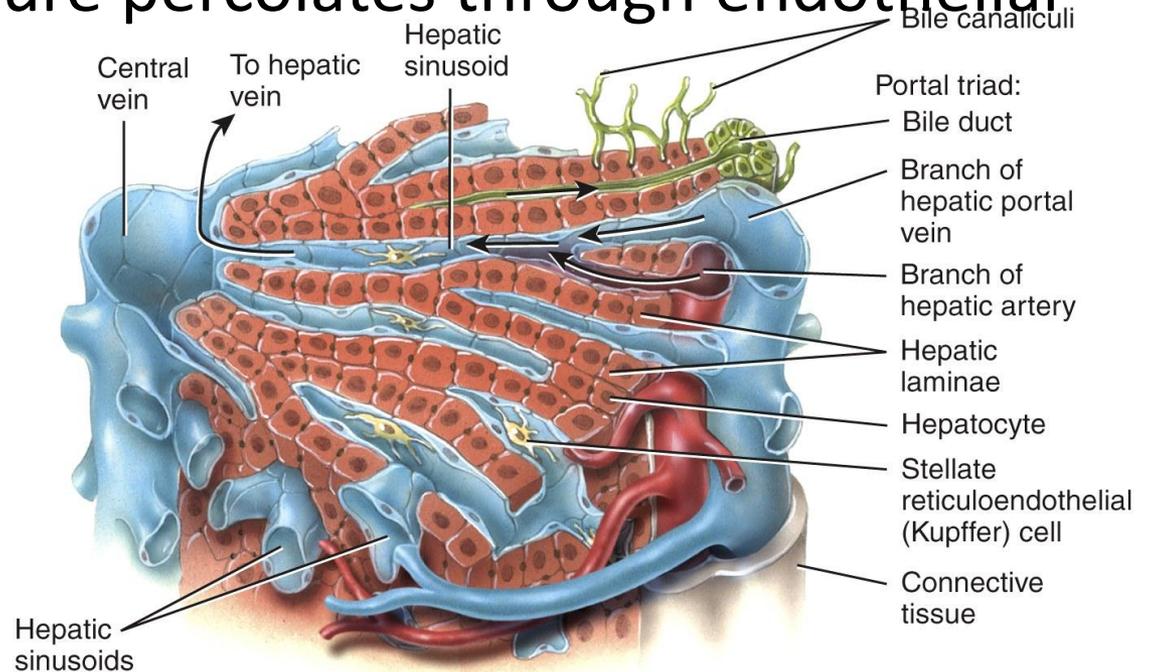


Human Albumin

# The Liver and Gallbladder

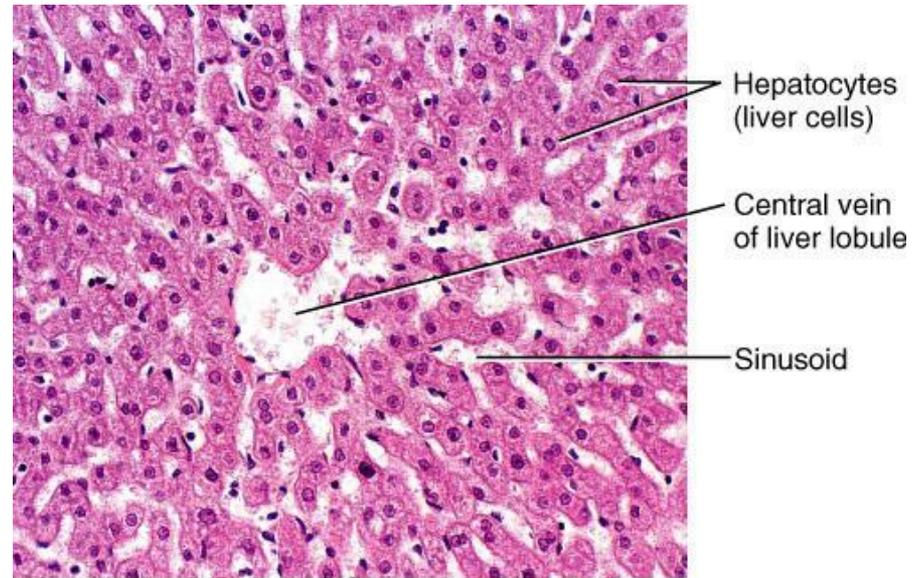
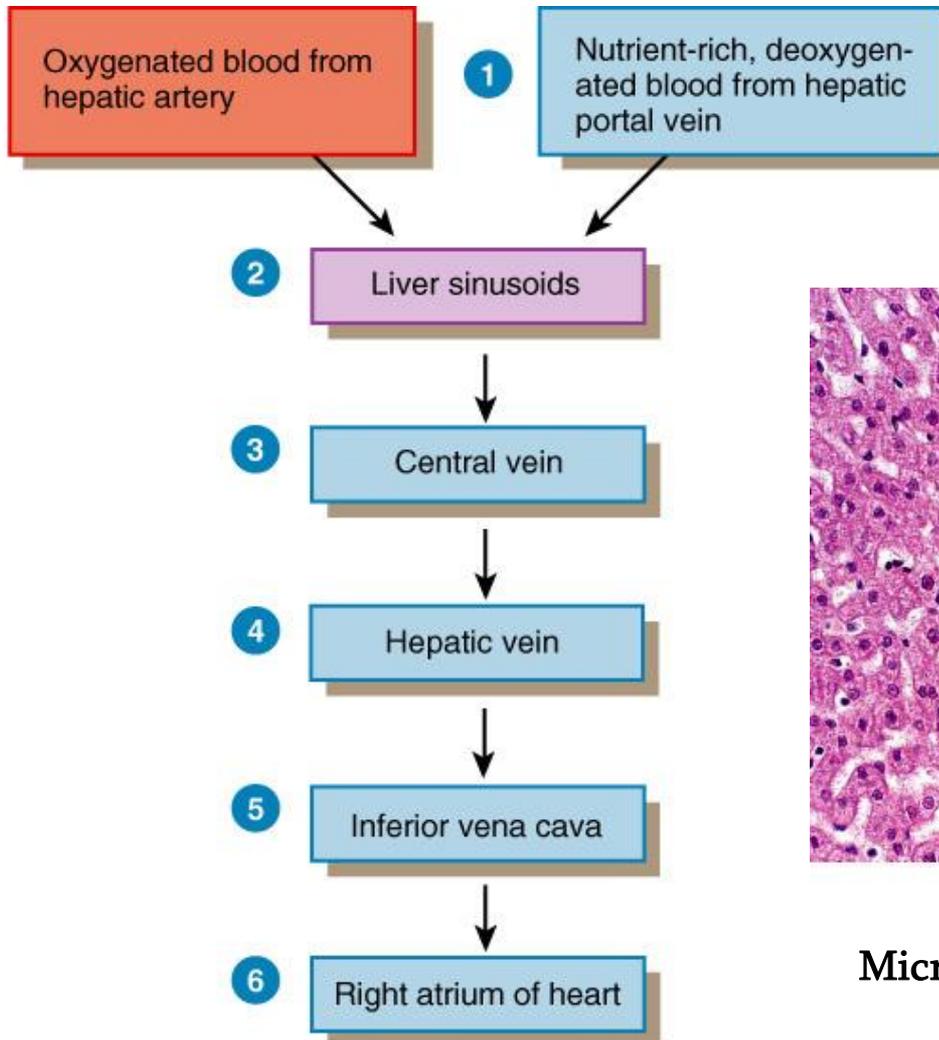
● Venous blood (from the hepatic portal vein) and arterial blood (from the hepatic artery) feed the lobule from the **triad** on its outer margin.

- The blood mixture percolates through endothelial-lined spaces called **sinusoids** (a specialized capillary) towards the **central vein**.



(b) Details of histological components of liver

# The Liver and Gallbladder



LM 150x

Microstructure of the liver lobule

Path of blood in hepatic sinusoid

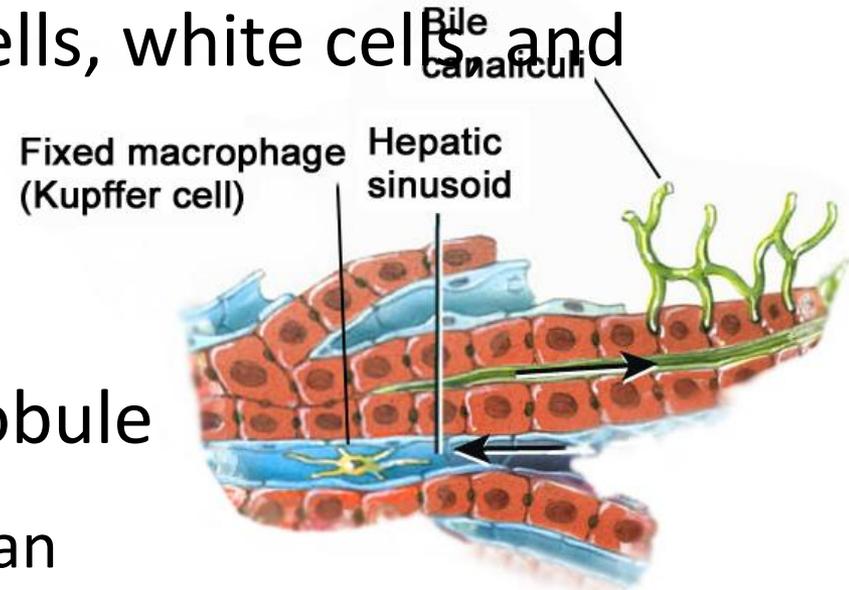
# The Liver and Gallbladder

- Fixed macrophages within the sinusoids called **Kupffer cells** destroy red cells, white cells, and bacteria in blood draining from the GI tract.

- An important function of lobule **hepatocytes** is to secrete bile, an

excretory product that helps emulsify fats for the watery environment of small intestine digestive juices.

- Hepatocytes secrete about 1 liter of bile per day.



# The Liver and Gallbladder

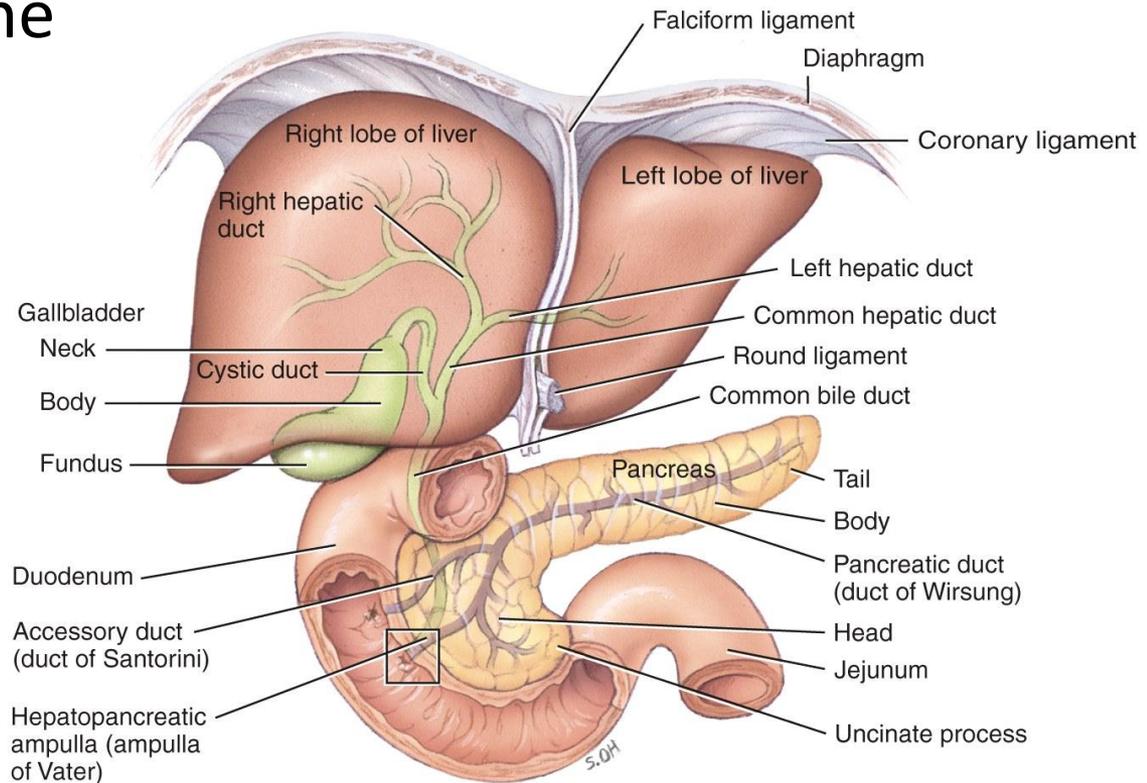
 Bile is an alkaline solution consisting of water, bile salts, cholesterol, and bile pigments. It is both an excretory product and a digestive secretion.

- Bile salts are used in the small intestine for the emulsification and absorption of lipids.
  - Without bile salts, most of the lipids in food would be passed out in feces, undigested.
- The dark pigment in bile is called bilirubin and comes from the catabolism of old red blood cells.

# The Liver and Gallbladder

🌿 Bile secreted into the canaliculi (located between the hepatocytes) exits the liver in the **common hepatic duct**.

- This duct joins the **cystic duct** from the gallbladder to form the common bile duct (**CBD**).

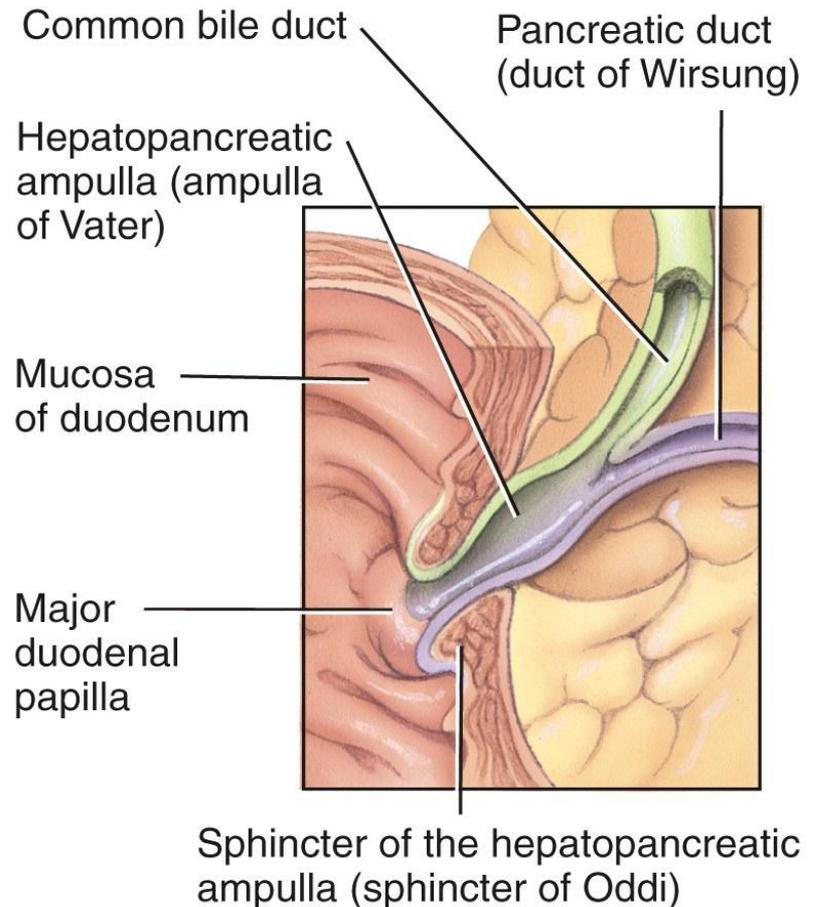


(a) Anterior view

# The Liver and Gallbladder

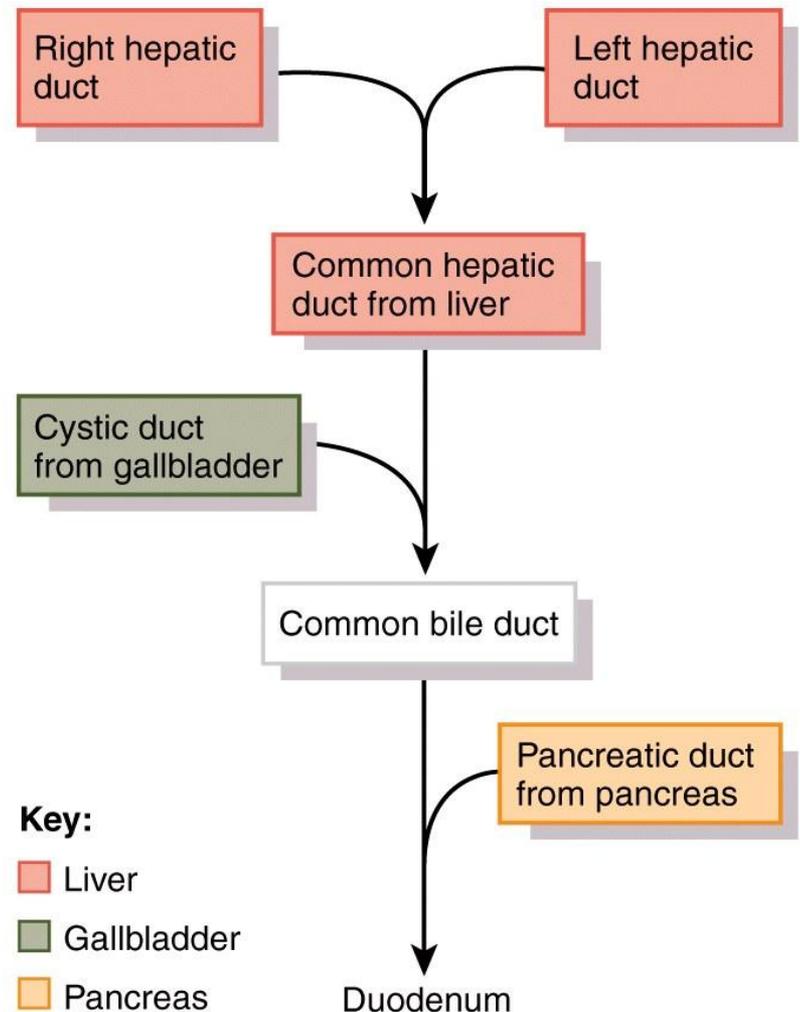
● The CBD works its way towards the duodenum and joins with the **pancreatic duct** to form the **hepatopancreatic ampulla** just proximal to the second part of the duodenum.

- The **duodenal papilla** (“nipple”) pierces the intestinal mucosa to deliver its contents.



# The Liver and Gallbladder

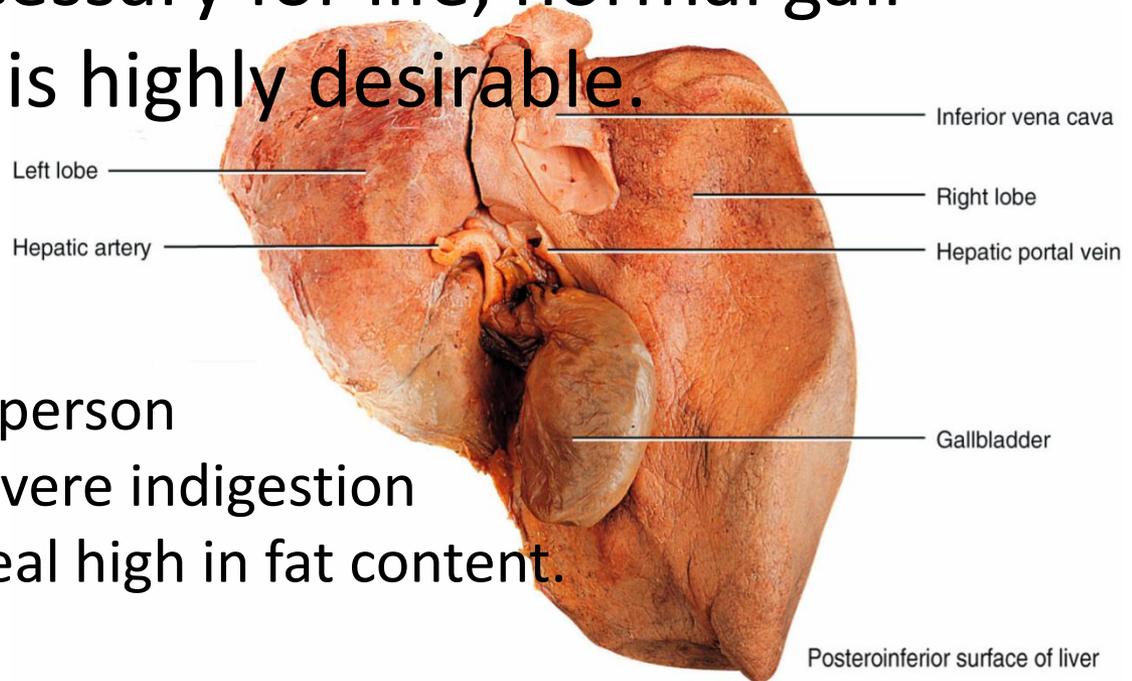
Between meals, the sphincter of the hepatopancreatic ampulla is closed – bile “backs-up” into the gall bladder where it is stored and concentrated up to ten-fold through the absorption of water and ions.



Ducts carrying bile from liver and gallbladder and pancreatic juice from pancreas to the duodenum

# The Liver and Gallbladder

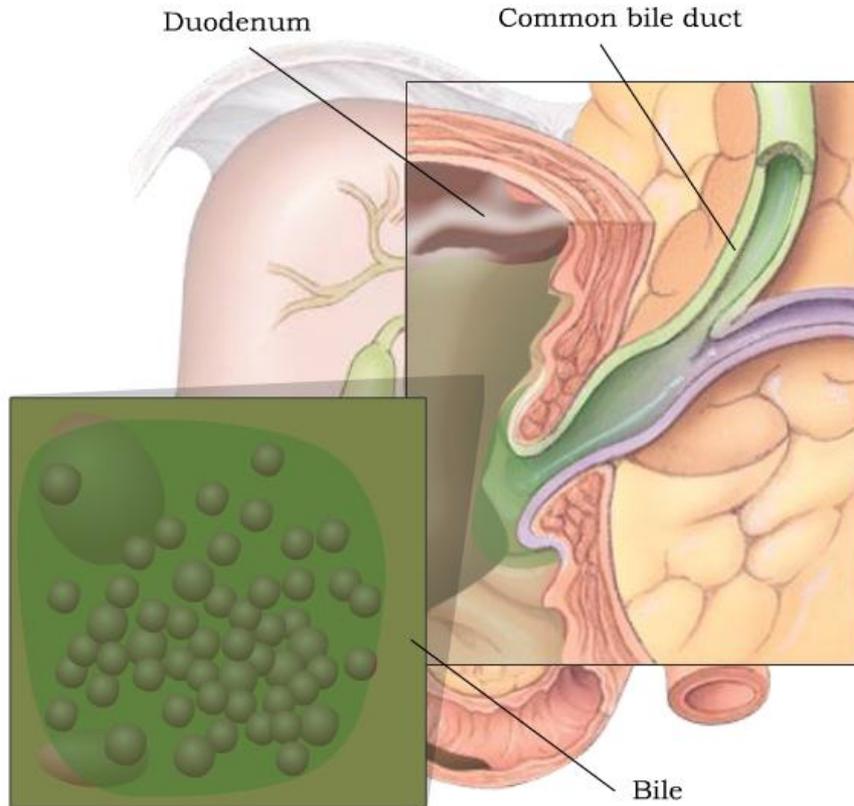
- Under the influence of the hormone cholecystokinin (**CCK**), the gallbladder contracts and ejects stored bile.
- Although not necessary for life, normal gall bladder function is highly desirable.
  - After surgical removal of the gall bladder (called a cholecystectomy), a person would experience severe indigestion if they ate a large meal high in fat content.



# The Liver and Gallbladder

*(Interactions Animation)*

## Chemical Digestion – Bile



### **Digestive chemicals - bile**

- Bile is produced by the liver.
- Bile consists mostly of bile salts (produced from cholesterol) and water.
- Primary function of bile is emulsification of fatty globules.

Digestive chemicals - bile 

**You must be connected to the internet to run this animation**

# The Small Intestine

- The **small intestine** is divided into 3 regions:
  - The duodenum (10 in)
  - The jejunum (8 ft)
  - The ileum (12 ft)
    - If measured in a cadaver, the intestines are longer than if measured in a live person due to the loss of smooth muscle contraction.
- In the small intestine, digestion continues, even while the process of absorption begins.

# The Small Intestine

 Mechanical digestion in the small intestine is a localized mixing contraction called

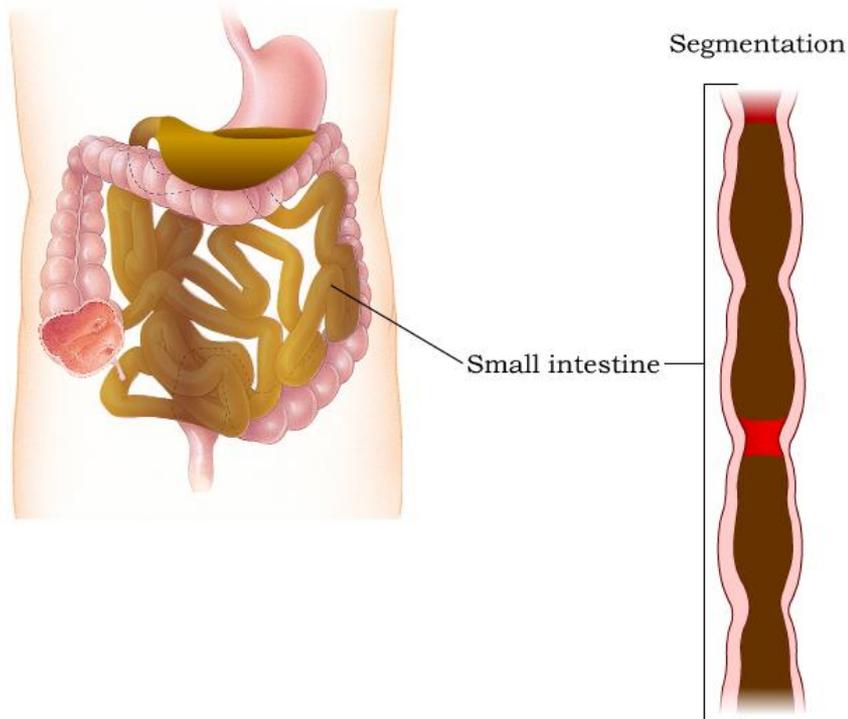
## **segmentations.**

- Segmentations is a type of peristalsis used to mix chyme and bring it in contact with the mucosa for absorption.
- It begins in the lower portion of the stomach and pushes food forward along a small stretch of small intestine.
  - It is governed by the myenteric plexus.

# The Small Intestine

*(Interactions Animation)*

## Segmentation Animation



### **Segmentation and migrating motility complexes**

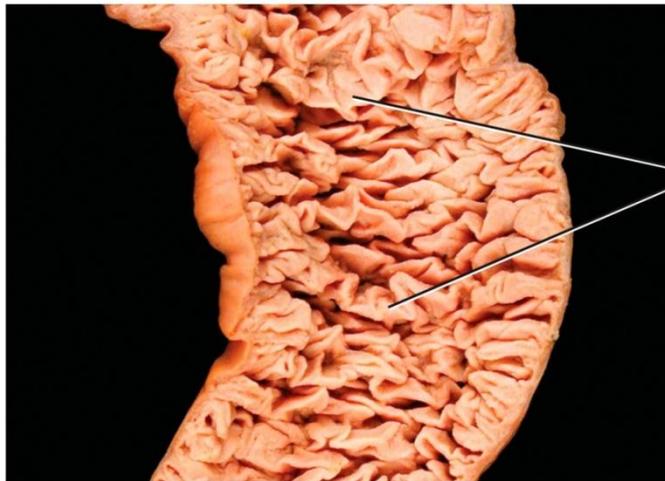
- Within a few hours, most of the stomach contents are in the duodenum.
- Distension of stretch receptors in the small intestine activates a reflex that stimulates segmentation, a mixing movement.



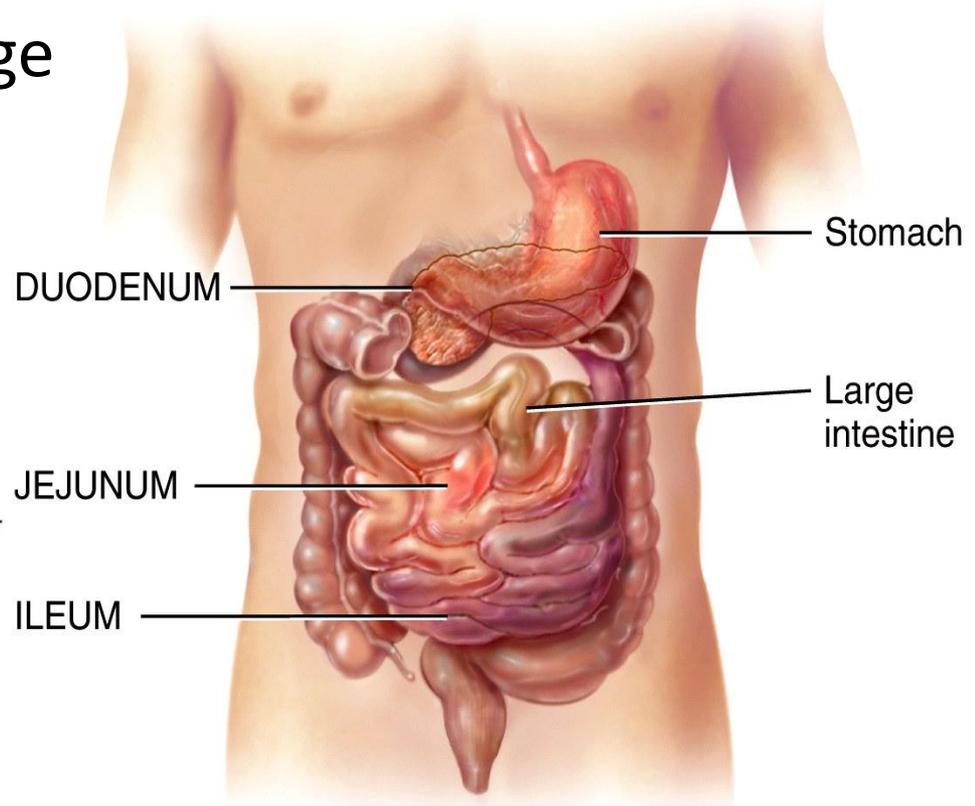
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# The Small Intestine

● Circular folds called the **plicae circulares** are permanent ridges of the mucosa and submucosa that encourage turbulent flow of chyme.



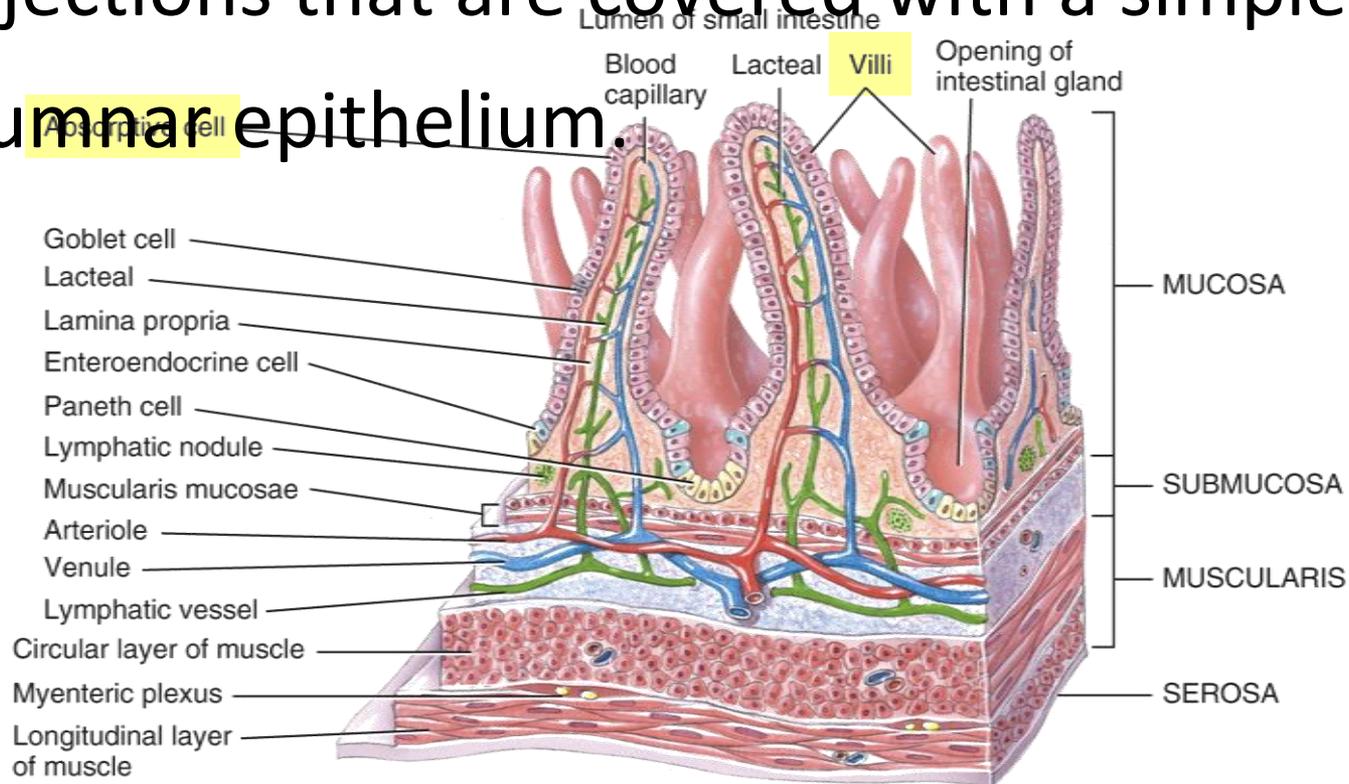
Internal anatomy of jejunum



Anterior view of external anatomy

# The Small Intestine

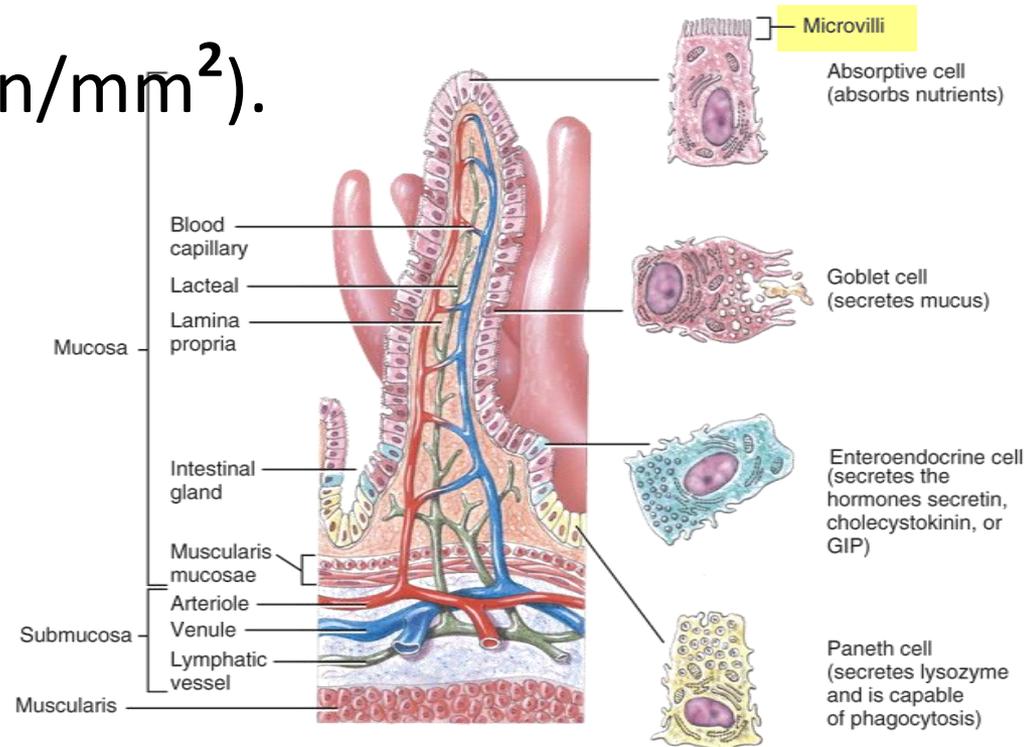
 **Villi** are multicellular structures that can barely be seen by the naked eye. They form finger-like projections that are covered with a simple columnar epithelium.



# The Small Intestine

🍄 **Microvilli** are microscopic folds in the apical surface of the plasma membrane on each simple columnar cell (about 200 million/mm<sup>2</sup>).

🍄 The plicae circulares, villi, and microvilli all contribute to **increase the surface area** of the small intestine, allowing for maximum reabsorption of nutrients.

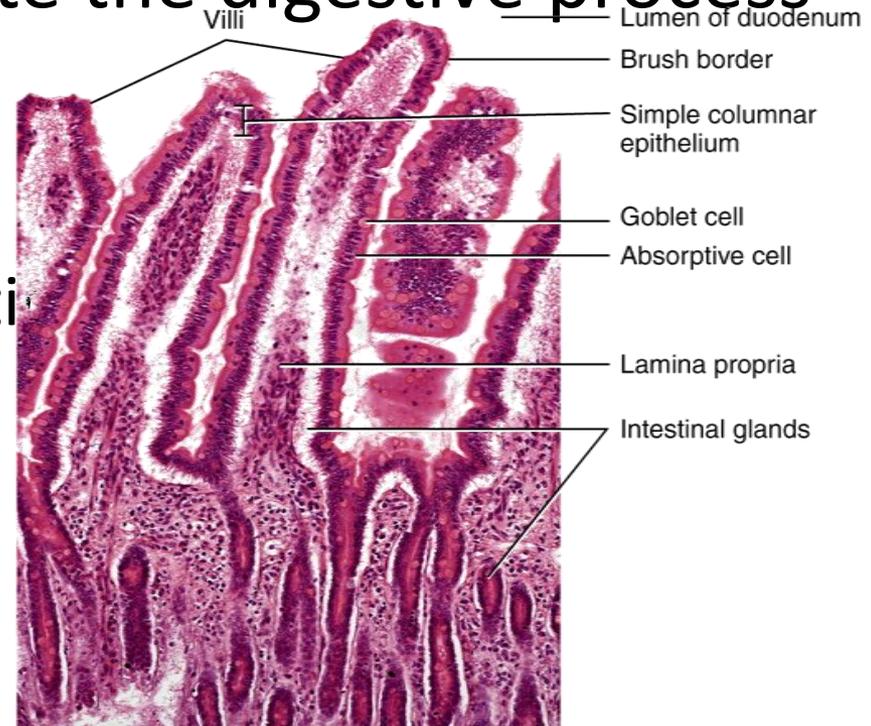


(c) Enlarged villus showing lacteal, capillaries, intestinal glands, and cell types

# The Small Intestine

- The small intestinal mucosa contains many deep crevices lined with glandular epithelium (**intestinal glands**) that secrete **intestinal juice**. Its function is to complete the digestive process begun by pancreatic juice.

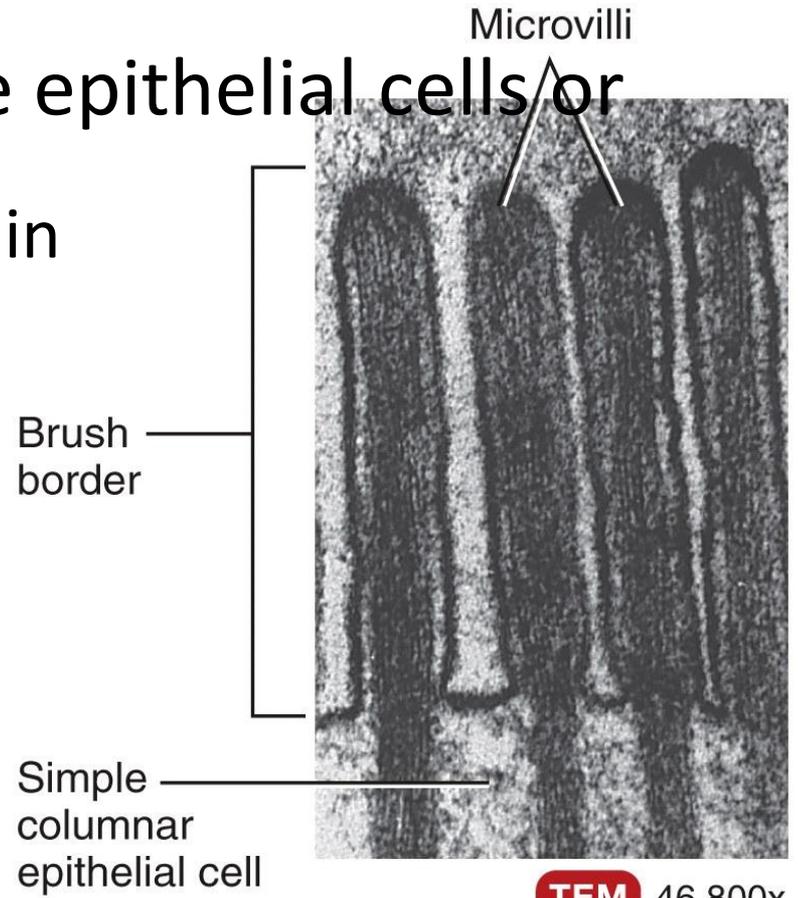
– Trypsin exists in pancreatic juice in the inactive form trypsinogen - it and other enzymes are activated by intestinal juice.



(b) Several villi from duodenum

# The Small Intestine

Most of the enzymatic digestion in the small intestine occurs inside the epithelial cells or on their surfaces (rather than in the lumen of the tube) as intestinal juice comes in contact with the **brush border** of the villi.

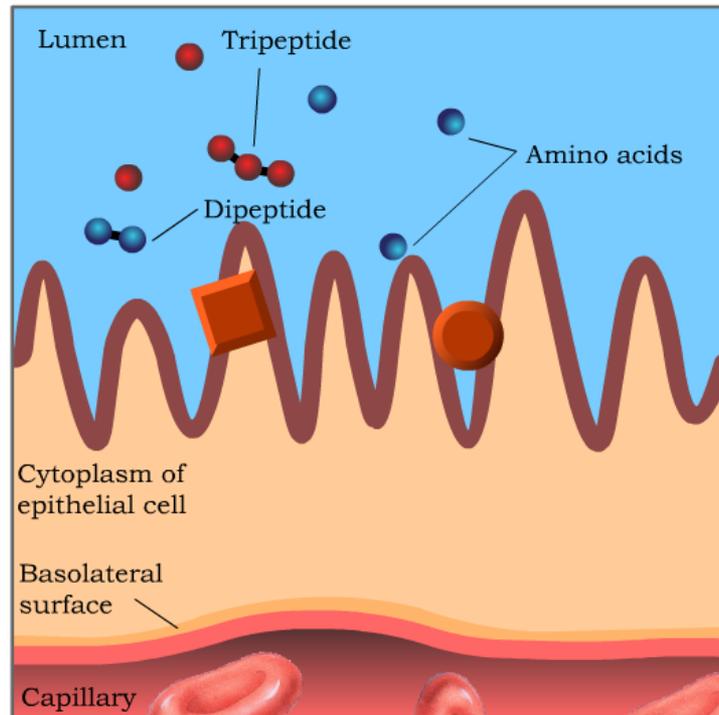


(d) Several microvilli from duodenum

# The Small Intestine

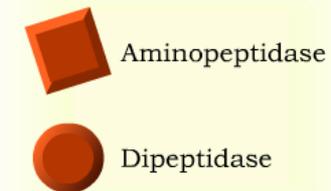
*(Interactions Animation)*

## Digestion on the Brush Border

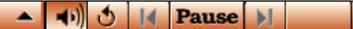


### Protein digestion - brush border enzymes

- End products of protein digestion:
  - Amino acids
  - Dipeptides
  - Tripeptides



Protein digestion - brush border enzymes

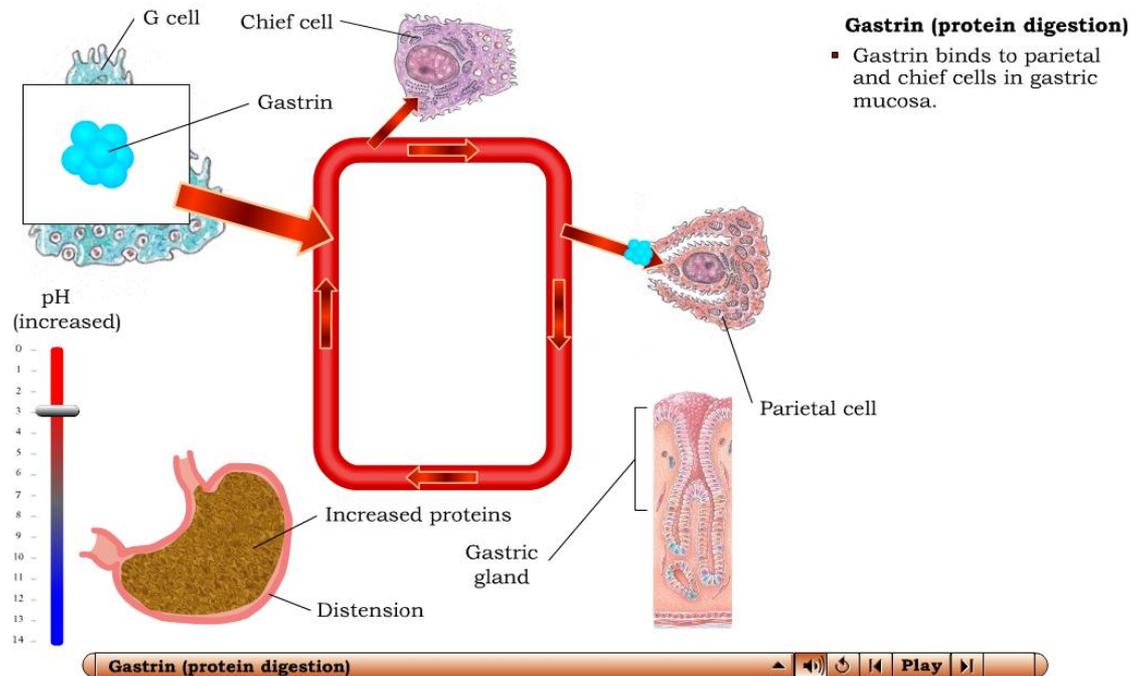


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# The Small Intestine

## *(Interactions Animation)*

- Before discussing the absorption of nutrients, the events of gastric and intestinal digestion are reviewed in this animation.
- [Hormonal Control of Digestive Activities](#)



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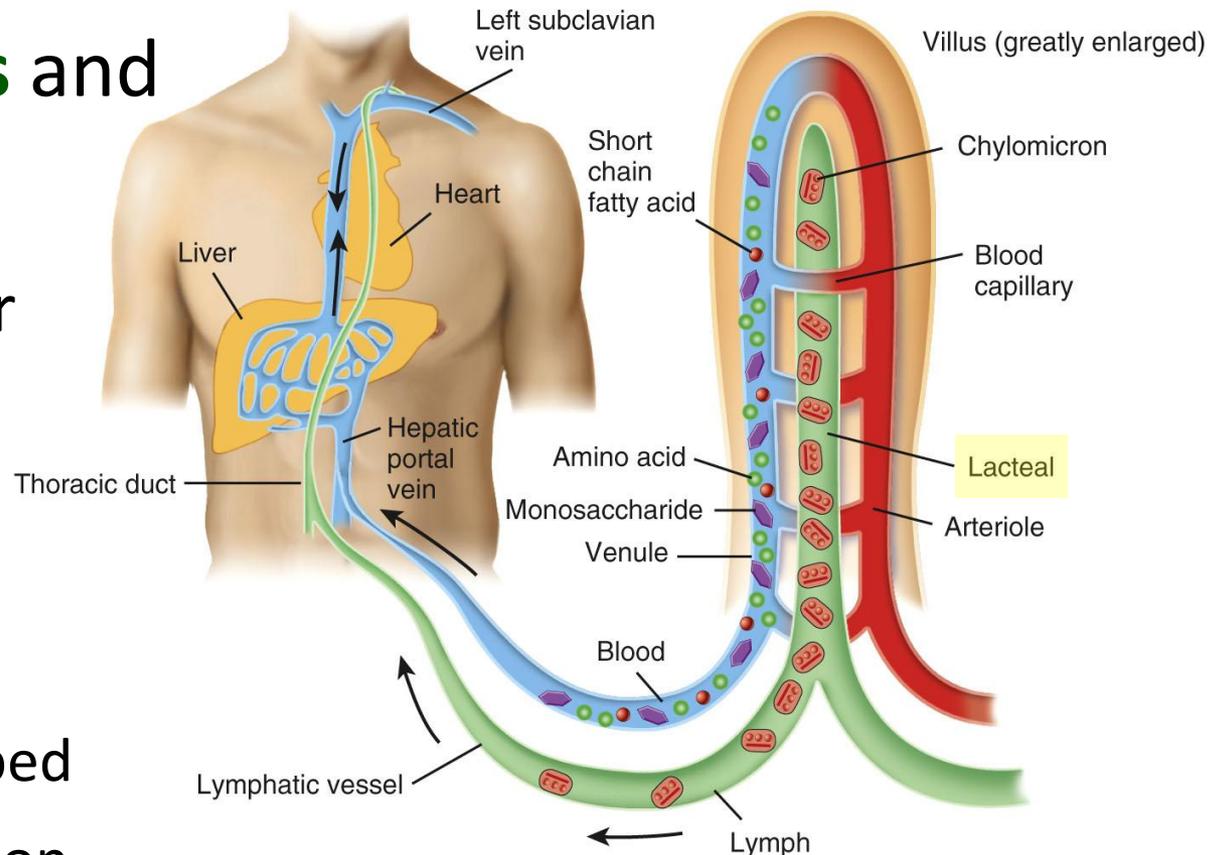
# The Small Intestine

-  Intestinal **absorption** is the passage of digested nutrients into the blood or lymph: 90% of all intestinal absorption occurs in the small intestine.
- Proteins (**amino acids**), **nucleic acids**, and sugars (**monosaccharides**) are absorbed into **blood capillaries** by facilitated diffusion or active transport.
  - **Triglycerides (fats)** aggregate into globules along with phospholipids and cholesterol and become coated with proteins. These large spherical masses are called **chylomicrons**.

# The Small Intestine

Chylomicrons, too large to enter blood capillaries, enter specialized lymphatic vessels called **lacteals** and eventually drain into the superior vena cava and mix with blood.

- All dietary lipids are absorbed by simple diffusion.



(b) Movement of absorbed nutrients into the blood and lymph

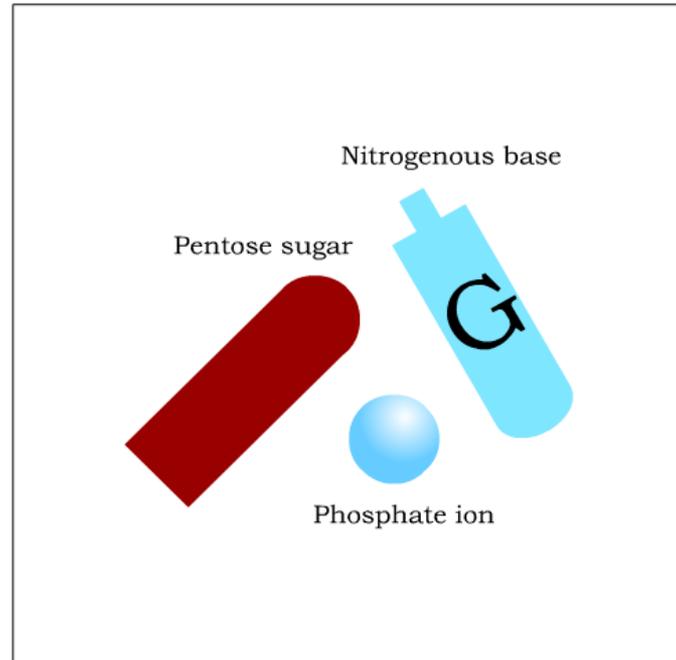
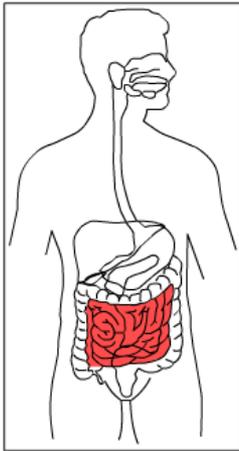




# The Small Intestine

*(Interactions Animation)*

## Nucleic Acid Absorption in the Small Intestine



### **Nucleic acid absorption - end products**

- Absorption of nucleic acid mainly occurs in the duodenum and jejunum of the small intestine.
- At the intestinal villus, all nucleic acids are absorbed as:
  - Nitrogenous bases.
  - Pentose sugars.
  - Phosphate ions.

Nucleic acid absorption - end products

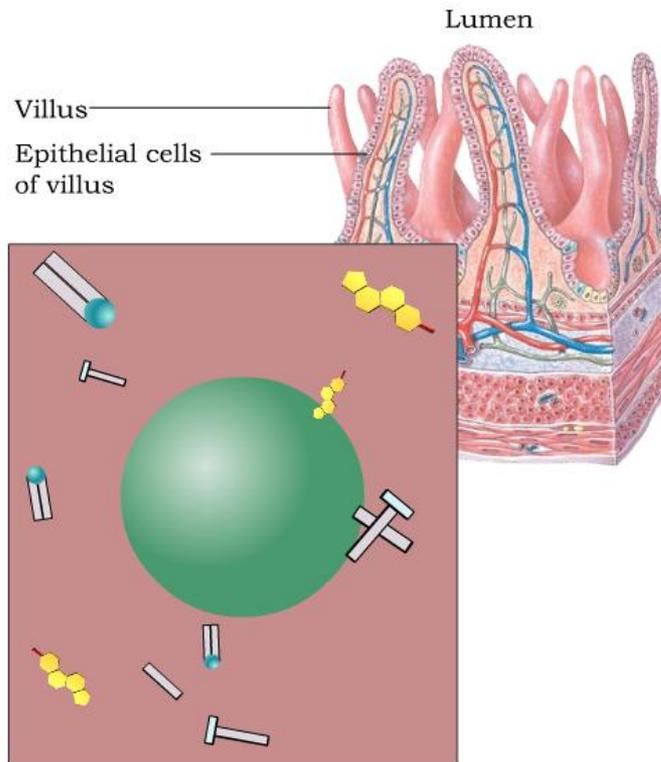
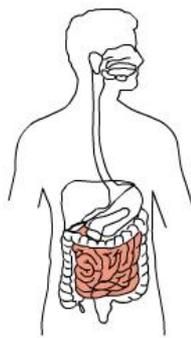


**You must be connected to the internet to run this animation**

# The Small Intestine

*(Interactions Animation)*

## Lipid Absorption in the Small Intestine



### **Lipid absorption - transport mechanism**

- Bile salts form micelles (tiny spheres), which ferry fatty acids and monoglycerides to epithelial cells.

- Bile salt
- Micelle
- Phospholipid
- Cholesterol
- Monoglyceride
- Fatty acids

Lipid absorption - transport mechanism 

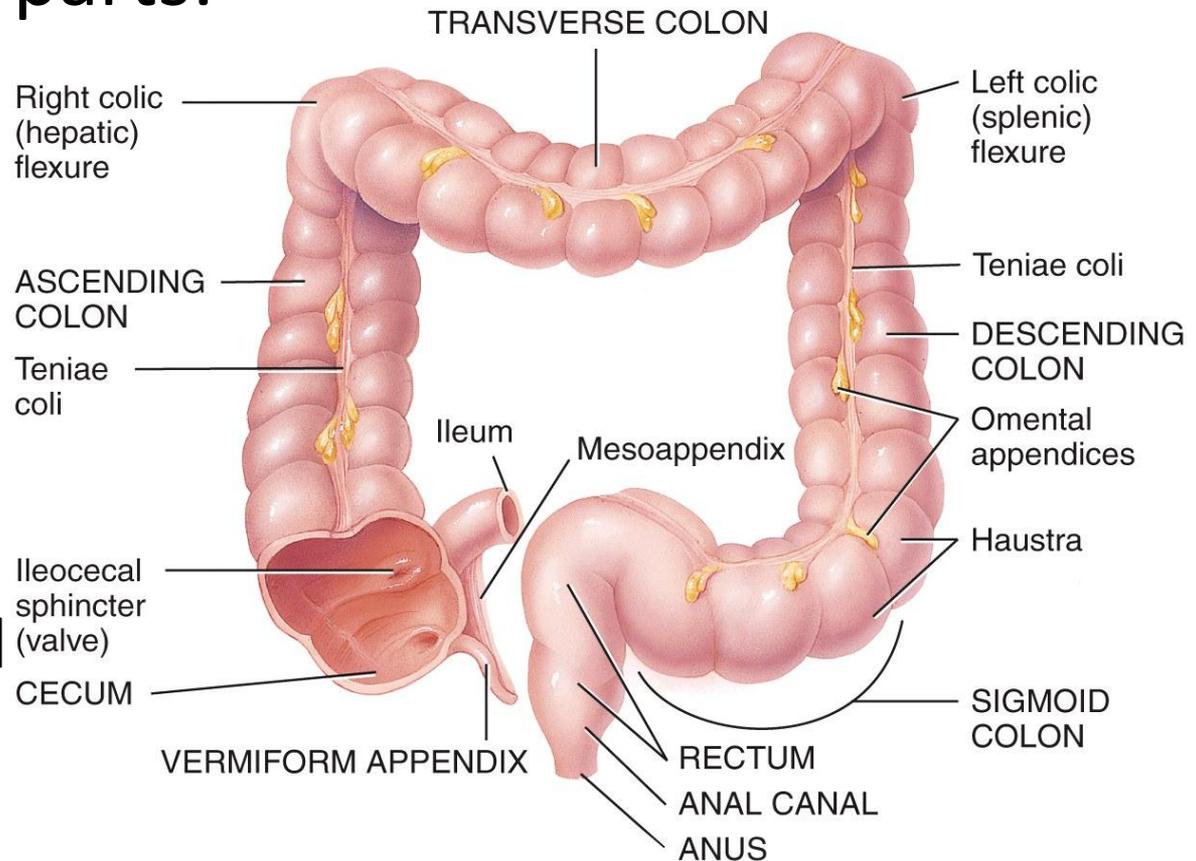
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# The Large Intestine

🍌 The **large intestine** is about 5 feet in length.

Starting at the ileocecal valve, the large intestine has 4 parts:

- The cecum
- The colon
  - ascending
  - transverse
  - descending
  - sigmoid
- The rectum
- The anal canal



# The Large Intestine

There are no circular folds or villi in the large intestine.

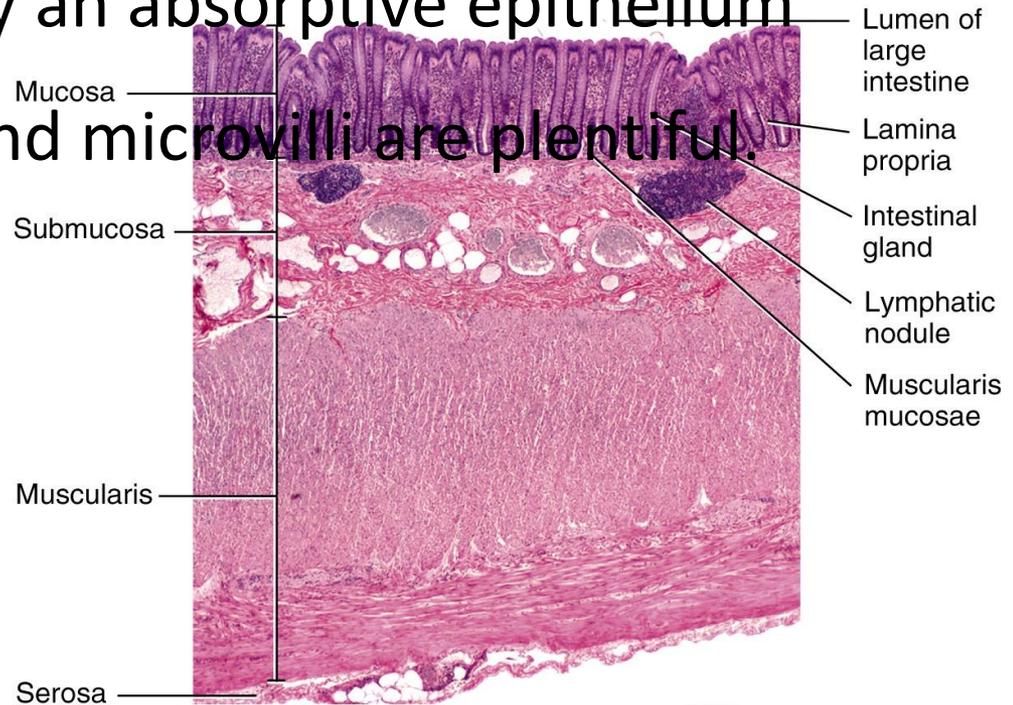
- The mucosa is mostly an absorptive epithelium (mainly for water), and microvilli are plentiful.

- Interspersed goblet cells produce mucous,

but not digestive

Microvilli  
are secreted.

Absorptive cell  
(absorbs water)



LM 315x

(c) Portion of wall of large intestine

# The Large Intestine

- The large intestine is attached to the posterior abdominal wall by its **mesocolon** peritoneal membrane.
- **Teniae coli** are 3 separate longitudinal ribbons of smooth muscle that run the length of the colon.
  - Because the teniae coli is shorter than the intestine, the colon becomes sacculated into small pouches called **haustra** (giving it a segmented appearance).
    - As one haustrum distends, it stimulates muscles to contract, pushing the contents to the next haustrum.

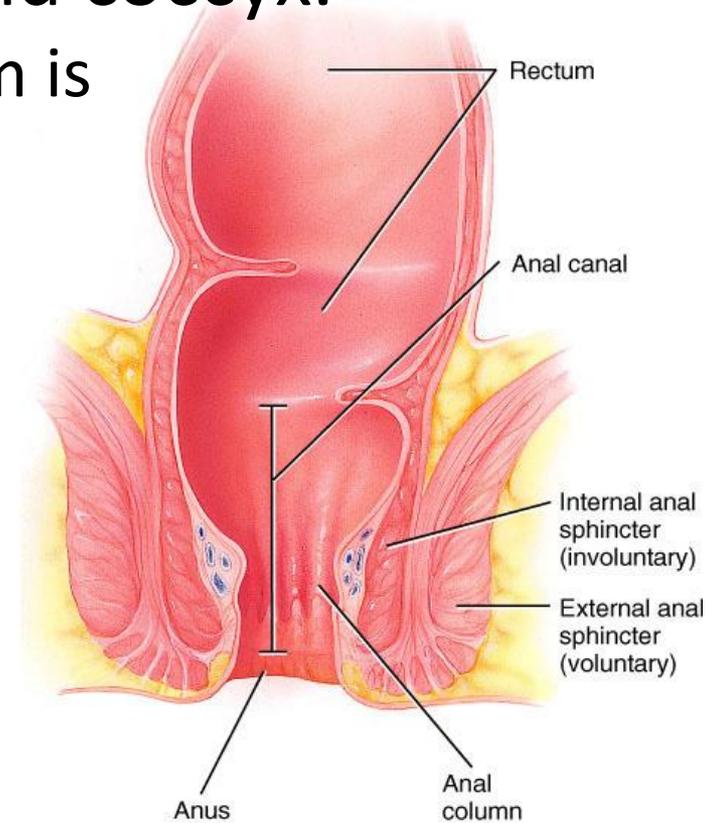
# The Large Intestine

- Hanging inferior to the ileocecal valve is the **cecum**, a small pouch about 2.5 in long.
  - Attached to the cecum is a 3 in coiled tube called the **appendix**.
- The open end of the cecum merges with a long tube called the **colon**, with its various parts.
  - Both the ascending and descending colon are retroperitoneal; the transverse and sigmoid colon are not.

# The Large Intestine

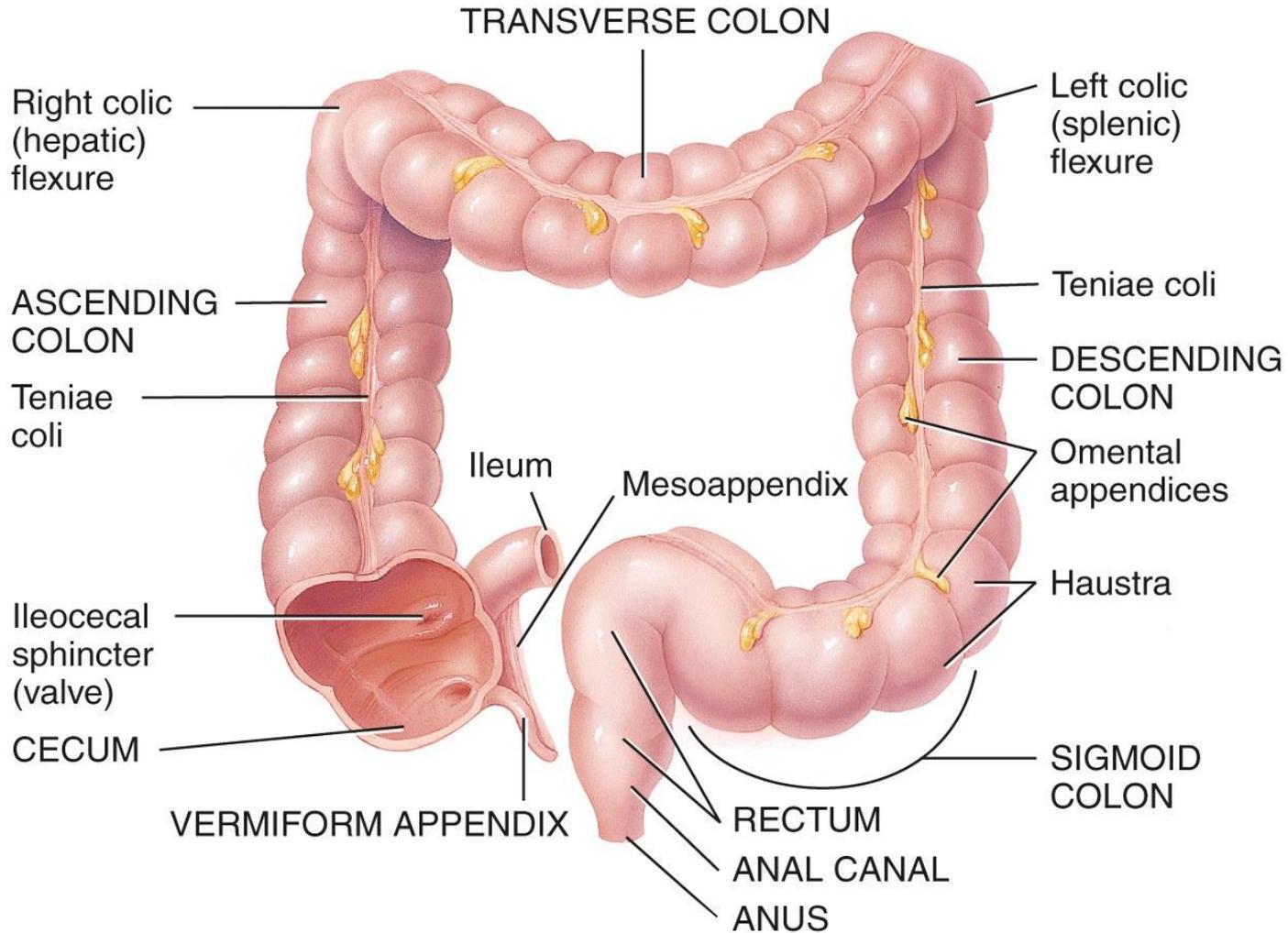
• The **rectum** is the last 8 in of the GI tract and lies anterior to the sacrum and coccyx.

- The terminal 1 in of the rectum is called the **anal canal**. The mucous membrane of the anal canal is arranged in longitudinal folds called anal columns that contain a network of arteries and veins.
- The opening of the anal canal to the exterior is called the **anus**.



(b) Frontal section of anal canal

# The Large Intestine

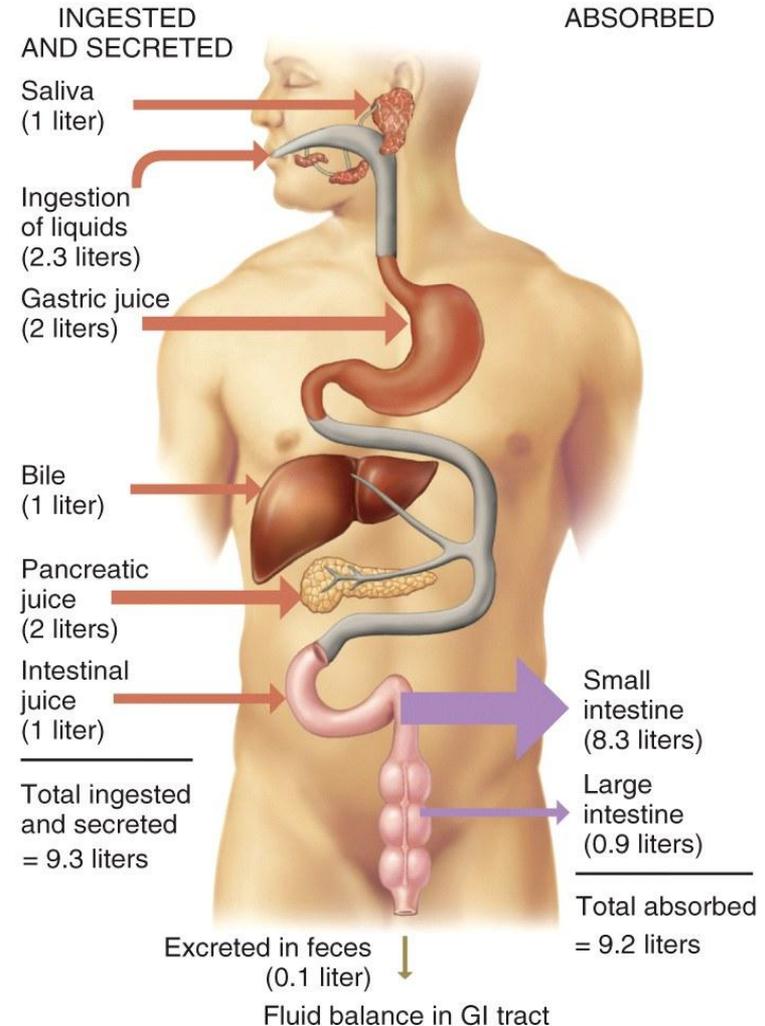


(a) Anterior view of large intestine showing major regions

# The Large Intestine

Including the 2 liters we drink, about 9 liters of fluid enter the small intestine each day.

- The small intestine absorbs about 8 liters; **the remainder passes into the large intestine, where most of the rest of it is also absorbed.**



# The Large Intestine

- Feces are the waste leftover after digesting and absorbing all the nutrients we can from eaten material. Though it is lower in energy than the food it came from, feces may still contain a large amount of energy, often 50% of that of the original food.
  - The characteristic brown coloration comes from a combination of bile and bilirubin.
  - The distinctive odor is due to bacterial action - both aerobic and anaerobic bacteria participate.

# The Large Intestine

● Though the human body consists of about 100 trillion cells, we carry about ten times as many microorganisms in the intestines. Bacteria make up most of the flora in the colon and about 60% of the dry mass of feces.

● As these bacteria digest/ferment left-over food, they secrete beneficial chemicals such as vitamin K, biotin (a B vitamin), and some amino

# The Large Intestine

- The **mechanical events** associated with defecation include localized haustral churning and peristalsis.
- Two autonomic nervous system reflexes that initiate strong bouts of mass peristalsis are the **gastroileal reflex** and the **gastrocolic reflex**.
  - Both reflexes occur with distension of the stomach.



Donna Day/Getty Images

Gastric distension initiates mass peristalsis by the ANS

# The Large Intestine

- 🍌 The **gastroileal reflex** causes relaxation of the ileocecal valve, intensifies peristalsis in the ileum, and forces any chyme into the cecum.
- 🍌 The **gastrocolic reflex** intensifies strong peristaltic waves that begin at about the middle of the transverse colon and quickly drive the contents of the colon into the rectum.
  - This **mass peristalsis** takes place three or four times

# The Large Intestine

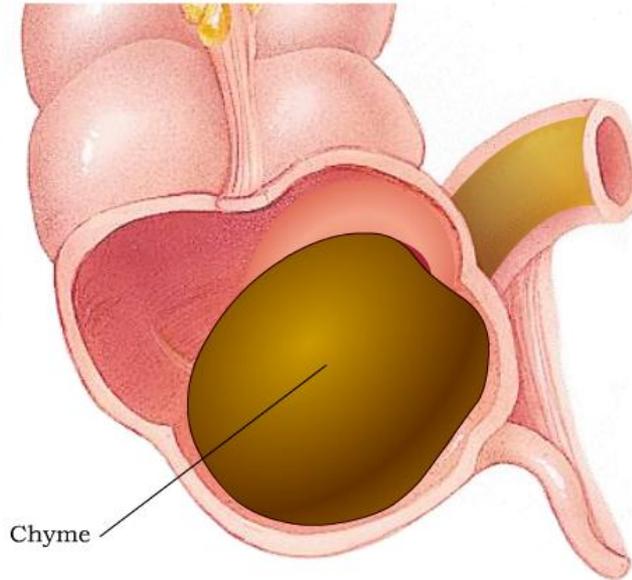
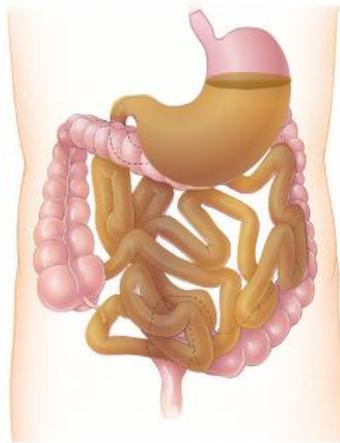
 The **defecation reflex** is activated by stretch receptors stimulated by filling of the rectum.

- The events leading to defecation include:
  - Food in the stomach stimulates mass peristalsis.
  - Food moves through the intestine into the rectum.
  - Rectal pressoreceptors respond to distention and longitudinal muscles shorten the rectum.
  - ANS releases the internal anal sphincter and gives a conscious awareness of distention.
  - Release of external sphincter is under conscious control.

# The Small Intestine

*(Interactions Animation)*

## Mechanical Digestion in the Large Intestine



### **Gastroileal reflex**

- The ileocecal valve is normally closed, so chyme cannot enter the large intestine.
- The gastroileal reflex is triggered when food enters and distends the stomach.
- Migrating motility complexes are intensified by this reflex, forcing chyme through the ileocecal valve into the cecum.

Gastroileal reflex 

**You must be connected to the internet to run this animation**

**TABLE 24.7****Summary of Organs of the Digestive System and Their Functions**

<b>ORGAN</b>	<b>FUNCTION(S)</b>
<b>Tongue</b>	Maneuvers food for mastication, shapes food into a bolus, maneuvers food for deglutition, detects sensations for taste, and initiates digestion of triglycerides.
<b>Salivary glands</b>	Saliva produced by these glands softens, moistens, and dissolves foods; cleanses mouth and teeth; initiates the digestion of starch.
<b>Teeth</b>	Cut, tear, and pulverize food to reduce solids to smaller particles for swallowing.
<b>Pancreas</b>	Pancreatic juice buffers acidic gastric juice in chyme, stops the action of pepsin from the stomach, creates the proper pH for digestion in the small intestine, and participates in the digestion of carbohydrates, proteins, triglycerides, and nucleic acids.
<b>Liver</b>	Produces bile, which is required for the emulsification and absorption of lipids in the small intestine.
<b>Gallbladder</b>	Stores and concentrates bile and releases it into the small intestine.
<b>Mouth</b>	See the functions of the tongue, salivary glands, and teeth, all of which are in the mouth. Additionally, the lips and cheeks keep food between the teeth during mastication, and buccal glands lining the mouth produce saliva.
<b>Pharynx</b>	Receives a bolus from the oral cavity and passes it into the esophagus.
<b>Esophagus</b>	Receives a bolus from the pharynx and moves it into the stomach; this requires relaxation of the upper esophageal sphincter and secretion of mucus.
<b>Stomach</b>	Mixing waves combine saliva, food, and gastric juice, which activates pepsin, initiates protein digestion, kills microbes in food, helps absorb vitamin B <sub>12</sub> , contracts the lower esophageal sphincter, increases stomach motility, relaxes the pyloric sphincter, and moves chyme into the small intestine.
<b>Small intestine</b>	Segmentation mixes chyme with digestive juices; peristalsis propels chyme toward the ileocecal sphincter; digestive secretions from the small intestine, pancreas, and liver complete the digestion of carbohydrates, proteins, lipids, and nucleic acids; circular folds, villi, and microvilli help absorb about 90 percent of digested nutrients.
<b>Large intestine</b>	Haustral churning, peristalsis, and mass peristalsis drive the colonic contents into the rectum; bacteria produce some B vitamins and vitamin K; absorption of some water, ions, and vitamins occurs; defecation.

# End of Chapter 24

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