

## The Digestive System

### Learning Outcome C1

## Learning Outcome C1

- Analyse the functional interrelationships of the structures of the digestive system

## Learning Outcome C1

*Students who have fully met this learning outcome are able to:*

- 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

## Learning Outcome C1

- Describe swallowing and peristalsis
- Identify the pancreas as the source gland for insulin, and describe the function of insulin in maintaining blood sugar levels.
- List at least six major functions of the liver
- Explain the role of bile in the emulsification of fats
- Describe how the small intestine is specialized for chemical and physical digestion and absorption.
- Describe the structure of the villus, including microvilli, and explain the functions of the capillaries and lacteals within it.
- Describe the functions of anaerobic bacteria in the colon
- Demonstrate the correct use of the dissection microscope to examine the various structures of the digestive system.

## Learning Outcome C2

- Describe the components, pH, and digestive actions of salivary, gastric, pancreatic, and intestinal juices

## Student Achievement Indicators

*Students who have fully met this learning outcome are able to:*

- Relate the following digestive enzymes to their glandular sources and describe the digestive reactions they promote:
  - salivary amylase
  - pancreatic amylase
  - proteases (pepsinogen, pepsin, trypsin)
  - lipase
  - peptidase
  - maltase
  - nuclease

## Student Achievement Indicators

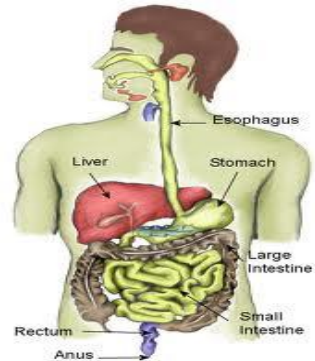
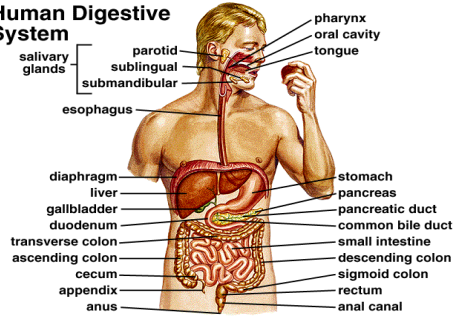
- Describe the role of water as a component of digestive juices
- Describe the role of sodium bicarbonate in pancreatic juice
- Describe the role of hydrochloric acid (HCl) in gastric juice
- Describe the role of mucus in gastric juice
- Describe the importance of the pH level in various regions of the digestive tract

## Introduction to the Digestive System

- Digestion takes place within a tube called the digestive tract, which begins with the mouth and ends with the anus.
- The function of the digestive system is to ingest food, digest the nutrients that can cross plasma membranes, absorb nutrients and eliminate wastes.

### Human Digestive System

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## The Mouth

- Receives food
- Sensory receptors known as taste buds are located on the tongue and are activated by the presence of food.
- Nerve impulses from the tongue travel to the cranial nerves of the brain.
- The tongue is composed of skeletal muscle whose contractions change the shape of the ingested food.
- Helps break down and manipulate food

## The Mouth

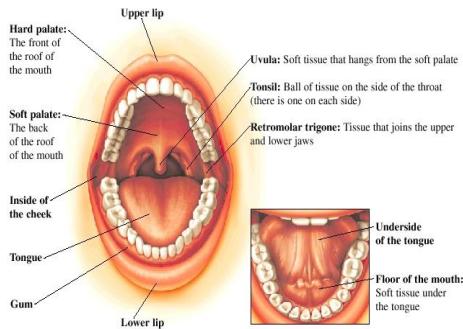
- The roof of the mouth separates the nasal cavities from the oral cavity.
- The roof has two parts :
  - ✓ hard palate (towards the front of the mouth)
  - ✓ soft palate (back of mouth)
- Soft palate is composed entirely of muscle.

## The Mouth

- The soft palate ends in a finger shaped protection called the uvula.
- Three pairs of salivary glands send saliva containing digestive juices to the mouth to help break down ingested food.
- One pair of salivary glands lies at the sides of the face immediate before and in front of the ears.
- These glands swell when a person has mumps.
- These salivary glands have ducts that open on the inner surface of the cheek at the location of the second upper molar.

## The Mouth

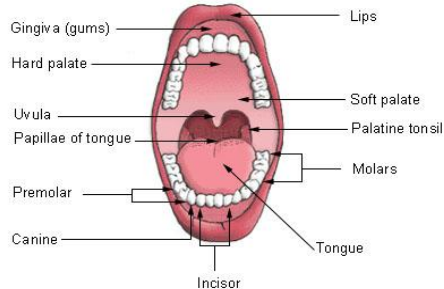
- Another pair of salivary glands lies beneath the tongue and there is another pair on the floor of the oral cavity.
- You can find these openings if you use your tongue to feel for small flaps on the inside of your cheek or under your tongue.
- Saliva contains the digestive enzyme salivary amylase which begins the process of digesting carbohydrates.
- First step in chemical digestion of food.



## The Teeth

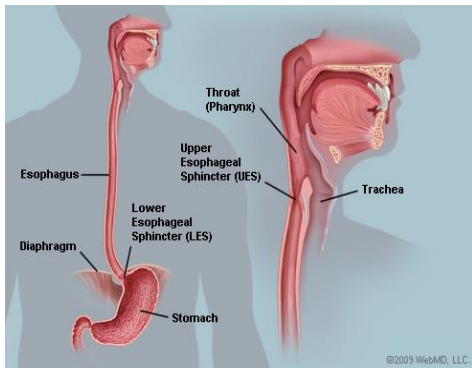
- Allow food to be broken into smaller pieces so it can be swallow.
- Teeth have different structures for different functions
- Canines – ripping and tearing meat
- Molars/pre-molars – grinding food
- Incisors – specialized to eat specific foods (example – apples, carrots)
- The teeth and tongue are the first step in mechanical digestion of food.
- As food leaves the mouth to the pharynx, the process of digestion has begun and the ball of food is now known as a bolus.

### Mouth (Oral Cavity)



## The Pharynx

- Receives food from the mouth and air from the nasal cavities.
- The food passage and air passage cross in the pharynx because the trachea is in front of the esophagus.



## The Pharynx

- Swallowing occurs in the pharynx and is a reflex action that is performed automatically without conscious thought.
- During swallowing food normally enters the esophagus because the air passages are blocked.
- If for some reason the air passages are not blocked, food can go down the wrong way and end up in the trachea or nasal passage.
- Usually during swallowing the soft palate moves back to close off the nasopharynx (entry way to the nasal cavity) and the trachea moves up under the epiglottis to cover the glottis.

## The Pharynx

- The glottis is the opening the larynx
- The up and down movement of the Adam's apple which is the front to the larynx is easy to observe when a person swallows.
- We don't breathe when we swallow.

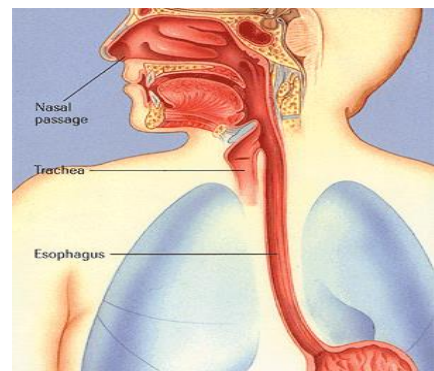
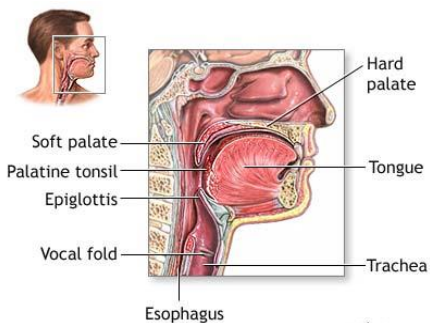
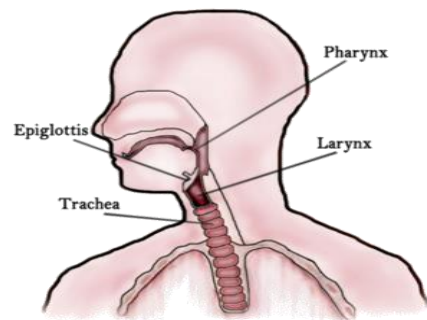


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## The Esophagus

- A muscular tube that passes from the pharynx through the thoracic cavity and diaphragm into the abdominal cavity where it goes to the stomach.
- The esophagus is normally collapsed but it opens and receives the bolus when swallowing occurs.
- Rhythmic contractions called peristalsis push the food along the digestive tract.
- Occasionally peristalsis occurs when there is no food present; this produces a lump in the throat.
- Plays no role in chemical digestion, purpose is mechanical digestion and to move the bolus to the stomach.

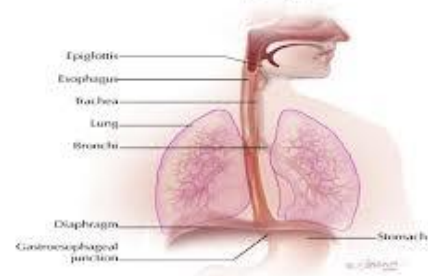
## The Esophagus

- Moves the food bolus from the mouth to the stomach.
- Sphincters are muscles that encircle the esophagus and act as a valve.
- When the sphincters contract the esophagus closes, when the sphincters relax the esophagus opens.
- The entrance of the esophagus to the stomach is also controlled by a sphincter.
- Relaxation of this sphincter allows the bolus to pass to the stomach when contraction prevents the acidic contents of the stomach from entering the esophagus.

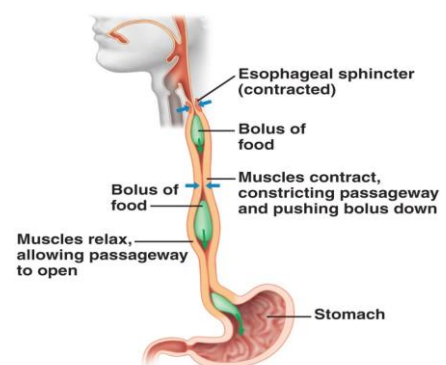
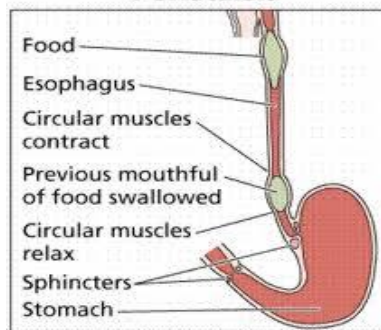
## The Esophagus

- Heartburn occurs when the stomach acid can enter the esophagus
- When vomiting occurs the contraction of abdominal muscle and diaphragm propels the contents of the stomach upwards through the esophagus.

## The Esophagus



## Peristalsis



## The Walls of the Digestive Tract

- Esophagus, digestive tract and abdominal cavity all are composed of the following layers.:

### Mucosa (mucous membrane)

- ✓ A layer of epithelium supported by connective tissue and smooth muscle
- ✓ Lines the lumen (central cavity)
- ✓ Contains glandular epithelial cells that secrete digestive enzymes and goblet cells that secrete mucus

## The Walls of the Digestive Tract

### Submucosa (submucosal layer)

- ✓ A broad band of loose connective tissue that contains blood vessels
- ✓ Lymph nodules called Peyer's Patches are in the submucosa and they help protect humans from diseases (immune function).

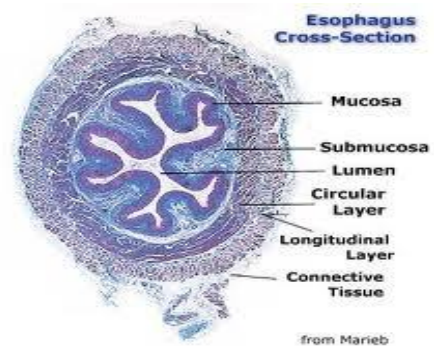
### Muscularis (smooth muscle layer)

- ✓ Two layers of smooth muscle
- ✓ The inner layer is circular and encircles the gut
- ✓ The outer layer is longitudinal and it lies in the same direction as the gut

## The Walls of the Digestive Tract

### Serosa (serous membrane layer)

- ✓ Most of the digestive tract has a serosa which is the outermost layer of squamous epithelium supported by connective tissue.
- ✓ The serosa secretes a serous fluid that keeps the outer surface of the intestines moist so that the organs of the abdominal cavity slide smoothly against one another.
- ✓ The esophagus has an outer layer composed only of loose connective tissue called the adventia.



## The Stomach

- Is a thick-walled, J-shaped organ that lies on the left side of the body beneath the diaphragm.
- The stomach is continuous with the esophagus and the duodenum (small intestine).
- The stomach stores food and aids in digestion
- The walls of the stomach have deep folds which disappear as the stomach fills.
- The muscular walls of the stomach churn food, mixing the food with gastric juice.
- The stomach walls has glands known as gastric glands, these glands produce gastric juice
- Gastric juice contains an enzyme called pepsin, which digests protein plus hydrochloric acid and mucus.

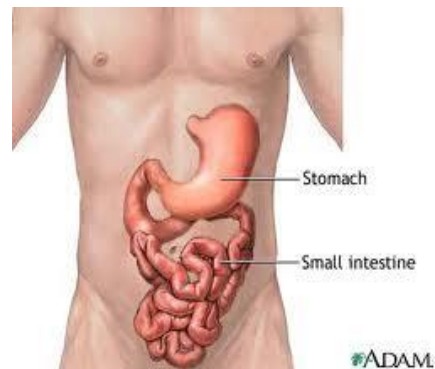
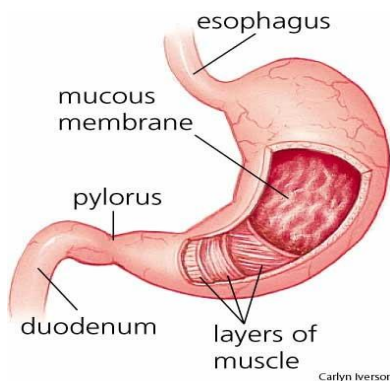
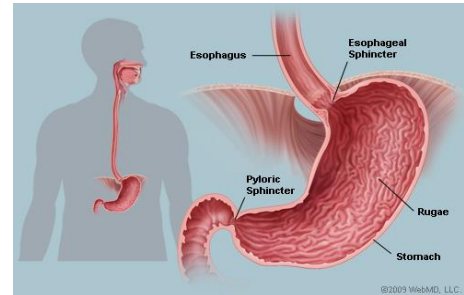
## The Stomach

- HCl causes the stomach to have a pH of 2 and this is why most bacteria in food is killed
- HCl does not digest food; it does break down the connective tissue of meat and activates the enzyme pepsin.
- The walls of the stomach are protected by a thick layer of mucus secreted by goblet cells in the stomach's lining.
- Mucus prevents the stomach lining from the HCl.



## The Stomach

- If this mucus barrier breaks down the HCl will burn the walls of the stomach causing an ulcer.
- Generally ulcers are due to a bacterial infection, this specific species of bacteria impairs the ability of the epithelial cells in the stomach lining to produce mucus.
- Alcohol is absorbed in the stomach but food is not
- Normally the stomach empties in about 2-6 hours
- When food leaves the stomach it is a soupy liquid called chyme.
- Chyme leaves the stomach and enters the small intestine in squirts by way of the sphincter which opens and closes



## Small Intestine

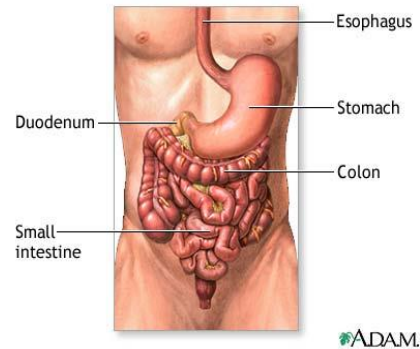
- Named after its small diameter but it very long
- Average person's small intestine measure 3 meters in length
- Large intestine is only about 1.5 m but has a much wider diameter.
- After death the small intestine is about 6 meters due to the relaxation of muscles.
- The first 25cm of the small intestine is called the duodenum.
- Ducts from the liver and pancreas join to form usually one duct that enters the duodenum.

## Small Intestine

- The small intestine receive bile from the liver and pancreatic juices from the pancreas via this duct.
- Bile emulsifies fat (breaks down fat)
- The intestine has a slightly basic pH because the pancreatic juice contains sodium bicarbonate which neutralizes chyme.
- The enzyme in pancreatic juice and enzymes produced by the intestinal wall completes the process of digestion.

## Small Intestine

- Small intestine has small finger like projections called villi which significantly increase surface area for absorption.
- Villi give the intestinal wall a soft, velvety appearance
- Each villus has thousands of extensions called microvilli.
- Microvilli contain intestinal enzymes
- Sugars and amino acids pass through the mucosa and enter a blood vessel



## The Large Intestine

- Includes the cecum, the colon, the rectum and the anal canal
- Larger in diameter than the small intestine but shorter in length
- Absorbs water, salts and some vitamins
- Also stores indigestible material until it is eliminated at the anus.
- The cecum, which lies below the junction with the small intestine is the blind end of the large intestine.
- The cecum has a small projection called the appendix

## The Large Intestine

- The appendix plays a role in fighting infections
- This organ is subject to inflammation, a condition called appendicitis
- If inflamed the appendix should be removed before the fluid content rises enough for it to burst.
- A burst appendix can cause peritonitis which is a generalized infection of the abdominal cavity and can lead to death.

## The Large Intestine

- The colon has several parts:
  - descending colon
  - ascending colon
  - transverse colon
  - sigmoid colon
- The ascending colon goes up the right side of the body to the liver.
- The transverse colon crosses the abdominal cavity just before the liver and stomach
- The descending colon passes down the left side of the body
- The sigmoid colon enters the rectum and is the last 20 cm of the large intestine
- The rectum opens at the anus where defecation occurs

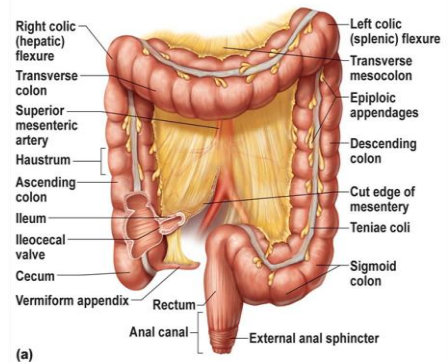
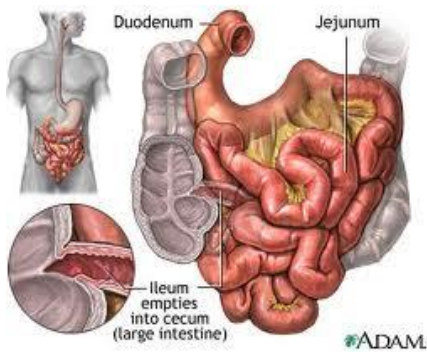
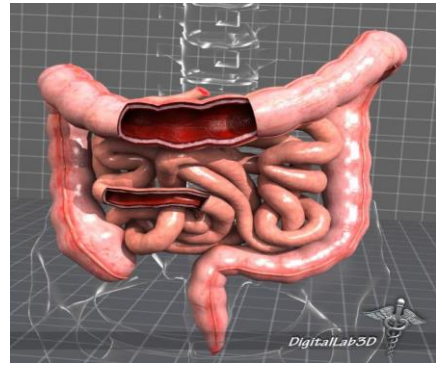
## The Large Intestine

- When feces are forced into the rectum by peristalsis, a defecation reflex occurs.
- The stretching of the rectal walls initiates nerve impulses in the spinal cord and causes the contraction of the rectal muscles and the relaxation of the sphincter.
- Feces are three quarters water one quarter solid.
- Bacteria, fiber and other indigestible materials are in solid portion.
- The brown color of feces is due to bilirubin



## The Large Intestine

- Bilirubin is a bile pigment that has an orange-yellow color and is produced by the liver.
- Odor is due to the breakdown of materials as bacteria work on the non-digested remains
- The bacterial action also causes gas
- The bacteria in the large intestine also produce some vitamins and other molecules that can be absorbed by our bodies.



## Accessory Organ in the Digestive System

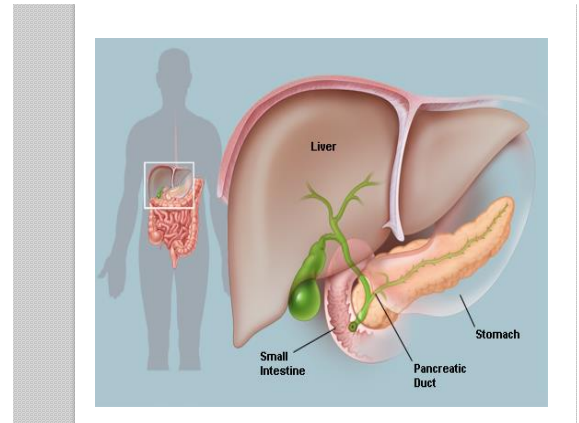
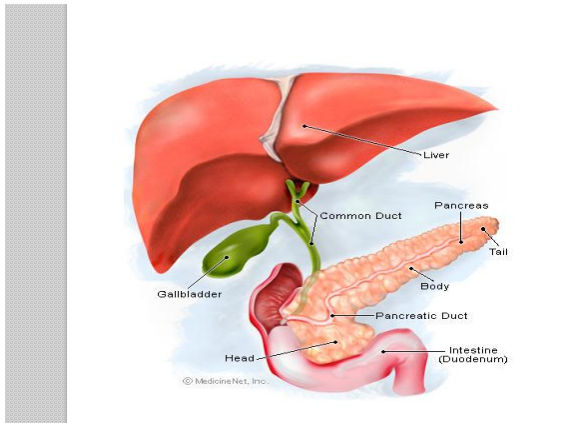
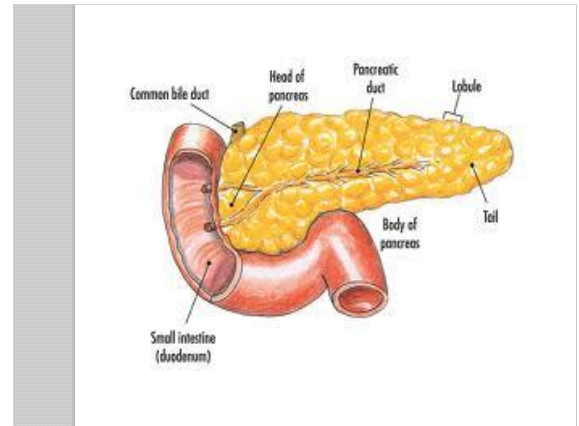
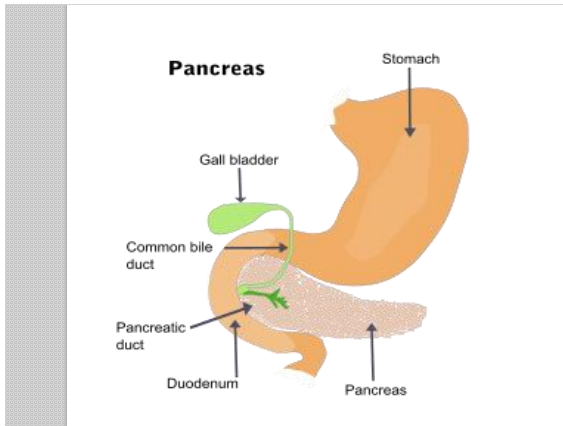
- There are three accessory organs; the pancreas, liver and gallbladder.

### The Pancreas

- Lies deep in the abdominal cavity resting on the back abdominal wall.
- It is an elongated flat organ that has both an endocrine and exocrine function
- As an endocrine gland it secretes insulin and glucagon, which are hormones that help keep the blood glucose levels within normal limits.
- Its exocrine function involves the production of pancreatic juice which contains sodium bicarbonate and digestive enzymes for all type of food.

## Accessory Organs of the Digestive System

- Sodium bicarbonate neutralizes chyme.
- Pepsin in the stomach acts best in an acid pH, pancreatic enzymes require a slightly basic pH to be activated.
- Pancreatic amylase digests starch, trypsin, digests proteins and lipases digest fat



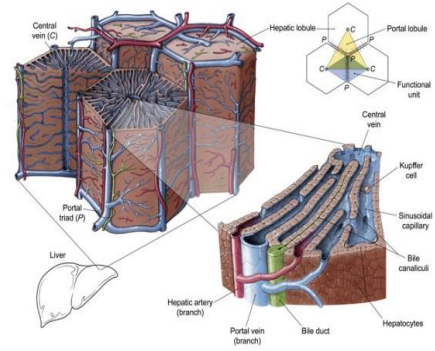
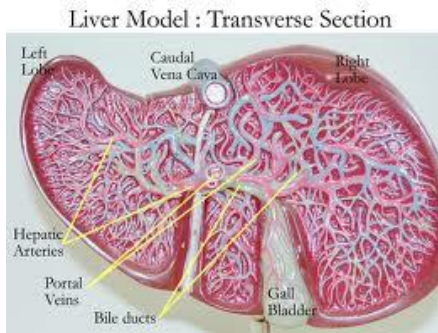
## Accessory Organs of the Digestive System

### The Liver

- Largest organ in the body
- Lies mainly in the upper right section of the abdominal cavity, under the diaphragm
- The liver has two main lobes; the right lobe and the smaller left lobe
- The left lobe crosses the body's midline and lies above the stomach
- The liver contains approximately 100 000 lobules that serve as the structural functional units of the liver.

## Accessory Organs of the Digestive System

- Three structures are located between each lobule:
  - ✓ A branch of the hepatic artery that bring oxygenated blood to the liver
  - ✓ The branch of the hepatic portal vein that transports nutrients from the intestine
  - ✓ A bile duct that takes bile away from the liver
- The central veins of the lobules enter the hepatic veins



### Accessory Organs of the Digestive System

- The liver acts as a gatekeeper to the blood
- As the blood from the intestines passes through the liver, it removes poisonous substances and works to keep the contents of the blood constant.
- It also remove and stores iron and the fat-soluble vitamins A,D, E and K.
- The livers make the plasma proteins from amino acid and lipids form fatty acids
- It also produces cholesterol and helps regulate the quantity of it in the blood.
- The liver maintains the blood glucose level about 0.1%
- Any excess glucose that is present tin the hepatic portal vein is removed and store by the liver as glycogen.

### Accessory Organs of the Digestive System

- Between eating, glycogen is broken down to glucose, which enters the hepatic vein, this way the blood glucose levels can remain constant.
- If the supply of glycogen is depleted the liver will convert glycerol from fats and amino acids to glucose molecules
- The conversion of amino acids to glucose involves the removal of the amine group.
- By a complex metabolic pathway, the liver then combines ammonia with carbon dioxide to form urea.
- Urea is the usual nitrogenous waste product form amino acid breakdown in humans
- After its formation in the liver urea is excreted by the kidneys

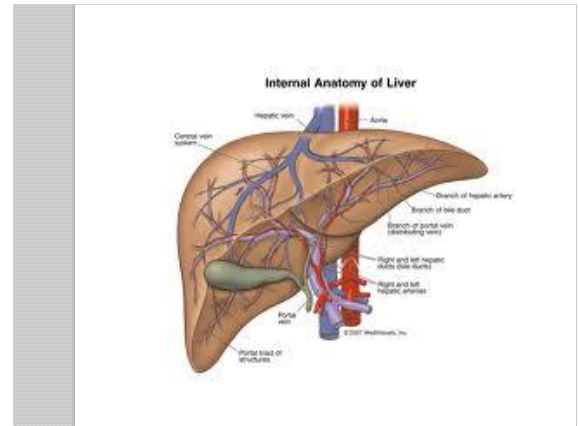
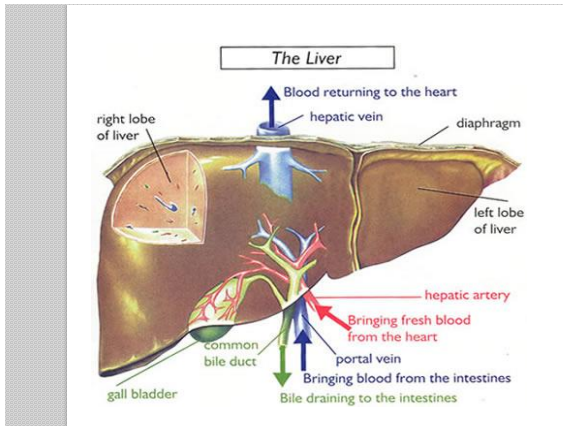
### Accessory Organs of the Digestive System

- The liver produces bile, which his stored in the gallbladder.
- Bile has yellowish color because it contains the pigment bilirubin
- This pigment is formed from the breakdown of hemoglobin, the red pigment of red blood cells.
- Bile also contains bile salts which are derived from cholesterol and emulsifies fats in the small intestine.
- When fat is emulsified breaks up droplets providing a much larger surface area which can be acted upon by the digestive enzyme form the pancreas.

### Accessory Organs of the Digestive System

#### Functions of the Liver

1. Detoxifies blood by removing and metabolizing poisonous substances
2. Stores iron and the fat-soluble vitamins A, D, E and K
3. Makes plasma proteins such as albumin and fibrinogen from amino acids
4. Stores glucose as glycogen after eating, and breaks down glycogen to glucose to maintain glucose concentrations of blood between eating periods.
5. Produces urea form the breakdown of amino acids
6. Removes bilirubin, a breakdown product of hemoglobin from the blood and excretes it in bile
7. Produces lipids from fatty acids, produces and helps regulate blood cholesterol levels , converting some to bile salts.



## Accessory Organs of the Digestive System

### The Gallbladder

- Is a pear-shaped muscular sac attached to the surface of the liver
- About 1 000 mL of bile are produced by the liver each day, and any excess is stored in the gallbladder.
- Bile emulsifies fat
- Water is reabsorbed by the gallbladder so that bile becomes a thick, mucus-like material.
- When needed, bile leaves the gallbladder and proceeds to the duodenum via the common bile duct.
- The cholesterol content of bile can come out of solution and form crystals.
- If the crystals grow in size, they form gallstones.
- The passage of the stones from the gallbladder may block the common bile duct and causes pain.