



Digestive system

After studying these lectures, you should be able to

1. Understand the main functions of the gastrointestinal tract.
2. Knew the parts of the oral cavity and their functions.
3. Understand the secretions of each part of gastrointestinal tract and their functions.
4. Explain the regulation mechanism of that secretion.

The digestive system provides the body with nutrients and water as well as various vitamins and minerals. it is consists of the alimentary canal(= gastro- intestinal tract or **(GIT)**).

The GastroIntestinal Tract (GIT) (alimentary canal) is a coiled hollow tube which passes right through the body and opened to the outside at both ends(mouth and anus)

The digested food along with water and electrolytes will be absorbed by the intestinal mucosa to enter the blood or lymph and will be utilized either to build up the body structure or to provide energy.

The **undigested food** will pass at the lower end (the anal canal).

The GIT is divided into successive compartments starting with:

1- Oral cavity

2- Pharynx.

3- Esophagus

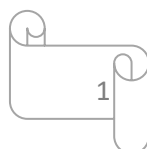
4- Stomach.

5- Small intestine. - **Duodenum**

- **Jejunum**

- **Ileum**

6- large intestine -**Caecum** -**Ascending colon** -**Transverse colon** -**Descending colon** -**Appendex** -**Rectum and Anus**

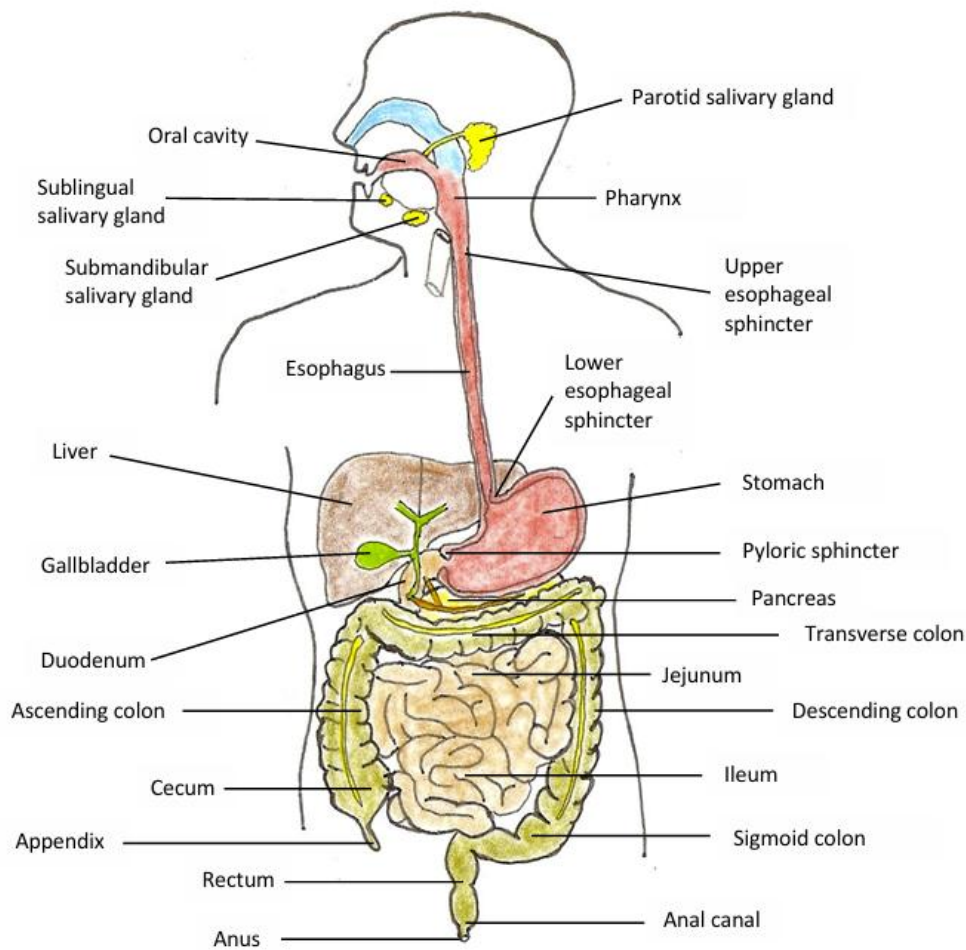


The accessory structures and organs are:

1- Pancreas. 2-Gallbladder 3- Liver 4- Salivary glands

5- mucous glands 6- tongue 7- teeth

the nervous and circulatory systems are also important in digestion, as are the bacteria that live in the gut.



The six Basic Digestive Processes :

- 1. Ingestion** – taking food or drink into the mouth or oral cavity.
- 2. Propulsion** – movement through alimentary canal. This includes movement of tongue and cheeks and involves contraction of the muscles of swallowing,

3. Mechanical Digestion – the Physical breakdown of food (chewing, churning), mechanical processing and moistening of foods. This is most often required prior to chemical digestion.

4. Chemical Digestion – the Enzymatic breakdown of food (from complex to simple building blocks) by the use of enzymes made by the body. This involves the breaking of chemical bonds.

5. Absorption – the transportation of digested products from lumen of G.I. tract across an epithelial lining and into the blood and lymph vessels, which are considered to be inside the body.

6. Defecation – the Elimination of indigestible material and waste products from body (feces).

Oral Cavity

There are 3 main structures in the oral cavity these are:

- 1- **Teeth.**
- 2- **Tongue.**
- 3- **Salivary glands.**

TEETH: they are important for the process of mastication (chewing).

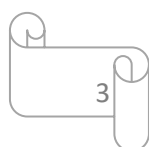
Mastication is vital because

1-the process of mastication will result in the **opening or destruction of the cellulose covering of most fruits and raw vegetables** since most fruits and vegetables have indigestible cellulose membranes that must be broken down before the food can be utilized. Cooking and steam also breaks the cellulose covering.

2-**chewing aids in the digestion of food because the digestive enzymes** act only on the surface of the food particles. Therefore **chewing** will help in **digestion by cutting the large food particles into smaller**

3-with proper mastication the **bolus formed** will be reduced into a **paste form**. This will prevent damage of the mucus membrane of the esophagus, stomach and small intestine, and will facilitate the movement of food in GIT to the succeeding segment of the gut.

After understanding the importance of chewing one can understand why people without teeth or dentures will have difficulty in swallowing dry food and they often complain of indigestion in addition they may complain of painful contraction of the esophagus upon swallowing **because the food bolus hasn't been turned into a paste.**



TONGUE: this is an extremely mobile mass of striated muscle covered with a mucus membrane. **It helps greatly in mastication and swallowing.**

SALIVARY GLANDS:

There are 3 chief paired salivary glands these are:

- 1- **Parotid.**
- 2- **Submandibular (submaxillary).**
- 3- **Sublingual.**

In addition there are many small salivary glands scattered in the lining of the oral cavity and are named according to their position.

- Labial** ----- **lips**
- Buccal** ----- **cheeks**
- Palatal** ----- **palate**
- Lingual** ----- **lingual tonsils**

There are 3 types of **secretory cells** in the salivary glands.

- 1- **Serous cells:** these cells secrete the serous secretion that provide the enzyme **ptyalin** (salivary **α -amylase**) for the digestion of **starch**, and the secretion of these cells is thin and watery.
- 2- **Mucus cells:** these cells secrete mucus secretion which contains **mucin** and the secretion is viscid (thick).
- 3- **Seromucinous cells.**

The daily secretion of saliva is about 1-1.5 liter per day. A large proportion of this 24 hours volume is secreted at meal time. Ordinary mixed saliva contains:

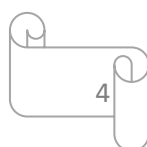
- 1- **Water 99.5%.**
- 2- **Solids 0.5%. (Protein mucin.**

Ptyalin or α -amylase for the digestion of starch.

Lingual lipase hydrolysis of triglycerides

And different ANIONS such as chloride, phosphate, bicarbonate, fluoride and CATIONS such as calcium, sodium and potassium.

Parotid gland is the largest of the three major pairs of salivary glands. It is a serous gland and located anteriorly and inferiorly to the ear. The parotids produce about **25% of saliva** and it is a **serous (watery) secretion** which is also rich in proteins, **enzyme α -amylase** start to breakdown complex carbohydrates.



Submandibular gland is a serous gland, located inferiorly to the mandible. This gland secretes **70% of the saliva** in the mouth. These glands produce a more viscid (thick) secretion, rich in **mucin** and with a smaller amount of protein. **Mucin is a glycoprotein that acts as a lubricant.**

Sublingual gland is the smallest of the three, is a mucus gland on either side of the tongue. they produce approximately **5% of the saliva** and their secretions are very sticky due to the large **concentration of mucin.** The main functions are to provide buffers and lubrication.

Pharynx The throat is the pharynx, a funnel-shaped tube posterior to the mouth. The pharynx connects the nasal cavity and mouth to the esophagus and larynx (voice box) in the neck. The region of the throat forming the posterior wall of the mouth is the oropharynx.

The esophagus is a muscular tube of approximately 25 cm. long and a little less than 2.5 cm in diameter. It extends from the pharynx to the stomach, going through an opening in the diaphragm called the esophageal hiatus. **The esophagus functions primarily to transport the bolus from the mouth to the stomach.**

Esophageal secretion: Mucus only, in the upper esophagus to prevent excoriation and in the lower esophagus to protect from acid.

Stomach The stomach is a J shaped expanded bag, located just left of the midline between the esophagus and small intestine.

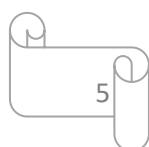
It is divided into **four main regions** and has **two borders** called the **greater and lesser curvatures.**

cardiac sphincter. The **first section is the cardia** which surrounds the cardiac orifice where the esophagus enters the stomach.

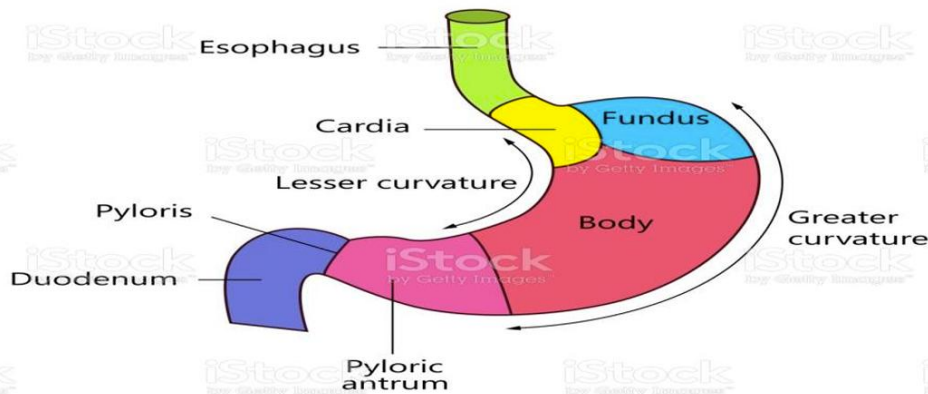
The **fundus is the superior**, dilated portion of the stomach that has contact with the left dome of the diaphragm.

The **body** is the largest section between the fundus and the curved portion of the J. This is where most gastric glands are located and where most mixing of the food occurs.

pyloric sphincter Finally the pylorus is the curved base of the stomach.



Stomach



The stomach can hold up to 1.5 Liters of materials. **The functions of the stomach include:** The short-term storage of ingested food. Mechanical breakdown of food by churning and mixing motions. Chemical digestion of proteins by acids and enzymes. Stomach acid kills bugs and germs. Some absorption of substances such as alcohol.

The stomach contains gastric juice, which contains mostly:

- **Hydrochloric acid** — an acid that is strong enough to dissolve razor blades.
- **Pepsin** — an enzyme that breaks down proteins.

Both of these chemicals could potentially harm the lining of the stomach, so it produces a slimy layer to protect itself from damage. In the stomach, **peristalsis** continues, which helps to mix the food with the gastric juices.

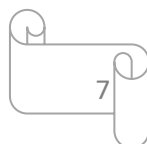
After 1–2 hours in the stomach, the food is a **thick paste**, referred to as **chyme**. It leaves the stomach through the **pyloric sphincter** at the bottom of the stomach. As digestion proceeds more vigorous mixing wave start at **body** of stomach and intensify as they reach pylorus. **At pylorus**, each wave periodically pushes little amount of **chyme into small intestine** thorough **pyloric sphincter**. This process is called **gastric emptying**. **Starch is digested by salivary amylase when food is in fundus.** When food moves into **body**, **mixing of chyme with gastric juices starts.** The **salivary amylase is inactivated and lingual lipase is activated.** This **stops digestion of starch and starts digestion of triglycerides** into **diglycerides and fatty acids**. • Parietal cell present in walls of stomach **start secretion of a strong acid HCl**, which kills microbes and denature

proteins. HCl also **stimulate secretion of hormones** which further **increases flow of bile and pancreatic juices**

Mechanical degradation and liquification of the food, the stomach mixes the food with gastric secretion until it forms a semi-fluid mixture called **chyme**.

PEPSIN: secreted as pepsinogen and activated by HCL

Enzymatic digestion of proteins also begins in the stomach. The chief cells in • stomach secrete proteolytic (protein-digesting) enzyme in the stomach called **pepsin**. Pepsin breaks peptide bonds to breaking down a large protein chain smaller peptide fragments. **Pepsin is most effective in the very acidic environment of the stomach (pH 2)**; it becomes inactive at a higher pH.





Physiology II

Lecturer : Esraa Mohammed

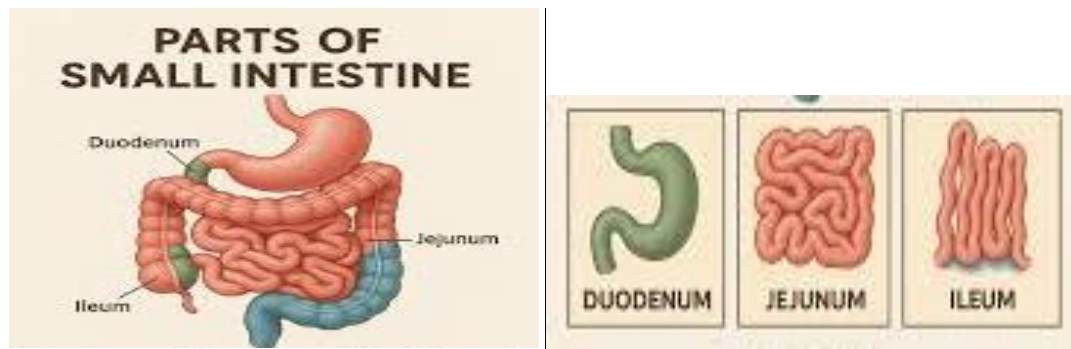
Lec. 2

Digestive system

The lower gastrointestinal tract:

Small intestine

The small intestine is the part of the gastrointestinal tract following the stomach, and is where much of the **digestion and absorption** of food takes place. The entire small intestine measures about 6.5 metres. The small intestine consists of three sections.



- ❖ **Duodenum:** It is approximately 25 cm long. The duodenum is largely responsible for the breakdown of food in the small intestine, using enzymes. The duodenum also regulates the rate of emptying of the stomach.
- ❖ **Jejunum:** The section of the small intestine is beyond the duodenum. The inner surface of the jejunum covered in Tiny finger-like projections called **villi**, which increase the surface area to absorb nutrients from the gut contents.
- ❖ **Ileum:** The ileum is the final and longest segment of the small intestine. It is specifically responsible for the absorption of vitamin B12 and the reabsorption of conjugated bile salts. The ileum extends from the jejunum to the ileocecal valve, which empties into the colon.

In the small intestine, the chyme mixes with enzymes from the pancreas, bile from the liver, and intestinal juice

Bile \ produced by the liver and stored in the gall bladder, it helps break down fats.

Pancreatic juice \ contains a cocktail of enzymes, including trypsinogen, elastase and amylase.

Intestinal juice \ **digestive enzymes** produced by the inner wall of the small intestine help in **the breakdown of food**

These enzymes will digest the food as they come in contact with the microvilli prior to the absorption of the end products of digestion.

The enzymes are-:

1-Peptidases: there are several peptidases which act on peptides → amino acids.

2-Disaccharidases: there are

-**Maltase** acts on maltose and gives two molecules of glucose.

- **Sucrase** acts on sucrose to give glucose + fructose.

-**Lactase** acts on lactose to give glucose + galactose.

3-Lipase acts on triglycerides → glycerol + fatty acids.

4-Nucleases: will breakdown nucleic acids into pentoses and purine + pyrimidine bases.

The food continues its journey through the remaining parts of the small intestine, the jejunum and ileum — being gradually digested as it goes. Once it is fully broken down, it is absorbed into the blood.

Large intestine:

The large intestine consists of **four regions: cecum, colon, rectum and anus.** The large intestine is wider and shorter than the small intestine (approximately 1.5 metres in length) and has a smooth inner wall. Many microbes) bacteria like **Bacteroides, Lactobacillus acidophilus,**

Escherichia coli, and Klebsiella) in the large intestine help in the digestion

Functions of Large Intestine

- 1-Reabsorb water and compact feces .
- 2-Absorb vitamins and electrolytes and helps make Vitamin K.
- 3-Stores fecal matter .

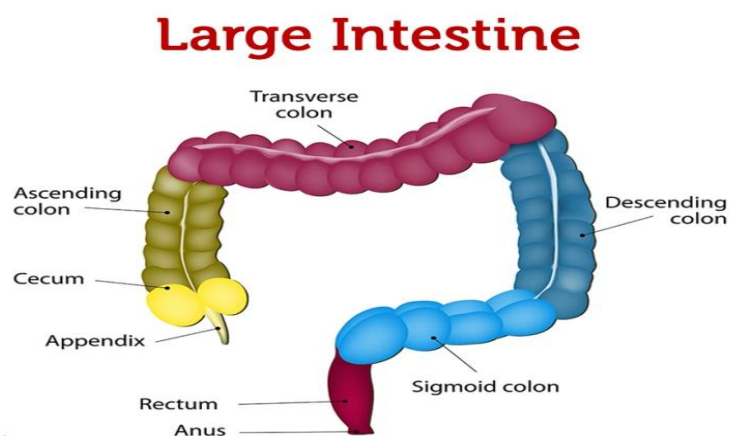
Parts

The Cecum is the first part of the large intestine and so receives the contents from the ileum and so contains the **Ileocecal valve**. It is like a blind-ended pouch and the vermiform **appendix** (the appendix is connected to the cecum). attaches to its terminal end.

From the cecum, the **Colon** begins, it is composed of 4 regions: **Ascending Colon** ,**Transverse Colon**, **Descending Colon** and **Sigmoid Colon**. The food travels across the abdomen in the transverse colon, goes back down the other side of the body in the descending colon, and then through the sigmoid colon.

rectum - the lower part of the large intestine, where feces are stored before they are excreted .

anus - the opening at the end of the digestive system from which feces (waste) exits the body.



Digestion and Absorption

In the mouth and esophagus **no significant absorption** of food stuff occurs, although some drugs are absorbed through the oral mucus membrane such as trinitrin, morphine and steroids.

In the stomach **absorption is very limited** to a small amount of water, alcohol and aspirin. The stomach has no villi and has tight junctions so little absorption.

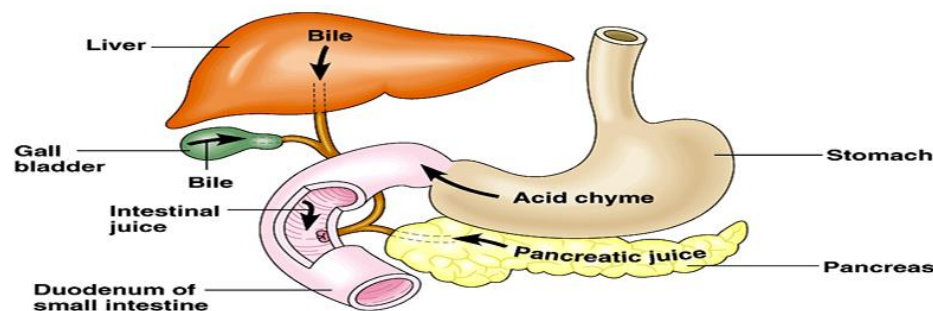
In the intestine **major site of absorption** is the intestine and particularly the small intestine. In the small intestine there will be almost complete absorption of the digestive products. In the colon absorption is confined to water and some electrolytes such as Na^+ , K^+ , Cl^- and glucose; however it cannot absorb protein, fat?? Or calcium.

The total quantity of fluids presented to the intestine each day is about 9 liters and is equal to ingested food(2liters)

Accessories

pancreas - an enzyme-producing gland located below the stomach and above the intestines. Enzymes from the pancreas help in the digestion of carbohydrates, fats and proteins in the small intestine .

gall bladder - a small, sac-like organ located by the duodenum. It stores and releases bile (a digestive chemical which is produced in the liver) into the small intestine.



liver - a large organ located above and in front of the stomach. It filters toxins from the blood, and makes bile (which breaks down fats) and some blood proteins .

bile - a digestive chemical that is produced in the liver, stored in the gall bladder, and secreted into the small intestine.



Physiology II

Lectuerer : Esraa Mohammed

Lec. 3 & 4

Urinary System

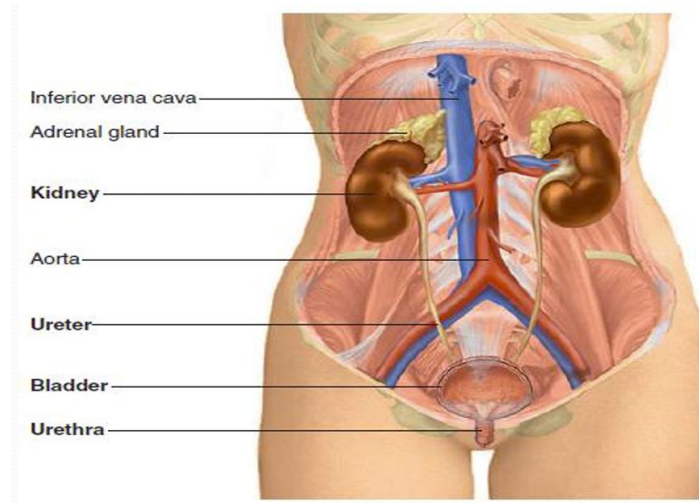
Introduction:

During the nutrient metabolism carried out by cells during physiological processes, **protein catabolism** leads to the production of **toxic nitrogenous wastes** such as ammonia and urea, in addition to the **accumulation** of large amounts of sodium, sulfate, phosphate and hydrogen ions. Therefore, these toxic substances accumulated in the body must be eliminated.

Urinary System: It is the group of organs that manufacture, store and excrete urine.

Urinary System consists of

- 1- The two kidneys.
- 2- Ureters.
- 3- Bladder.
- 4- Urethra.
- 5- Blood supply



function of the urinary system :



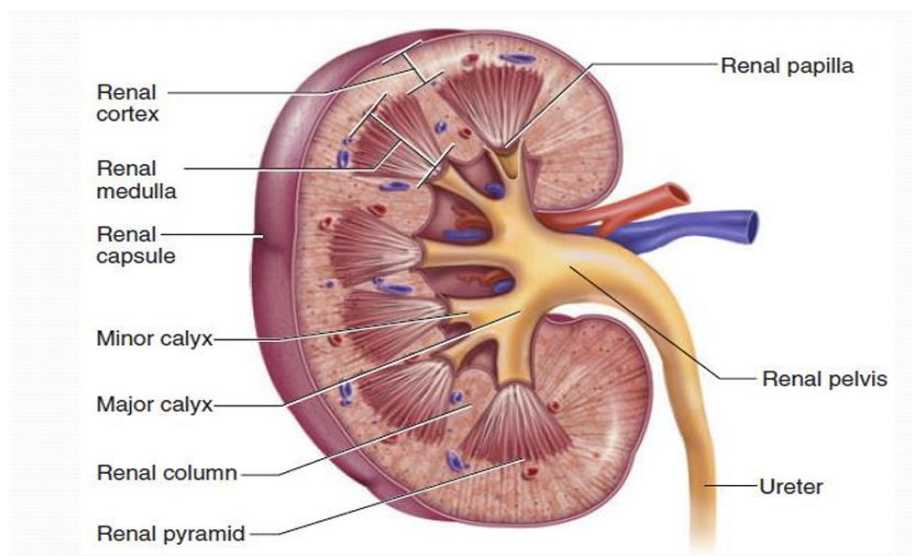
1. Maintain the stability of the natural state of the body by controlling the volume .
2. Components and pressure of blood .
3. removing and restoring certain amounts of water and salts.

The kidney

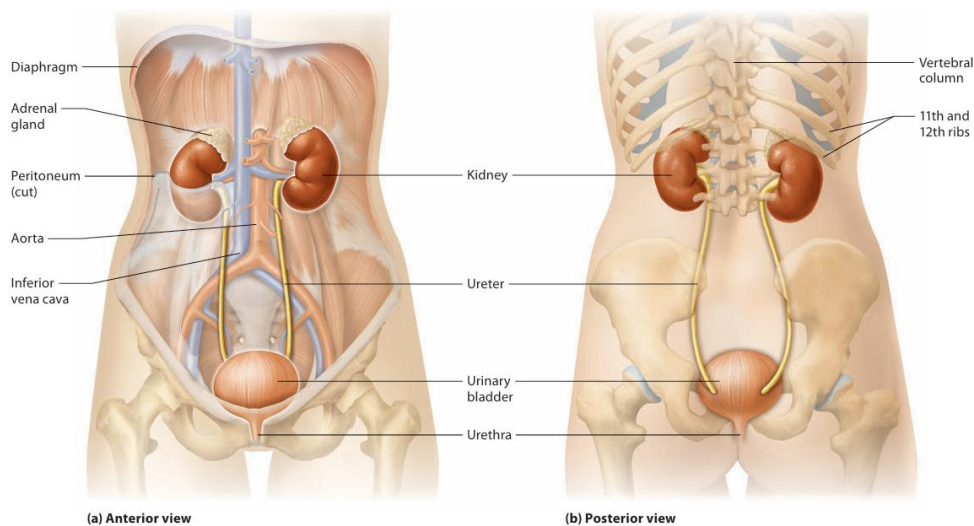
✚ is the main the **excretory organs** in human, that participate in the removal of these nitrogenous wastes, water and salts in excess of the body's need, and some heat .

✚ The kidneys are two **dark red glands** located in **the dorsal side** of the body on both sides of the spine, in the **back part** of the abdominal cavity .

- The **left kidney is higher**, in position than the right kidney .
- its **shape** like to a bean .
- the kidney has a **convex outer surface** and a **concave inner surface** known as the **navel of the kidney** .



- connected each kidney from the **navel side to two blood vessels**, one of which branches from **the aorta**, and is known as **the renal artery** that enters the kidney and branches inside it,
- the other is **The renal vein**, in which the blood from the kidney returns after separating the excretory substances from it, to then flow into the **inferior vena cava**, which in turn empties into the heart .
- ✚ Each kidney is surrounded by a **fatty layer** that forms a covering around the kidney that protects it from shocks and helps to stabilize it in place
- ✚ The **ureter** exits from the kidney to the **urinary bladder**, and the **urethra**, which carries urine out of the body.



Function of Kidney :

- **Removal of metabolic wastes.** the Kidneys filter the blood, removing metabolic wastes. These wastes are eliminated from the body via the urine.
- **Regulation of fluid and electrolyte balance.** The kidneys regulate blood solute concentration, or osmolarity, by conserving or eliminating water and electrolytes such as sodium, potassium, and calcium ions.

- **Regulation of acid-base balance.** The kidneys assist in the long-term regulation of blood pH by conserving or eliminating hydrogen (H⁺) and bicarbonate (HCO₃⁻) ions.
- **Maintenance of blood pressure.** The kidneys directly influence systemic blood pressure through their control of blood volume. Additionally, they secrete an enzyme that influences both blood volume
- **Regulation of erythropoiesis.** The kidneys regulate red blood cell production in the bone marrow by releasing the hormone erythropoietin
- **Performing other metabolic functions.** The kidneys play many important metabolic roles, including detoxifying substances in the blood, activating vitamin D, and making new glucose through the process of gluconeogenesis. They degrade several polypeptide hormones, including insulin, glucagon, and parathyroid hormone.

Structure of kidney

- ☒ A frontal section of the kidney reveals **the three distinct regions** of this organ: the outermost **renal cortex**, the middle **renal medulla** and the inner **renal pelvis**.
- ☒ Together, the **renal cortex and the renal medulla** make up the urine-forming portion of the kidney. The **renal pelvis** and associated structures drain urine that the cortex and medulla have formed.
- ☒ Within the renal medulla we also find **cone-shaped renal pyramids** (or medullary pyramids), which are separated from one another by a renal column on each side.

The Nephron

The functional units of the kidney are nephrons. Each kidney contains approximately 1 million nephrons. Each nephron consists of:

I. **The renal corpuscle** consists of a compact of interconnected capillary , called the **glomerulus or glomerular capillaries**, surrounded by a balloon-like hollow capsule (**Bowman's capsule**). Blood is ultrafiltered across the glomerular capillaries into Bowman's space, which is the first step in urine formation.

The Nephron

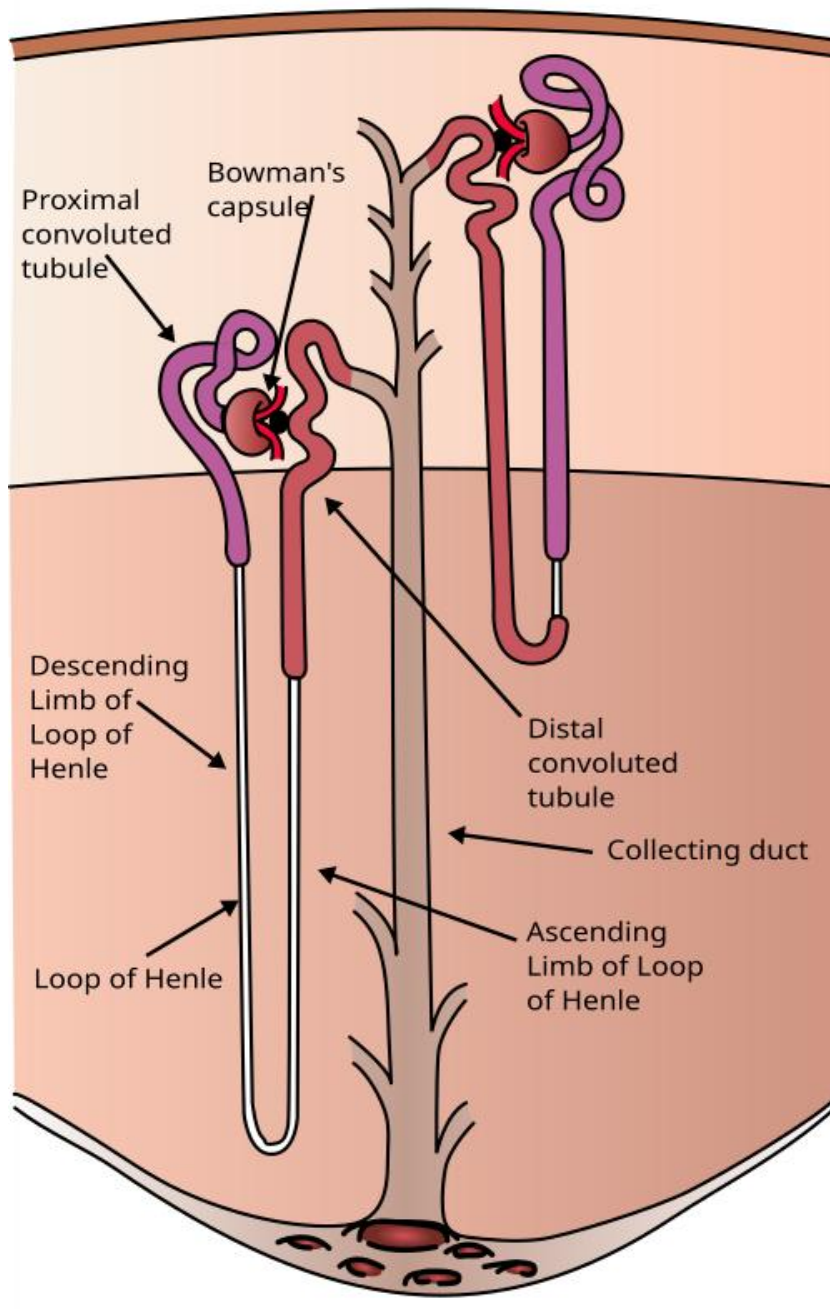
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II. **Renal tubule** ; a long tubule in which the filtered fluid is converted into urine on its way to the pelvis of the kidney , the **renal tubule consist of:**

1. the proximal convoluted tubule which lies in renal cortex. It drains Bowman's capsule, and consists of a coiled segment—the proximal convoluted tubule—followed by a straight segment—the proximal straight tubule—which descends toward the medulla

2.the loop of Henle, it start at the end of proximal tubule and dips into the renal medulla to varying depths. Each loop consists of a descending and an ascending limb.



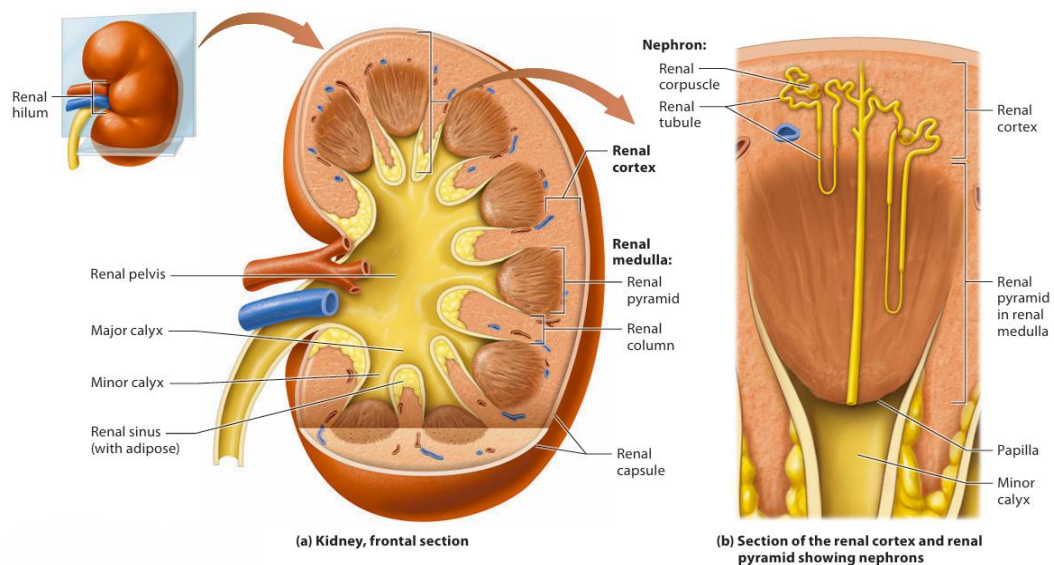
3. the distal convoluted tubule, the thick ascending limb rises back into the cortex to form the distal tubule that passes directly between the afferent and efferent arterioles, as they enter and exit that renal corpuscle

4.the cortical collecting tubule, which lead to the cortical collecting duct.

Several nephrons drain into a cortical collecting duct. The cortical collecting ducts join to form a single larger collecting duct that runs downward into the medulla and becomes the medullary collecting duct.

5. The medullary collecting duct; the medullary collecting duct passes through outer medulla then through the inner medulla. In the inner medulla, that eventually empty into the renal pelvis

In each kidney, there are about 250 of the very large collecting ducts (Bellini duct), each of which collects urine from about 4000 nephrons.



Renal blood flow

The blood enters the kidneys in large quantities for the purpose of getting rid of waste and estimating the amount of blood

The blood that enters the kidneys is about 25% of the blood that is pumped out of the heart, that is, every 4 or 5 minutes .

This blood flow in the circulatory system passes through the kidneys .

Blood vessels Participating in this process are :

1. **The renal artery**, which branches from the abdominal **aorta** and enters the kidney from the **navel area**, then branches into small arteries and then into smaller arteries called arterioles, and this branch of the arteries is called the **afferent glomerular arteries** .
2. **Afferent glomerular arterioles** deliver blood to the glomerular capillaries of **Malpighian corpuscle** .
3. **Glomerular capillaries** are extensions of the glomerular arterioles. Incoming plasma is filtered into Bowman's capsule, called **glomerular filtration**. Not all of the plasma is filtered, so a portion remains that exits the glomerulus through the efferent glomerular capillaries .
4. **The efferent glomerular capillaries** branch into a network of capillaries that surround the urinary unit and are called **peritubular capillaries**. These capillaries unite to form veins and unite to form large veins that drain into the **renal vein** .
5. **The renal vein** leaves the kidney through the umbilicus and connects to the inferior **vena cava**.

Innervations of renal vessels

The kidney is an organ rich in **sympathetic nerves** from the **autonomic nervous system**, that follow the course of the previous renal arterioles and arterioles, where they innervate the smooth muscles in the walls of those vessels and stimulate their contraction and this regulates blood flow through the capillaries in the glomerulus.

Micturition

Micturition is the process by which the **urinary bladder empties** when it

becomes filled .This process involves two main steps :

1. **First**, the bladder fills progressively until the tension in its walls rises above a threshold level .
2. **This tension elicits the second step**, which is a **nervous reflex** called the **micturition reflex** that empties the bladder or, if this fails , at least causes a conscious **desire to urinate** .

Although the micturition reflex is an autonomic spinal cord reflex, it can also be **inhibited or facilitated** by centers in the **cerebral cortex** or **brain stem**.

Hormones Secreted by Kidneys

- 1- Renin
- 2- Erythropoietin (EPO)
- 3- Calcitriol (Active vitamin D)
- 4-Prostaglandins

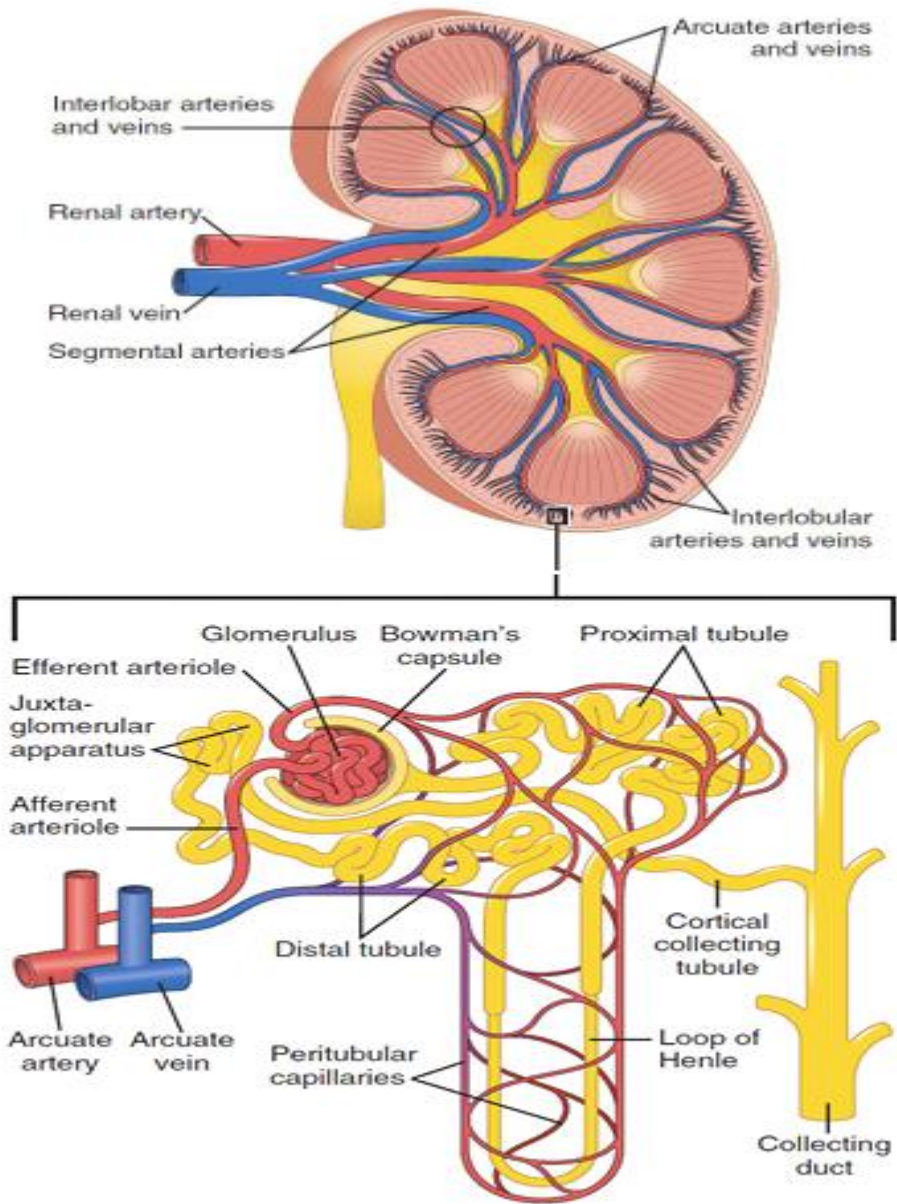


Figure 2. Section of the human kidney showing the major vessels that supply the blood flow to the kidney and schematic of the microcirculation of each nephron.

The physiology of urine formation

Urine is formed by the following processes

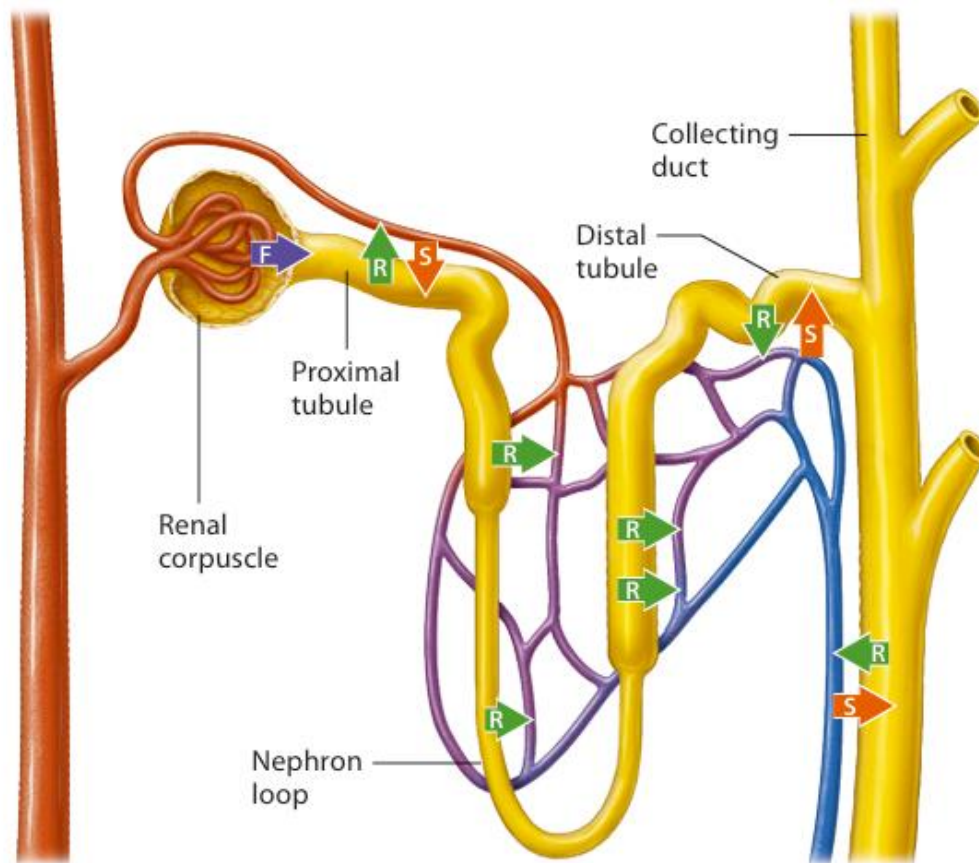
1. Filtration. 2- Reabsorption. 3- Secretion. 4- Synthesis

- 1. Filtration:** The filtration takes place in Malpighian bodies by the transfer of materials by diffusion in the blood capillaries to the cavity of Bowman's capsule, and it is noted that the filtrate is similar to blood plasma in its composition, except that it is devoid of proteins .

Hormones affecting filtration

- 1- **Antidiuretic hormone (ADH):** reabsorption of H₂O.
- 2- **Aldosterone:** reabsorption of Na⁺
- 3- **Atrial natriuretic peptide:** decrease reabsorption of Na⁺

- 2. Reabsorption:** The filtrate is considered a "**reduced**" solution when compared to the final urine, where the filter volume is 180 liters per day while the urine volume is 1.5 liters per day. The glucose in the filtrate and a large proportion of mineral salts and other dissolved substances are absorbed. The renal tubules have a limited ability to absorb glucose. If the glucose concentration exceeds this capacity, it appears in the urine .
- 3. Secretion:** The kidney **expels or excretes** excess substances from the body's need, such as sodium, for excretion in the urine. This process is the opposite of re-absorption, but is complementary to it in order to ensure the required balance for the body .
- 4. Synthesis:** It is the process of creating new substances that are not present in the filtrate, such as the formation of ammonia from amino acids, so that the body can overcome the increased acidity that it may be exposed to.



F → **Glomerular filtration:**
Blood is filtered at the glomerulus.

R → **Tubular reabsorption:**
Fluid and solutes are reabsorbed from the filtrate and returned to the blood.

S → **Tubular secretion:**
Substances are secreted from the blood into the filtrate.



Muscle physiology

Muscle physiology is a branch of physiology that studies the mechanism behind muscle contraction

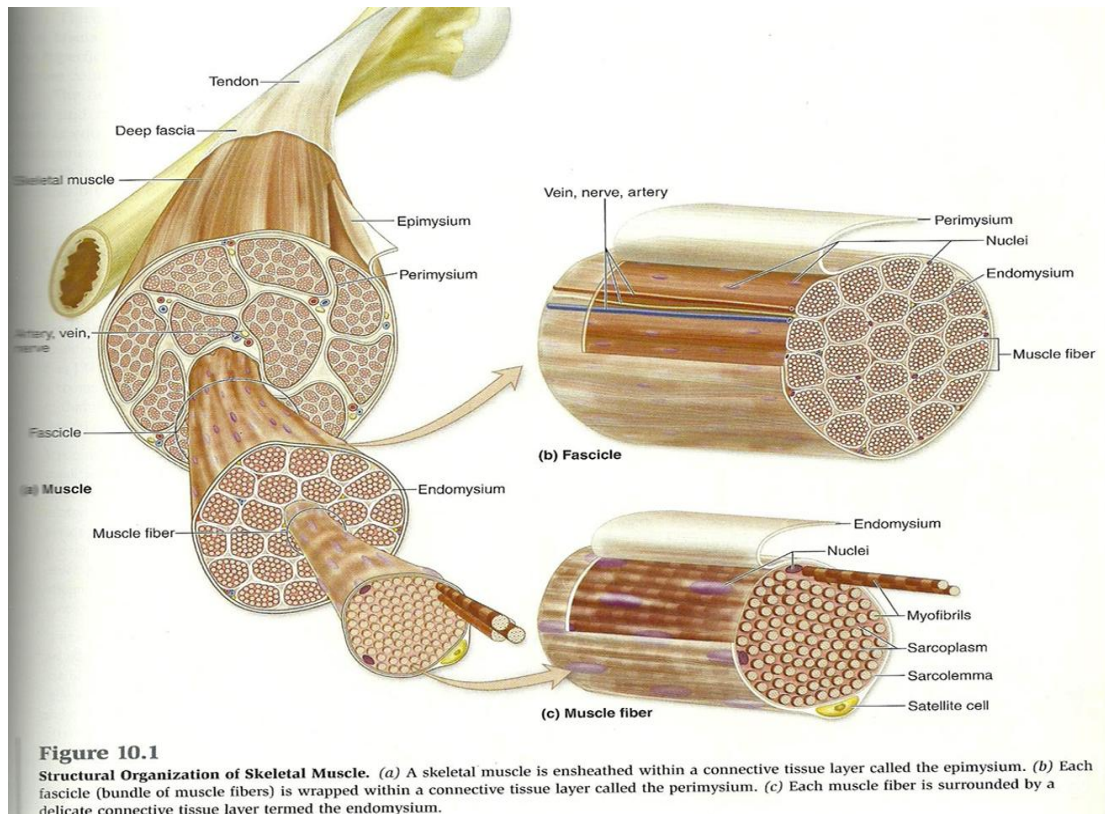
Skeletal Muscle: is situated in association with bones forming the skeletal system. The skeletal muscles form 40 to 50% of body mass and are voluntary and striated. These muscles are supplied by somatic nerves.

Structure of Skeletal Muscle

The skeletal muscle fibers are multinucleated and arranged parallel to one another with some connective tissue in between. The muscle mass is separated from the neighboring tissues by the thick fibrous tissue layer known as **fascia**. Beneath the fascia, the muscle is covered by a connective tissue sheath called **epimysium**. In the muscle, the muscle fibers are arranged in various groups called **the bundles or fasciculi**. The connective tissue sheath that covers each fasciculus is called **perimysium**. Each muscle fiber is covered by the connective tissue layer called **the endomysium**

The muscle mass (or tissue) is made up of a large number of individual muscle cells or **myocytes**. The muscle cells are commonly called **muscle fibers** because these cells are long and slender in appearance.





Skeletal muscle fibers

The average length of muscle fiber is 12–14 cm. It contains many nuclei. Its membrane is called the **sarcolemma**. The cytoplasm of muscle cells is called **sarcoplasm**

A skeletal muscle is made up of bundles :

•Muscle → Fascicles → Muscle fibers (cells)

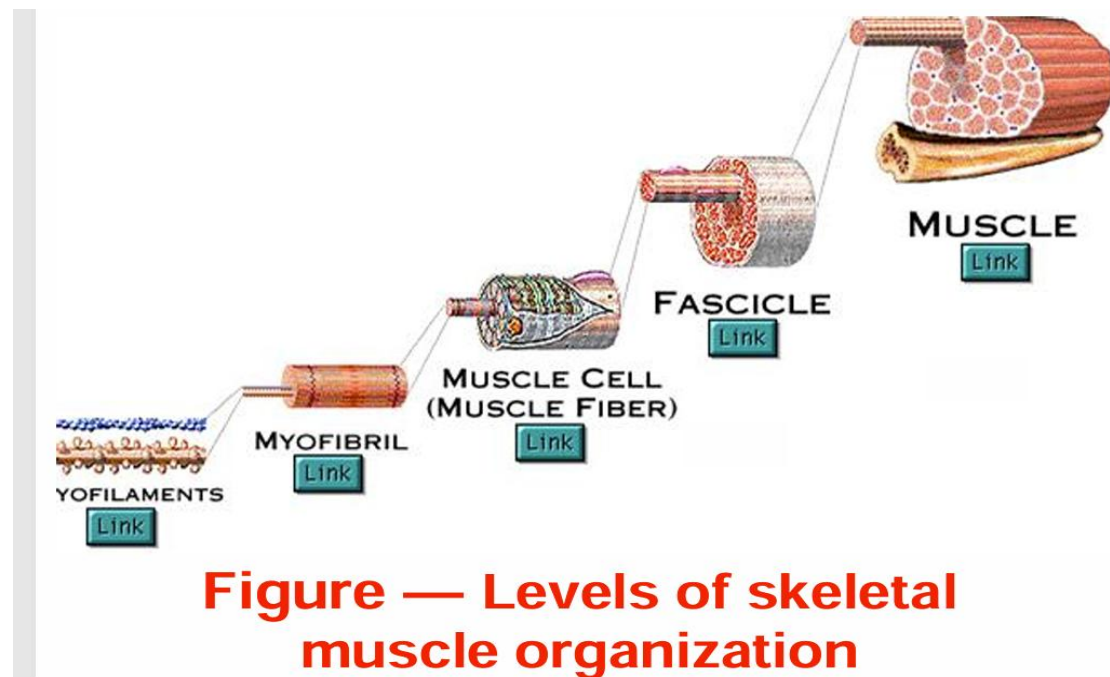
→Myofibrils → Myofilaments

•Myofilaments are the proteins :

•Actin (thin filament)

•Myosin (thick filament)

❖ The sarcomere is the basic contractile unit of muscle — from Z line to Z line



Myofibrils or myofibrillae are the special structures present only in muscle fibers. These are the fine parallel filaments present in sarcoplasm of the muscle cell.

MICROSCOPIC STRUCTURE OF A MYOFIBRIL

Light microscopic studies show that, each myofibril consists of a number of **two alternating bands**.

The two bands are:

1. Light band or 'I' band
2. Dark band or 'A' band.

In an intact muscle fiber, 'I' band and 'A' band of the adjacent myofibrils are placed side by side. It gives the appearance of characteristic cross striations in the muscle fiber.

I band is divided into two portions by a narrow dark line called '**Z' line** or 'Z' disk. The 'Z' line is formed by a protein disk which does not permit passage of light. The portion of myofibril in between two 'Z' lines is called **sarcomere**.

muscle fibers have a striated (striped) appearance on histological sections **because they are made up of smaller units called sarcomeres** that run parallel to each other, giving the muscle the striated appearance.

A sarcomere is the smallest functional unit of skeletal muscle tissue, has thick and thin filaments primarily composed of the proteins **thick myosin** and **thin actin**. The interaction of actin and myosin causes muscle contraction and therefore movement

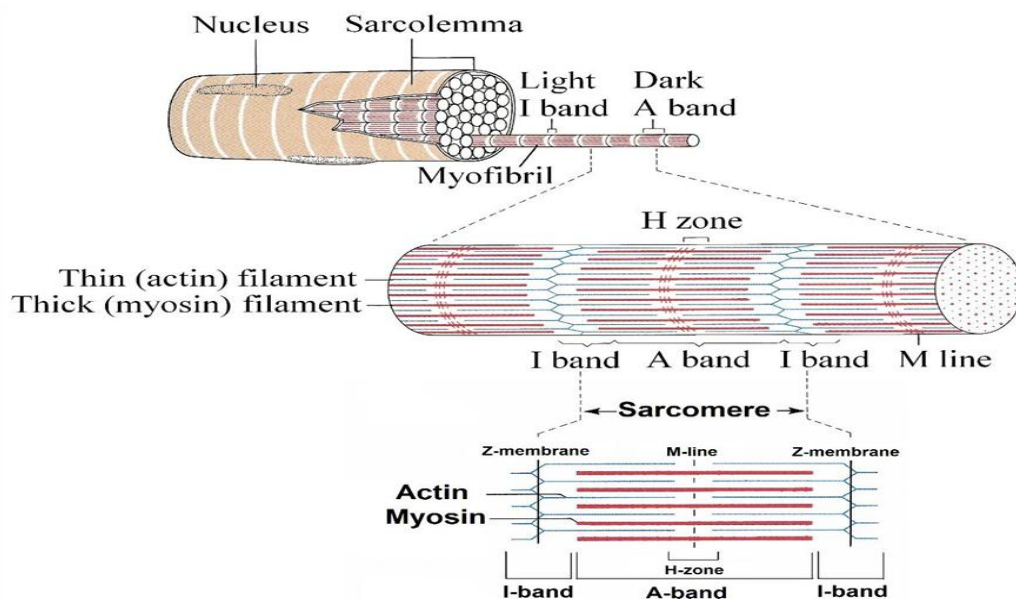


Figure — Structure of muscle fiber and sarcomere

CONTRACTILE ELEMENTS (PROTEINS) OF MUSCLE

1-MYOSIN MOLECULE Each myosin filament consists of about 200 myosin molecules. Myosin is a globulin which is made up of 6 polypeptide chains. Out of these, **two are heavy chains** and **four are light chains**. The two heavy chains twist around each other to form a **double helix**. At one end, the two chains remain twisted around one another and form **the tail portion**. At the other end, both the chains turn away in opposite directions.

2-ACTIN MOLECULE

Actin molecules are the major constituents of the thin actin filaments. Each actin molecule is **called F actin** and it is derived from **G actin**. There are about 300-400 actin molecules in each actin filament. The actin molecules in the actin filament are also arranged in the form of a **double helix**. Each F actin molecule has an active site to which the myosin head is attached

3-TROPOMYOSIN

There are about 40-60 tropomyosin molecules situated along the double helix strand of actin filament. In relaxed condition of the muscle, the tropomyosin molecules cover all the active sites of F actin molecules.

4-TROPONIN

It is formed by three subunits:

1. **Troponin I** – attached to F actin
2. **Troponin T** – attached to tropomyosin
3. **Troponin C** – attached to calcium ions.

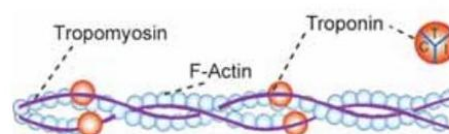
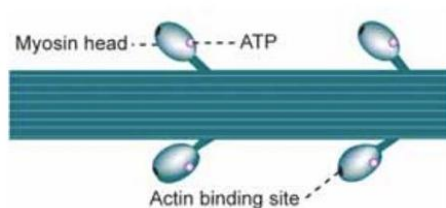


FIGURE 21-6: Part of actin filament. Troponin has three subunits, T, C and I

Properties of Skeletal Muscle

EXCITABILITY

Excitability is defined as the reaction or response of a tissue to irritation or stimulation. It is a physicochemical change.



STIMULUS

Stimulus is the change in environment. It is defined as an agent or influence or act, which brings about the response in an excitable tissue.

There are four types of stimuli, which can excite a living tissue:

1. **Mechanical stimulus** (Pinching)
2. **Electrical stimulus** (Electric shock) Electrical stimulus is commonly used for experimental purposes.
3. **Thermal stimulus** (By applying heated glass rod or icepiece)
4. **Chemical stimulus** (By applying chemical substances like acids).

CONTRACTILITY: is the response of the skeletal muscle to a stimulus by change in either the length or tension of the muscle fibers.

TYPES OF CONTRACTION: Muscular contraction is classified into two types based on **change in the length** of muscle fibers or **tension of the muscle**:

1. Isotonic contraction
2. Isometric contraction.

Isotonic Contraction is the type of muscular contraction in which the tension remains the same and the length of the muscle fiber is altered (Iso = same: Tonic = tension). **Example** is the simple flexion of arm, where shortening of muscle fibers occurs but the tension does not change.

Isometric Contraction is the type of muscular contraction in which the length of muscle fibers remains the same and the tension is increased. **Example** is pulling any heavy object when muscles become stiff and strained with increased tension but the length does not change.

Mechanism of Muscle Contraction: Sliding Filament Theory

Step-by-step process:

1. **Nerve impulse** reaches the muscle fiber → releases acetylcholine (ACh) at the neuromuscular junction.
2. This **triggers depolarization** of the muscle membrane → Calcium ions (Ca^{2+}) are released from the sarcoplasmic reticulum (SR).
3. **Calcium binds to troponin**, moving tropomyosin away from binding sites on actin.
4. **Myosin heads attach to actin** → forming cross-bridges.
5. **Using ATP**, myosin heads pull actin filaments toward the center of the sarcomere → contraction.
6. When **stimulation stops**, Ca^{2+} returns to SR, cross-bridges detach, and the muscle relaxes.

Summary Formula:

Excitation → Calcium release → Cross-bridge cycling → Contraction → Relaxation

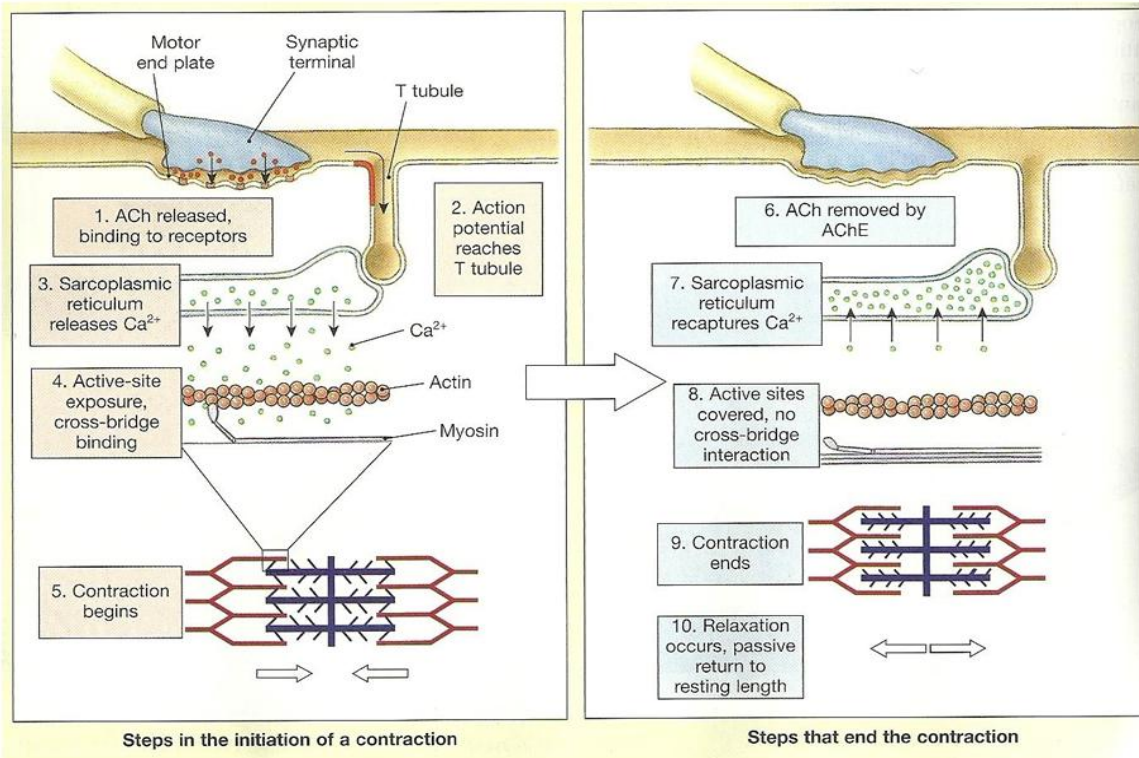
Role of ATP and Calcium

- **Calcium** (Ca^{2+}): Starts contraction by binding to troponin.
- **ATP:**
 - Detaches myosin from actin.

- Provides energy for myosin head movement.
- Powers calcium reuptake into SR.

Without ATP → muscles stay stiff (as in rigor mortis).

Steps in the initiation and the end of contraction



Neuromuscular Junction

