III B Sc

ANIMAL PHYSIOLOGY AND BIOCHEMISTRY

Sub Code: 18K5Z08

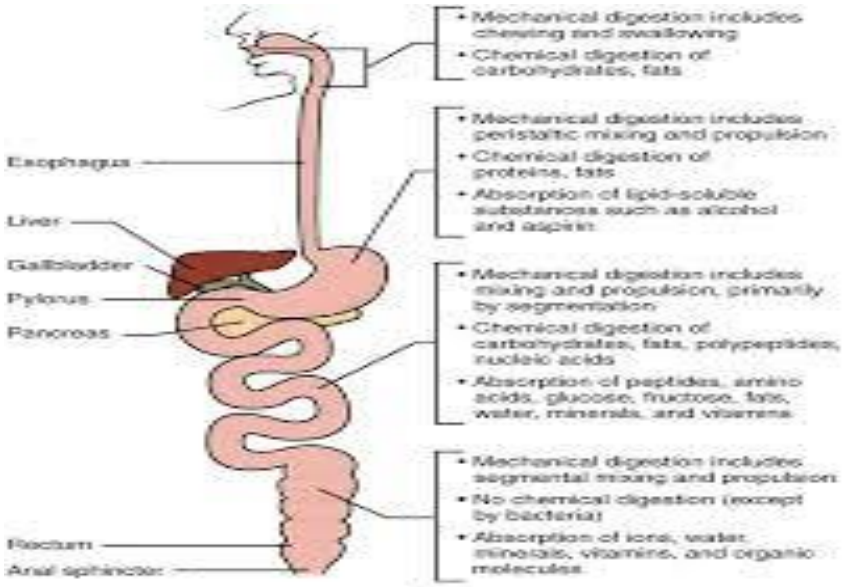
Digestive System

The digestive system ingests and digests food, absorbs released nutrients, and excretes food components that are indigestible. The six activities involved in this process are ingestion, motility, mechanical digestion, chemical digestion, absorption, and defecation.

There are four steps in the digestion process: ingestion, the mechanical and chemical breakdown of food, nutrient absorption, and elimination of indigestible food. The mechanical breakdown of food occurs via muscular contractions called peristalsis and segmentation

Food passes through the digestive system in the following order:

- **Mouth.**
- **Esophagus.**
- **Stomach.**
- **The small intestine.**
- **Colon (large intestine)**
- **Rectum.**



Absorption,

Absorption, in general sense, is the act or process of absorbing or assimilating. In biology, absorption pertains particularly to the process of absorbing or assimilating substances into the cell or across the tissues and organs. It is done through diffusion or osmosis.

Protein absorption

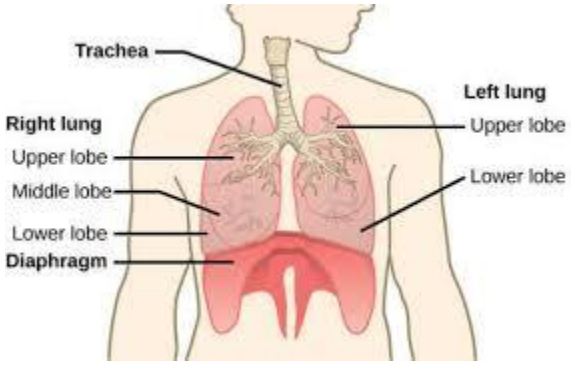
Active transport mechanisms, primarily in the duodenum and jejunum, absorb most proteins as their breakdown products, amino acids. Almost all (95 to 98 percent) protein is digested and absorbed in the small intestine.

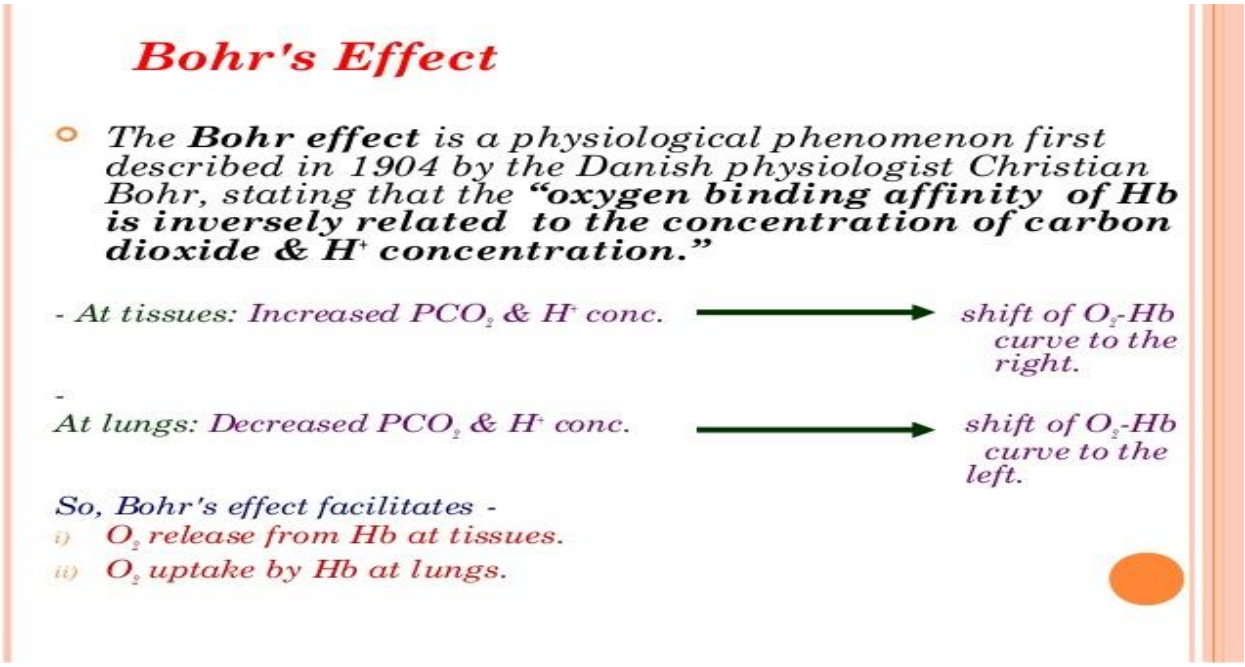
Carbohydrate Absorption

Carbohydrate digestion begins in the mouth and is most extensive in the small intestine. The resultant monosaccharides are absorbed into the bloodstream and transported to the liver.

Respiration in humans takes place through the lungs. It is the largest organ of the human respiratory system. The air inhaled moves down the trachea into the lungs where oxygen is exchanged for carbon dioxide from the body tissues. Carbon dioxide is then exhaled out of the lungs through the mouth.

BREATHING or ventilation. EXTERNAL RESPIRATION, which is the exchange of gases (oxygen and carbon dioxide) between inhaled air and the blood. INTERNAL RESPIRATION, which is the exchange of gases between the blood and tissue fluids. CELLULAR RESPIRATION.





Respiratory Pigment

A respiratory pigment is any molecule that increases the oxygen carrying capacity of blood. ... In humans and most other vertebrates, the most common respiratory pigment is a protein called haemoglobin.

There are two basic types, the gas transporters (hemoglobins, myoglobin, hemerythrin, etc.), and electron transport- ers (cytochromes).

A respiratory pigment is any molecule that increases the oxygen carrying capacity of blood. ... In humans and most other vertebrates, the most commonrespiratory pigment is a protein called hemoglobin. Respiratory pigments also pick up carbon dioxide from our tissues and bring it to our lungs, where we exhale it.

Hemoglobins are the most common and widespread respiratory pigments, occurring in at least nine phyla. ... Although many invertebrates also have hemoglobins in blood cells, some invertebrates have hemoglobins dissolved in their blood plasma. Hemocyanins are the second most common of the respiratory pigments in animals.

Hemocyanins are copper-containing respiratory pigments found in many mollusks (some bivalves, many gastropods, and cephalopods) and arthropods (many crustaceans, some arachnids, and the horseshoe crab, Limulus). They are colourless when deoxygenated but turn blue on oxygenation.

Respiratory quotient,

Respiratory quotient, also known as the respiratory ratio (RQ), is defined as the volume of carbon dioxide released over the volume of oxygen absorbed during respiration. It is a dimensionless number used in a calculation for basal metabolic rate when estimated from carbon dioxide production to oxygen absorption.

The respiratory quotient (RQ) is used in the calculations of basal metabolic rate (BMR). It is the ratio of the volume of carbon dioxide produced by the body to the volume of oxygen consumed by the body in respiration over a period of time.

The respiratory quotient (RQ) measures the ratio of the volume of carbon dioxide (V_c) produced by an organism to the volume of oxygen consumed (V_o). This is represented by the following equation: ... RQ = n / n = 1. For glucose, RQ = 6 / 6 = 1.

UNIT-II

CIRCULATION – TYPES OF CIRCULATION IN ANIMALS

Circulatory systems in animals

Transport systems are crucial to survival. Unicellular organisms rely on simple **diffusion** for transport of nutrients and removal of waste. Multicellular organisms have developed more complex **circulatory** systems.

C**irculatory system** is made up of blood vessels that carry blood away from and towards the heart. Arteries carry blood away from the heart and veins carry blood back to the heart. The **circulatory system** carries oxygen, nutrients, and hormones to cells, and removes waste products, like carbon dioxide.

There are two types of circulatory systems found in animals:

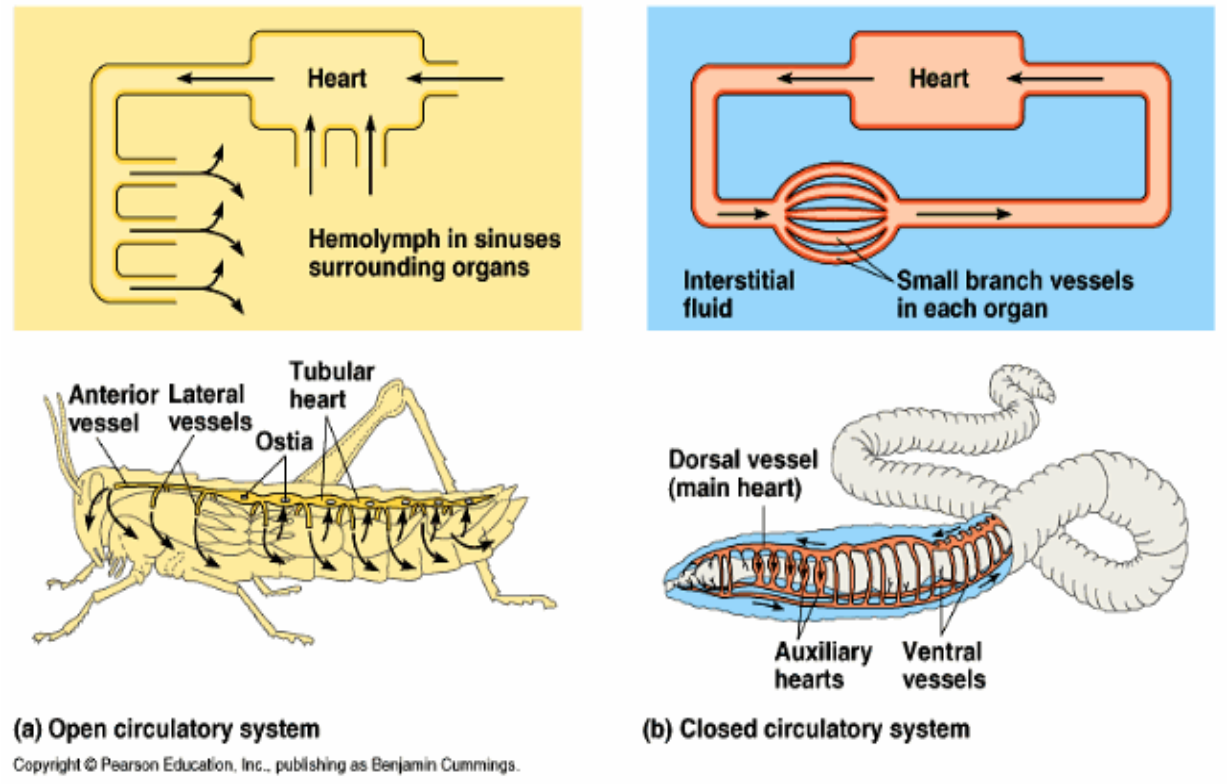
Open and **closed** circulatory systems.

Open circulatory systems

In an open circulatory system, blood vessels transport all fluids into a cavity. When the animal moves, the blood inside the cavity moves freely around the body in all directions. The blood bathes the organs directly, thus supplying oxygen and removing waste from the organs. Blood flows at a very slow speed due to the absence of smooth muscles, which, as you learnt previously, are responsible for contraction of blood vessels. Most invertebrates (crabs, insects, snails etc.) have an open circulatory system.

Closed circulatory systems

Closed circulatory systems are different to open circulatory systems because blood never leaves the blood vessels. Instead, it is transferred from one blood vessel to another continuously without entering a cavity. Blood is transported in a single direction, delivering oxygen and nutrients to cells and removing waste products. Closed circulatory systems can be further divided into **single** circulatory systems and **double** circulatory systems.



Single and double circulation systems

The circulatory system is a broad term that encompasses the **cardiovascular** and **lymphatic** systems. The lymphatic system will be discussed later in this chapter. The cardiovascular system consists of the heart (cardio) and the vessels required for transport of blood (vascular). The vascular system consists of arteries, veins and capillaries.

Vertebrates (animals with backbones like fish, birds, reptiles, etc.), including most mammals, have closed cardiovascular systems. The two main circulation pathways in invertebrates are the **single** and **double** circulation pathways.

Single circulatory pathways

Single circulatory pathways as shown in the diagram below consist of a double chambered heart with an atrium and ventricle (the heart structure will be described in detail later in this chapter). Fish possess single circulation pathways. The heart pumps deoxygenated blood to the gills where it gets oxygenated. Oxygenated blood is then supplied to the entire fish body, with deoxygenated blood returned to the heart.

Double circulatory systems

Double circulation pathways are found in birds and mammals. Animals with this type of circulatory system have a four-chambered heart.

The right atrium receives deoxygenated from the body and the right ventricle sends it to the lungs to be oxygenated. The left atrium receives oxygenated blood from the lungs and the left ventricle sends it to the rest of the body. Most mammals, including humans, have this type of circulatory system. These circulatory systems are called 'double' circulatory systems because they are made up of two circuits, referred to as the **pulmonary** and **systemic** circulatory systems.

Human circulatory systems

The human circulatory system involves the **pulmonary** and **systemic** circulatory systems. The **pulmonary circulatory system** consists of blood vessels that transport deoxygenated blood from the heart to the lungs and return oxygenated blood from the lungs to the heart. In the **systemic circulatory system**, blood vessels transport oxygenated blood from the heart to various organs in the body and return deoxygenated blood to the heart.

Pulmonary circulation system

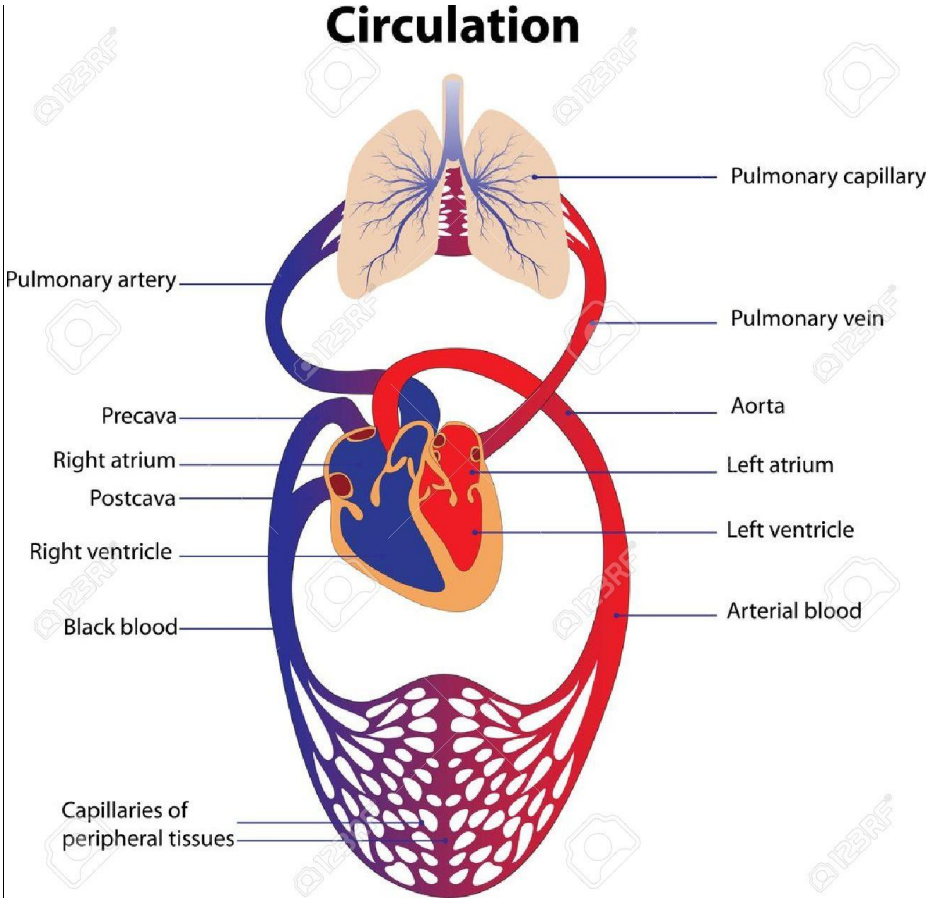
In the pulmonary circulation system, deoxygenated blood leaves the heart through the right ventricle and is transported to the lungs via the **pulmonary artery**. The pulmonary artery is the only artery that carries deoxygenated blood. It carries blood to the capillaries where carbon dioxide diffuses out of the blood into the **alveoli** (lung cells) and then into the lungs, where it is exhaled. At the same time, oxygen diffuses into the alveoli, and then enters the blood and is returned to the left atrium of the heart via the **pulmonary vein**.

Systemic circulation

Systemic circulation refers to the part of the circulation system that leaves the heart, carrying oxygenated blood to the body's cells, and returning deoxygenated blood to the heart. Blood leaves through the left ventricle into the **aorta**, the body's largest artery. The aorta leads to smaller arteries that supply all organs of the body. These arteries finally branch into capillaries. In the capillaries, oxygen diffuses from the blood into the cells, and waste and carbon dioxide diffuse out of cells and into blood.

Deoxygenated blood in capillaries then moves into venules that merge into veins, and the blood is transported back to the heart. These veins merge into two major veins, namely the **superior vena cava** and the **inferior vena cava** (figure:doublecirculation). The movement

of blood is indicated by arrows on the diagram. The deoxygenated blood enters the right atrium via the the superior vena cava. Major arteries supply blood to the brain, small intestine, liver and kidneys. However, systemic circulation also reaches the other organs, including the muscles and skin



STRUCTURE AND FUNCTIONS OF HUMAN HEART

The heart is a muscular organ that pumps blood throughout the body. It is located in the middle cavity of the chest, between the lungs. In most people, the heart is located on the left side of the chest, beneath the breastbone. The heart is composed of smooth muscle. It has four chambers which contract in a specific order, allowing the human heart to pump blood from the body to the lungs and back again with high efficiency. The heart also contains “pacemaker” cells which fire nerve impulses at regular intervals, prompting the heart muscle to contract.

This animation shows the functioning of this extraordinarily complex pump in action. As you read this article, try scrolling back up and seeing if you can spot the chambers, valves, and blood vessels we’re discussing in action:

The heart is one of the most vital and delicate organs in the body. If it does not function properly, all other organs – including the brain – begin to die from lack of oxygen within just a few minutes. As of 2009, the most common cause of death in the world was heart disease.

Most heart disease occurs as a result of age or lifestyle. Cholesterol can build up in the arteries as a person gets older, and this is more likely for people who have diets high in saturated fat and cholesterol. Rarely, however, heart disease can also occur due to a virus or bacterium that infects the heart or its protective tissues.

The four-chambered heart found in mammals and birds is more efficient than the one, two, or three-chambered hearts found in some other animals. It is thought that warm-blooded animals need highly efficient circulation to satisfy their cells' high demand for oxygen. This is especially true of humans, whose huge brains require a near-constant supply of oxygen to function!

Heart Structure

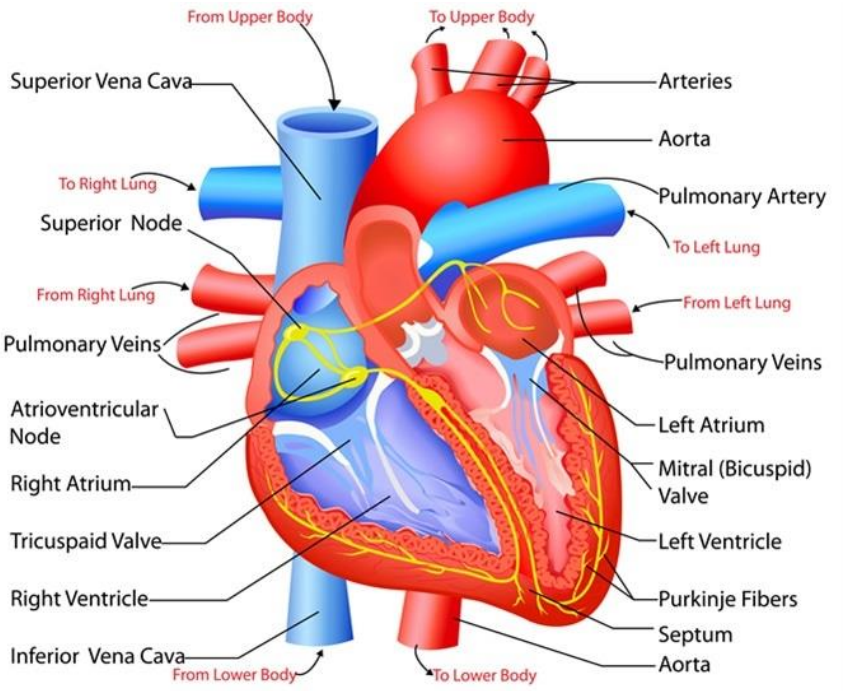
The heart's unique design allows it to accomplish the incredible task of circulating blood through the human body. Here we will review its essential components, and how and why blood passes through them.

Layers of the Heart Wall

The heart has three layers of tissue, each of which serve a slightly different purpose. These are:

- **The Epicardium**. The epicardium is also sometimes considered a part of the protective pericardial membrane around the heart. It helps to keep the heart lubricated and protected.
- **The Myocardium**. The myocardium is the muscle of the heart. You can remember this because the root word "myo" comes from "muscle," while "cardium" comes from "heart."

  The myocardium is an incredibly strong muscle that makes up most of the heart. It is responsible for pumping blood throughout the body.
- **The Endocardium**. The endocardium is a thin, protective layer on the inside of the heart. It is made of smooth, slippery endothelial cells, which prevent blood from sticking to the inside of the heart and forming deadly blood clots.



Chambers of the Heart

The heart has four chambers, which are designed to pump blood from the body to the lungs and back again with extremely high efficiency. Here we'll see what the four chambers are, and how they do their jobs:

- **The Right Atrium**. The right and left atria are the smaller chambers of the heart, and they have thinner, less muscular walls. This is because they only receive blood from the veins – they don't have to pump it back out through the whole circulatory system!

  The right atrium only has to receive blood from the body's veins and pump it into the left ventricle, where the real pumping action starts.

- **The Right Ventricle**. The ventricles are larger chambers with stronger, thicker walls. They are responsible for pumping blood to the organs at high pressures. There are two ventricles because there are two circuits blood needs to be pumped through – the pulmonary circuit, where blood receives oxygen from the lungs, and the body circuit, where oxygen-filled blood travels to the rest of the body. Maintaining these two separate circuits with two separate ventricles is much more efficient than simply pumping blood to the lungs and allowing it to flow to the rest of the body from there. It pumps blood through the pulmonary artery and to the lungs, where the blood fills with oxygen, at high pressure. The blood then returns to…

- **The left atrium** receives oxygenated blood from the pulmonary veins. It pumps this blood into the left ventricle, which…
- **The left ventricle** pumps blood throughout the rest of the body.

After the blood has circulated through the body and the oxygen has been exchange for carbon dioxide waste from the body's cells, the blood re-enters the right atrium and the process begins again.

In most people, this whole circulatory path only takes about a minute to complete!

Valves of the Heart

- **The Tricuspid Valve**. The tricuspid valve is what is called an "atrioventricular" valve. As you might guess by the name, it ensures that blood only flows from the atrium to the ventricle – not the other way around.
  These atrioventricular valves have to stand up to very high pressures to ensure that no blood gets through, as the ventricle contracts quite powerfully to squeeze blood out.
  The tricuspid valve is the valve that ensures that blood in the right ventricle goes into the pulmonary artery and reaches the lungs, instead of being pushed back into the right atrium.
- **The Pulmonary Valve**. The pulmonary valve is what is called a semilunar valve. Semilunar valves are found in arteries leaving the heart. Their role is to prevent blood from flowing backwards from the arteries into the heart's chambers.
  This is important because the ventricles "suck" blood in from the atria by expanding after they have expelled blood into the arteries. Without properly functioning semilunar valves, blood can flow back into the ventricle instead of going to the rest of the body. This drastically decreases the efficiency with which the heart can move oxygenated blood through the body.
  The pulmonary valve lies in between the pulmonary artery and the left ventricle, where it ensures that blood pumped into the pulmonary artery continues to the lungs instead of returning to the heart.
- **The Mitral Valve**. The mitral valve is the other atrioventricular valve. This one lies between the left atrium and the left ventricle. It prevents blood from flowing back from the ventricle into the atrium, ensuring that that blood is pumped to the rest of the body instead!

The mitral valve lies at the opening of the aorta, which is the largest blood vessel in the body. The aorta is the central artery from which all other arteries fill. It is thicker than a garden hose, extends all the way from our hearts down to our pelvis, where it splits in two to become the femoral artery of each leg.

- **The Aortic Valve**. As you might have guessed, the aorta needs a semilunar valve just like the pulmonary artery does. The aortic valve prevents blood from flowing backwards from the aorta into the left ventricle as the left ventricle "sucks" in oxygenated blood from the left atrium.

FUNCTION OF THE HEART

The heart pumps blood through our immense and complicated circulatory systems at high pressure. It is a truly impressive feat of engineering, as it must circulate about five liters of blood through a full 1,000 miles worth of blood vessels each minute! We will talk more about how the heart accomplishes this remarkable task under the "Heart Structure" section below.

The pumping action of the heart allows the movement of many substances between organs in the body, including nutrients, waste products, and hormones and other chemical messengers. However, arguably the most important substance it circulates is oxygen.

Oxygen is required for animal cells to perform cellular respiration. Without oxygen, cells cannot break down food to produce ATP, the cellular currency of energy. Soon, none of their energy-dependent processes can function. Without its energy-dependent processes, a cell dies.

Neural tissues, including the brain, are particularly sensitive to oxygen deprivation. Neural tissues maintain a special cellular chemistry which must be constantly maintained through the consumption of lots and lots of energy. If ATP production stops, neural cells can begin to die within minutes.

For this reason, the body has taken many special measures to protect the heart. It is located below the strongest part of the ribcage and cushioned between the lungs. It is also surrounded by a protective membrane called the pericardium, which is filled with additional cushioning fluid.

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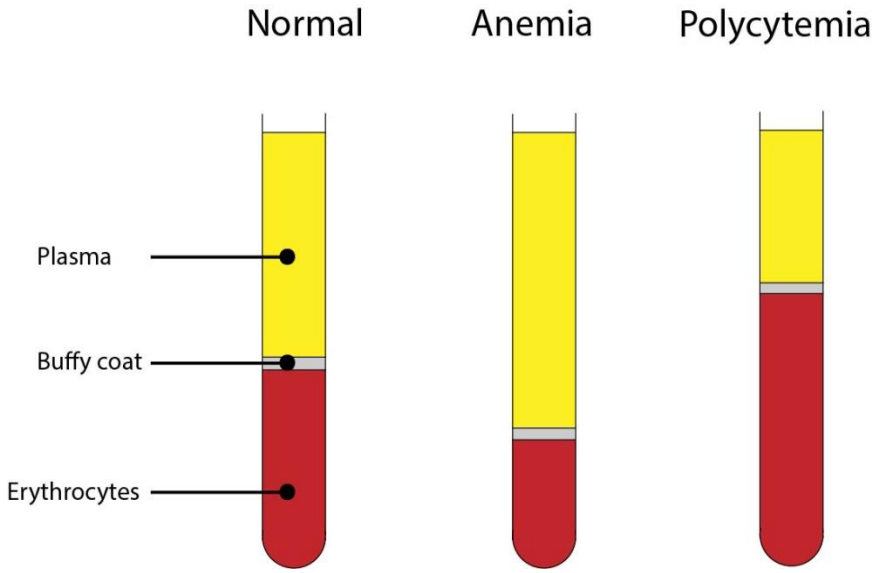
COMPOSITION OF BLOOD

Blood is a suspension of blood elements (erythrocytes, leukocytes, and platelets) in blood plasma. Blood elements can be separated from blood plasma using **centrifugal force**.

Figure shows that the most descended are erythrocytes – the volume of erythrocytes in a sample of blood is called the **hematocrit**. Hematocrit values differ **depending on sex** – in **men** the values range about **44 ± 5 %** of blood volume and in **women** about **39 ± 4 %** of blood volume.

Above the erythrocyte layer is found the white non-transparent layer composed of **leukocytes** and **thrombocytes**. This layer is called **buffy coat** (forms about 1 % of blood volume).



In our blood vessels circulate about **4.5-6 l of blood**, which represents approximately **6-9% of body weight**. Women have less blood than men.

Blood plasma, making up the **liquid** portion of blood, is a **colloid solution of organic and inorganic substances** (electrolytes, nutrients, proteins, hormones etc.) with an addition of dissolved blood gases.

It is slightly **opalescent** and its pale yellowish colour is caused by the presence of pigments, formed by decay of erythrocytes. **Volume** of blood plasma is approximately **2.8-3.5 l** (40-45 ml/kg of b.w.). Together with the lymph, it makes up to 25 % of extracellular fluid (ECF).

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BLOOD PRESSURE

Introduction

The heart supplies the organs and tissues of the body with blood. With every beat, it pumps blood into the large blood vessels of the circulatory system. As the blood moves around the

body, it puts pressure on the walls of the vessels. Blood pressure readings are made up of two values:

- **Systolic blood pressure** is the pressure when the heart beats – while the heart muscle is contracting (squeezing) and pumping oxygen-rich blood into the blood vessels.
- **Diastolic blood pressure** is the pressure on the blood vessels when the heart muscle relaxes. The diastolic pressure is always lower than the systolic pressure.

Blood pressure is measured in units of millimeters of mercury (mmHg). The readings are always given in pairs, with the upper (systolic) value first, followed by the lower (diastolic) value.

So someone who has a reading of 132/88 mmHg (often spoken “132 over 88”) has a

- systolic blood pressure of 132 mmHg, and a
- diastolic blood pressure of 88 mmHg.

Blood Pressure Monitor

Changes of Blood Pressure

Blood pressure is always measured on a number of different days and when you are at rest. If several of these measurements are too high, you are said to have high blood pressure, even if only one of the two – either the systolic or the diastolic one – is high. The medical term for high blood pressure is hypertension. In adults, blood pressure is considered to be normal under a systolic value of 140 mmHg and under a diastolic value of 90 mmHg.

When taking your blood pressure for the first time, it makes sense to measure the blood pressure in both arms, because it's sometimes high on only one side. The values that are higher are always the ones used for assessing blood pressure. After that it is enough to measure the blood pressure

only in the arm that produced the higher reading. A person is considered to have high blood pressure if the systolic value is over 140 mmHg, the diastolic value is over 90 mmHg, or if both are higher than these readings.

High blood pressure itself usually goes unnoticed. Only if it is extremely high can it sometimes result in symptoms like dizziness or trouble seeing. Over the long term, high blood pressure increases your risk of cardiovascular problems like heart attacks, strokes, and heart and kidney failure. So if you or your doctor thinks you have high blood pressure, it's important to have your blood pressure checked regularly. If the readings are repeatedly too high, there are several different ways of lowering your blood pressure and decreasing the risk of long-term health consequences.

Normal blood pressure	systolic under 140 mmHg and diastolic under 90 mmHg
High blood pressure	systolic over 140 mmHg and/or diastolic over 90 mmHg

Measuring blood pressure

It's important to measure blood pressure more than once because it fluctuates over the course of the day. It can also change due to things like physical exertion, stress, pain, or extreme heat or cold. But this kind of increase in blood pressure is only temporary and it soon returns to normal.

So, if blood pressure is measured just once and found to be high, it doesn't necessarily mean that it's always too high. A blood pressure reading taken at the doctor’s office can also be misleading: Going to the doctor makes some people so nervous that their blood pressure goes up.

Blood pressure is measured on several different days and while you are resting. This means sitting down and relaxing on a chair, and waiting about three minutes before taking a measurement so that your circulatory system comes to rest. The upper arm that is being used for the measurement should rest on a table, at about the same height as the heart, while the reading is being done.

Sources:

- Kasper DL, Fauci AS, Hauser SL, Longo DL, Jameson JL, Loscalzo J. Harrison's Principles of Internal Medicine. New York: McGraw-Hill; 2015.
- Pschyrembel. Klinisches Wörterbuch. Berlin: De Gruyter; 2017.
- Stierle U (Ed). Klinikleitfaden Kardiologie. Munich: Urban und Fischer; 2017.

33 Electrocardiogram (ECG)

The record of electric current generated by the heart is called ***electrocardiogram*** **(ECG)**.

The heart is made to beat by an ***electrical impulse*** originating in the sinu auricular node.

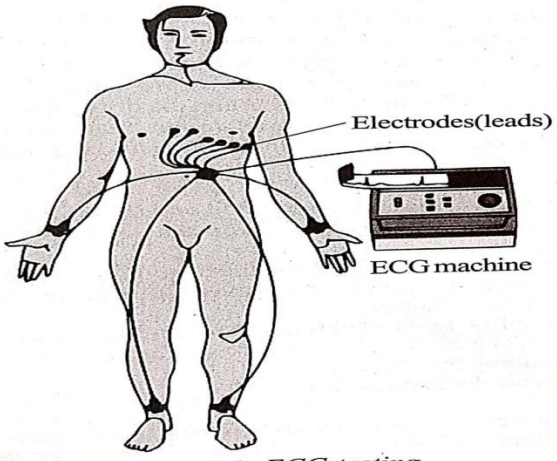


Fig.33.1: ECG testing.

The electrical impulse will be transmitted throughout the heart muscles and throughout the body. This electrical current can be recorded by a machine called ***electrocardiogram.***

ECG is a ***heart test.***

Einthen Willem is the ***father of ECG.***

ECG is used to measure the ***electrical conduction system*** of the heart (***Walraven,*** 2011).

ECG machine ***amplifies*** and ***records*** the electrical activities of the heart.

The electrical activities are recorded on a paper called ***ECG paper.***

The ECG paper has ***ECG grids*** of ***horizontal*** and ***vertical lines.***

Time duration of ***ECG waves*** are plotted horizontally on the ***X-axis.***

1mm = 0.04 second

5mm = 0.20 second

Amplitude of ECG waves is plotted vertically on ***Y- axis.***

1mm = 0.1 mV

5mm = 0.5 mV

The machine is connected to the surface skin of the body through ***electrodes*** called ***ECG leads***. The machine has ***10 electrodes.***

The electrocardiogram of man shows a series of ***waves***. The waves represent the sequence of depolarization and repolarization of the auricles and ventricles. Each ECG has 5 consecutive waves, namely three ***upward waves*** or ***positive waves*** and two ***downward waves*** or ***negative waves***. They are named as ***PQRST***.

The upward deflections are ***P, R*** and ***T*** and the downward waves are ***Q*** and ***S***. The waves are therefore ***alternately up*** and ***down.*** In addition, there are two ***iso-electric periods,*** the shorter one between ***P*** and ***Q*** and the longer one between ***S*** and ***T.***

P Wave

P wave is a ***positive wave***. It is also called ***atrial complex***. It is the ***first wave.***

It represents the wave of ***depolarization*** that spreads from ***sinu auricular node*** throughout auricles.

The period of time between the ***P*** and the beginning of ***QRS*** complex is called ***P-Q interval***. It represents the time between the onset of atrial depolarization and the onset of ventricular depolarization.

P represents the first upward deflection of the ECG. It is a small wave with a rounded top. It takes place when the impulse spreads over the atrial chambers. Its average duration is about ***0.1*** second.

It is due to ***atrial depolarization***.

QRS

These three waves are caused by ***ventricular depolarization***. It is called ***initial ventricular complex***. The average duration of ***QRS*** is ***0.06*** to ***0.1*** second.

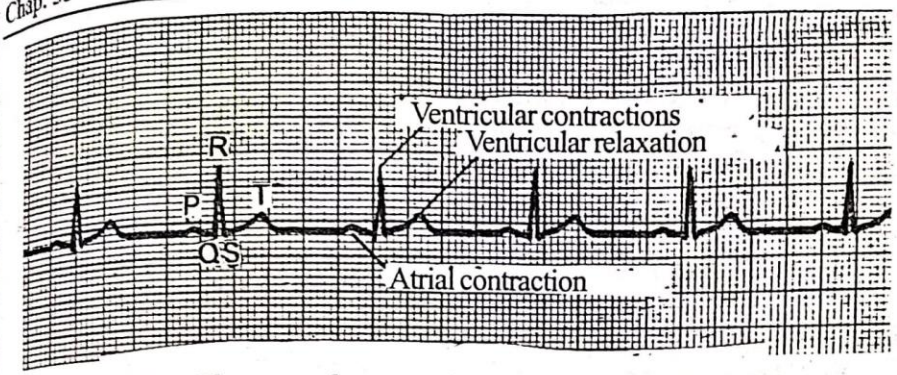


Fig.33.2: Electrocardiogram showing six normal heart beats.

Q

It is the first downward wave. In this stage, the impulse arrives at the interventricular septum and the septum contracts. Hence **Q** is caused by the ***activity of the septum***. It is absent from those animals which do not possess an interventricular septum. Eg. *Amphibians* and *reptiles*.

R

R is the 2nd upward deflection. It is a conspicuous wave with the tallest amplitude. R represents the activity of ***right ventricle***.

S

S is the second downward wave. It represents the activity of ***left ventricle***.

The actual contraction of ventricular muscles starts a fraction of a second after *Q-R* wave begins.

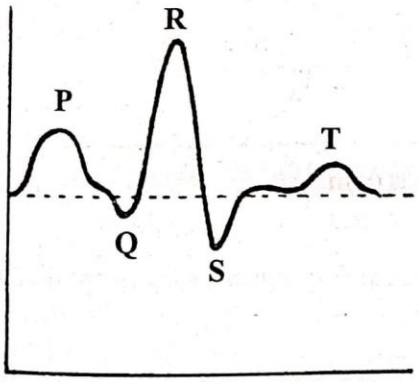


Fig.33.3: Electrocardiogram showing normal heart beat.

T

It is the ***repolarization*** wave of the ventricle.

T is the third upward deflection. It is a broad smoothly rounded deflection with a duration of *0.27* second. It is caused by the action current owing to the contraction of the basal part of the ventricle.

P and Q period

It is an ***isoelectric period*** where the curve is flat. It represents the time taken for the impulse to travel over auricle to auriculoventricular node and along the conducting tissues to the muscles of ventricles.

S T segment

It is the period at which the entire ***ventricle*** is ***depolarised***. It is called *final ventricular complex.*

It is the second ***isoelectric period.*** It is a long period. It has a duration of 0.27 second.

Uses of ECG

ECG helps to determine

Heart beat rate
Heart rhythm
Abnormal electrical conduction
Poor blood flow to heart muscles.

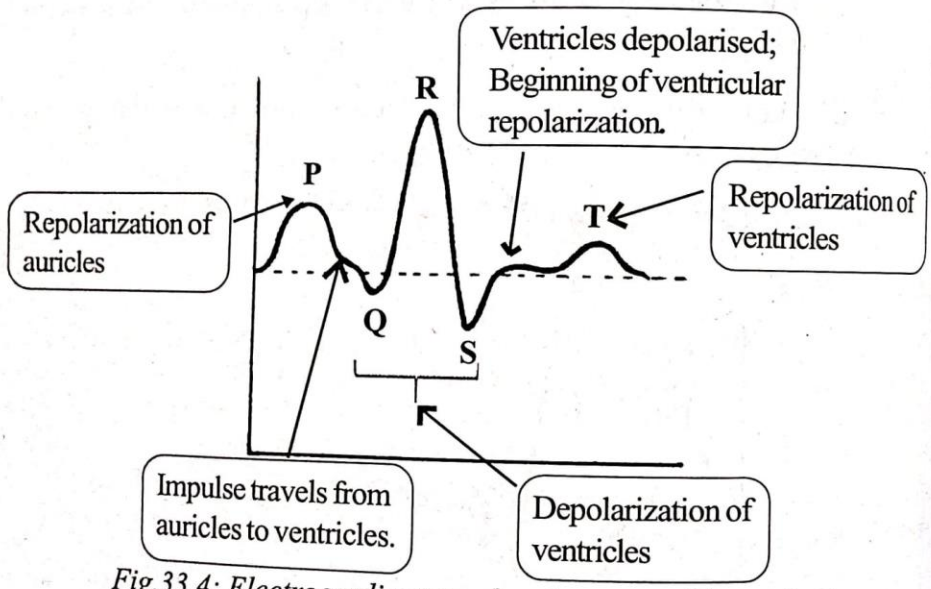


Fig.33.4: Electrocardiogram showing normal heart beat.

Heart attack
Coronary artery disease
Hypertrophy of heart chambers
Size of chambers
Position of chambers
Presence of damage in the heart.
Effects of drugs
Cardiac murmurs
Seizures.

PACEMAKER

Definition:

A pacemaker is a small device that's implanted under the skin of the chest. It produces electrical pulses to keep the heart beating at a normal rate. A pacemaker helps manage heart rhythm disorders, such as bradycardia, when the heart beats too slowly, or an arrhythmia, when the heart beats irregularly.

Importance of Pacemaker

The size of two half-dollars pressed together, a pacemaker contains a small computer and a battery that are connected to one or two flexible, insulated wires called leads, which extend from the device inside the chest to the heart.

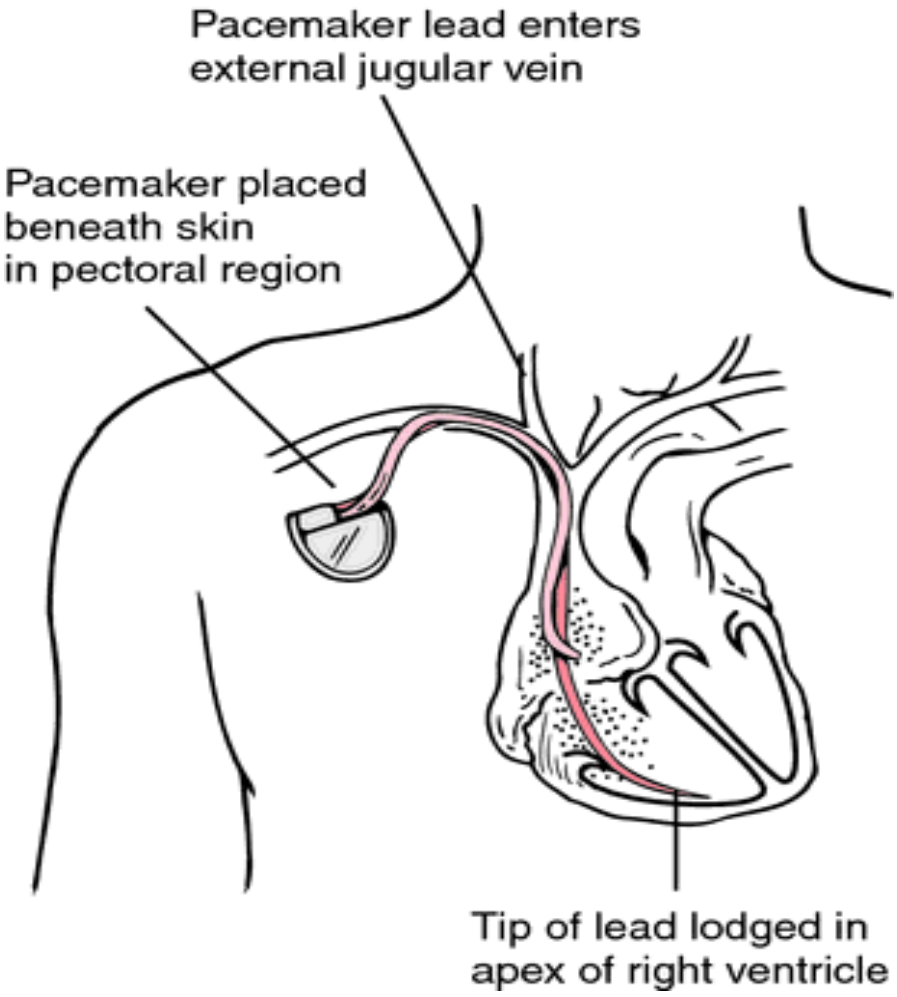
A pacemaker is implanted in the chest, beneath the collarbone during a procedure that requires local anesthesia and sedation. The surgery typically takes less than an hour to complete and usually requires an overnight stay in the hospital.

You can most likely return to your usual activities the day after pacemaker implantation, but your doctor may restrict some activities for two weeks. Restrictions include avoiding lifting anything heavier than 10 pounds and not engaging in exercises—such as swimming, golf, or tennis—that strain the affected side.

Two weeks after the procedure, your doctor examines the implantation site and checks to see how well the pacemaker is working by using a wand that transmits information stored in the device's generator to a computer. This includes information about the pacemaker's battery life, the condition of the lead or leads, and any arrhythmias experienced since the pacemaker was implanted. The battery typically lasts 7 to 13 years.

Every six months, you visit NYU Langone's Heart Rhythm Center, so your doctor can retrieve and analyze the information stored on the pacemaker. Sometimes, this information can be transmitted from home via a telephone line, cellular network, or the internet. This scheduled remote monitoring allows for more frequent checkups while reducing the need for office visits to once a year.

Ongoing monitoring helps your doctor determine if the device needs reprogramming or replacing. It can also determine if another therapy, such as medication, is needed to manage a heart rhythm disorder.


Pacemaker lead enters
external jugular vein
Pacemaker placed
beneath skin
in pectoral region
Tip of lead lodged in
apex of right ventricle

38 Excretion

Excretion may be defined as *the separation and elimination of the nitrogenous metabolic wastes from the body. The wastes eliminated* are called ***excretory products.***

Metabolism produces a great variety of substances in addition to energy. Some of these metabolic byproducts and end products are reutilized for metabolic activities. But certain byproducts and end products of metabolism are toxic and they will poison the body tissues if retained. Hence these substances are eliminated from the body through excretion.

The organs concerned with excretion are called ***excretory organs.***

Excretory Organs

Animals possess different types of excretory organs. The various excretory organs are summarised below:

1. Contractile vacuoles	- Protozoa
2. Protonephridia-Flame cells	- Platyhelminthes
3. Protonephridium-Solenocytes	- Polychaetes
4. Metanephridium	- Annelids
5. Chloragogen cells	- Annelids
6. Malpighian tubules	- Insects, Arachnids
7. Green glands	- Crustacea
8. Kidney (organ of Bojanus and Keber's gland)	- Mollusca
9. Pronephric kidney	- Bellostoma, Myxine
10. Mesonephric kidney	- Petromyzon, fishes,and amphibians
11. Metanephric kidney	- Reptiles, birds and mammals.

Excretory Products

Animals excrete a wide variety of excretory products. They are the following:

1. Amino acids

Amino acids are the end products of protein metabolism. Excess of amino acids are excreted as such in some animals. Eg. *Unio, Limnaea, Asterias, racentrotus,* etc.

2. Ammonia

Ammonia is formed by the deamination of amino acids. It is toxic and it should be eliminated immediately. It is highly soluble in water with which it forms ***ammonium hydroxide***. Ammonium hydroxide diffuses readily through water and passes rapidly across cell membranes.

$$NH_3 + H_2O \longrightarrow NH_4OH$$

Ammonia is a main excretory product in most of the ***aquatic animals*** like Protozoa, polychaetes, crustaceans, molluscs, teleost fishes, aquatic larvae of insects, amphibian tadpoles, tortoises and turtles.

The animals excreting ***ammonia*** are called ***ammonotelic animals.***

3. Urea

It is derived from ammonia through ***ornithine cycle***. It is less toxic and more soluble in water when compared to ammonia. It is excreted by ***semiterrestrial*** animals which are exposed to scarcity of water. Eg. *Earthworms, shore gastropods, amphibians, semi-terrestrial turtles* and *tortoises, elasmobranch fishes* and *mammals*.

The animals excreting ***urea*** are called ***ureotelic animals***.

4. Uric acid

Uric acid is less toxic and insoluble in water. It is excreted out as thick ***pastes*** or ***pellets***. It is excreted by true ***terrestrial vertebrates.*** Eg. *Insects, terrestrial snails, terrestrial reptiles* and *birds.*

The animals excreting ***uric acid*** are called ***uricotelic animals.***

5. Trimethylamine oxide

It is a soluble nitrogenous waste, excreted by ***marine teleosts.*** The characteristic odour of the dead fish is due to the presence of this substance in the body.

6. Hippuric acid

It is a ***mammalian*** excretory product. It is derived from ***benzoic acid***. When ***benzoic acid*** is present in the diet, it combines with glycine to form hippuric acid.

7. Guanine

It is excreted by ***spider.*** Its solubility is low and hence it does not require water for excretion.

8. Ornithinic acid

It is excreted by ***birds.*** When benzoic acid is present in the diet, it combines with ornithine to form ornithinic acid.

9. Allantoin

It is formed from uric acid by the catalytic action of the enzyme ***uricase.***

10. Allantoinic acid

It is formed from allantoin by oxidation. It is catalysed by ***allantoinase.***

11. Purines and Pyrimidines

These are formed by the breakdown of nucleic acids. Some animals excrete them as such.

12. Creatine

Mammals excrete creatine. It is synthesized in the ***liver*** from three amino acids, namely arginine, glycine and methionine.

13. Creatinine

Some mammals excrete creatinine. It is derived from creatine.

Origin of Excretory Products

The diet contains proteins in addition to other components. Proteins are digested into amino acids in the alimentary canal. The amino acids are absorbed into the blood and are transported to the cells.

In the cells, amino acids are used for synthetic (anabolism) and destructive (catabolism) processes.

In the process of catabolism, ***ammonia*** (NH_3) is released from amino acids. Ammonia is highly toxic and it must be eliminated from the body as the end product.

Aquatic animals dispose out ammonia as such. But other animals eliminate NH_3 by converting into other products such as urea, uric acid, guanine, etc.

Animals are classified according to the end products produced by them. They are:

Ammonotelic animals
Ureotelic animals
Uricotelic animals
Purinotelic animals
Guanotelic animals

The animals excreting ***ammonia*** are called ***ammonotelic animals***; Eg. *All aquatic animals.*

The animals excreting urea are called ***ureotelic animals***; Eg. *Amphibians, mammals.*

The animals excreting ***uric acid*** are called ***uricotelic animals***. Eg. *Insects, snails, reptiles* and *birds.*

The animals excreting ***purines*** are called ***purinotelic animals.***

The animals excreting ***guanine*** are called ***guanotelic animals.*** Eg. *Spiders, scorpions.*

Animals are classified based on the product which accounts for 50% or more of the total excreted nitrogen.

Origin of Ammonia

Ammonia is the chief breakdown product of amino acids. It is formed as a result of ***deamination process.*** Deamination chiefly occurs in the liver and tissues.

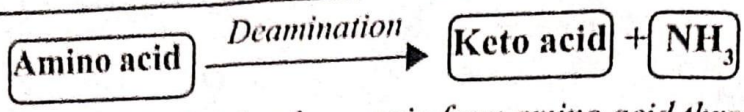


Fig.38.1: Origin of ammonia from amino acid through deamination.

Ammonia is highly soluble in water. In majority of aquatic animals, ammonia goes out by diffusion and gets dissolved in the surrounding water.

Origin of Urea

Urea is synthesized through three routes. They are:

1. *Ornithine cycle.*
2. *From dietary amino acid arginine.*
3. *From purine metabolism.*

1. Ornithine Cycle

In ornithine cycle, urea is synthesized. Here ornithine is involved and hence the name. The reactions involved in this cycle were discovered by ***Krebs.*** Hence this cycle was also called ***KREBS urea cycle.*** This cycle occurs in the ***liver.***

The raw materials for the synthesis of urea are NH_3 and CO_2.

1. The ornithine cycle starts with the combination of CO_2 and NH_3. The resulting compound is called ***carbamyl phosphate.*** This reaction is catalysed by the enzyme ***carbamyl phosphate synthetase*** in the presence of two molecules of ATP and Mg^{++}.

$$CO_2 + NH_3 + 2ATP \longrightarrow \textbf{Carbamyl phosphate} + 2ADP$$

2. In the second stage, carbamyl phosphate reacts with ***ornithine*** to form ***citrulline*** and inorganic phosphate (Pi).

$$\textbf{Carbamyl phosphate} + \textbf{Ornithine} \longrightarrow \textbf{Citrulline}$$

3. In the third stage, citrulline condenses with ***aspartic acid*** to form an intermediate additional compound called ***arginosuccinic acid.***

$$\textbf{Citrulline} + \textbf{Aspartic acid} \longrightarrow \textbf{Arginosuccinic acid}$$

4. In the fourth stage, arginosuccinic acid is cleaved into ***arginine*** and ***fumaric acid.*** This reaction is catalysed by the enzyme ***arginosuccinase.***

$$\textbf{Arginosuccinic acid} \longrightarrow \textbf{Arginine} + \textbf{Fumaric acid}$$

5. In the final stage, arginine is cleaved by ***arginase*** into ***ornithine*** and ***urea.*** Ornithine repeats the cycle by accepting another molecule of carbamyl phosphate.

$$\textbf{Arginine} \longrightarrow \textbf{Ornithine} + \textbf{Urea}$$

2. Urea Synthesis from Arginine

The dietary arginine in the tissues is converted into ornithine by ***arginase*** with the release of urea.

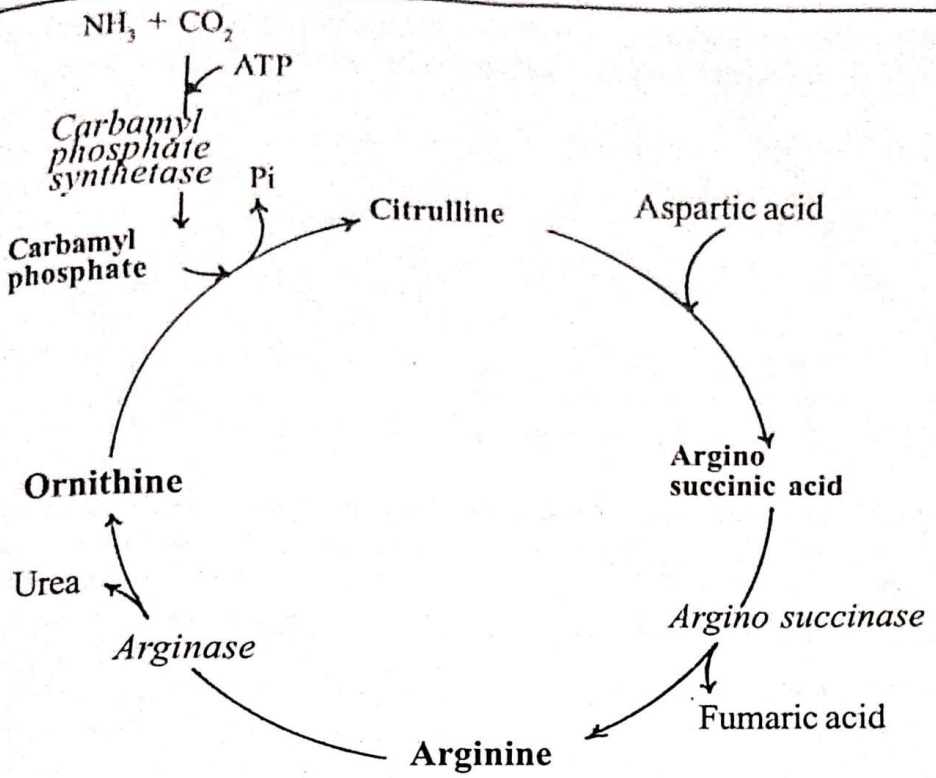


Fig.38.2: Ornithine cycle.

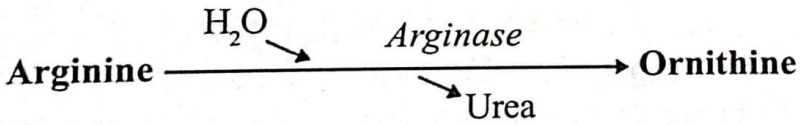


Fig.38.3: Urea Synthesis from arginine.

3. Urea Synthesis from Purine Metabolism

In most fishes, amphibian tadpoles and freshwater bivalves, urea is synthesized from purine.

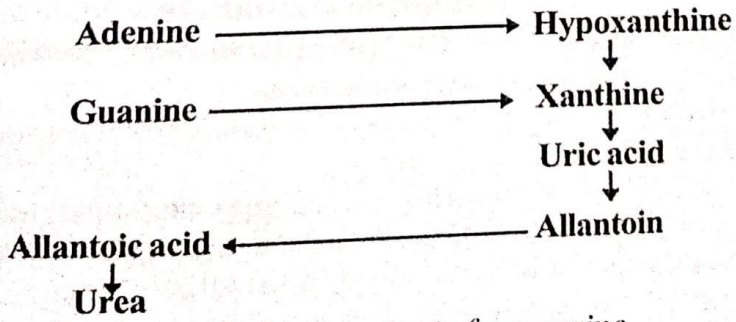


Fig.38.4: Urea synthesis from purine.

Origin of Uric Acid

Uric acid is the nitrogenous waste in the urine of birds, reptiles, land snails and

insects. It is formed from ammonia and it contains less hydrogen. It is formed in the ***liver*** of birds and in the ***Malpighian tubules*** of insects.

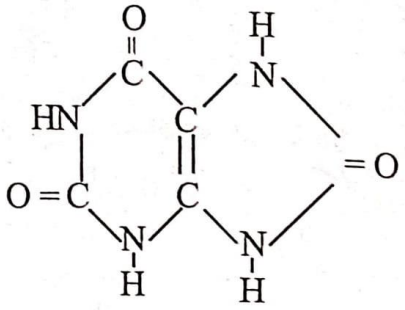


Fig.38.5: Uric acid.

It is formed either as an end product of purine metabolism or as a product of waste nitrogen derived from the protein. In man, uric acid is the end product of purine metabolism.

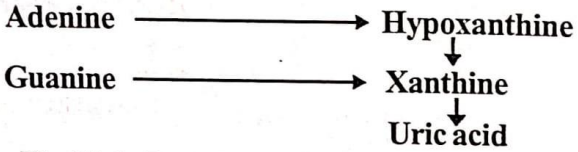


Fig.38.6: Purine metabolism to show the origin of uric acid.

Classification of Animals on the Basis of Excretory Products

Animals are broadly classified into three groups based on the type of excretory products. They are,

1. *Ammonotelic animals.*
2. *Ureotelic animals.*
3. *Uricotelic animals.*

1. Ammonotelic Animals

The animals excreting ammonia are called ***ammonotelic animals.*** The process of excretion of ammonia is called ***ammonotelism.***

Ammonotelism is exhibited by ***aquatic animals*** because ammonia is freely soluble and rapidly diffusible through water.

The ammonia diffuses out into the surrounding water slowly through the body surface or gills or other permeable parts of the body. As this diffusion is a slow process the ammonotelic animals have the ability to tolerate the presence of this poison to the extent of 3% or even to 4.8% (as in snails).

The ammonotelic animals include ***protozoans, actinozoans, polychaetes, annelids, crustaceans,*** *Aplysia, Sepia, Octopus,* ***echinoderms, teleosts,*** *tadpoles* and ***aquatic amphibians.***

Aquatic invertebrates remove ammonia in aqueous solution as ammonium ions ($NH4^+$). The ammonia in aqueous solution passes out either directly into the ambient water or is excreted in the urine.

In small freshwater invertebrates, ammonia diffuses through permeable surfaces directly into the surrounding.

In advanced invertebrates as well as vertebrates, most of the ammonia is excreted by the gills or skin with only small amounts formed by the kidneys.

Some ammonia passes through the gills by simple diffusion, but most of it is removed through the kidney.

Generally, ammonotelism depends on the abundance of water and ammonia is excreted in aqueous solution. However, there are two terrestrial groups which are ammonotelic. They are crustacean ***isopods*** and pulmonate ***snails.*** These animals excrete ammonia as gas (NH_3).

Ammonotelism is very strictly determined by the ***availability of plenty of water.*** This can be illustrated by a number of examples. A few are given below:

1. *Protopterus,* the lung fish, excretes its nitrogen in the form of ammonia when it is in the water. But when aestivating in the mud cocoon during hot summer it excretes urea and not ammonia ***(Smith)***.

2. When ***earthworms*** are immersed in water they become ammonotelic (***Delaunay,*** 1934). But when they are kept under moist air, they produce more urea than ammonia (***Bahl***, 1945).

3. *Xenopus* is ammonotelic in water, but becomes ureotelic during desiccation (***Janssens,*** 1972).

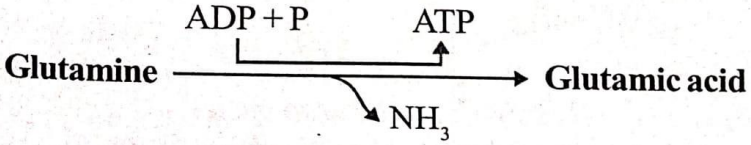
4. Amphibian ***tadpoles*** are ammonotelic. They excrete 40% of nitrogen as ammonia. After metamorphosis ammonia excretion is reduced to 12.5% and urea excretion increases proportionately.

Advantages of Ammonia Excretion

Ammonotelic animals receive two benefits by the direct excretion of ammonia.

1. Prevention of Energy Loss

Urea or uric acid synthesis requires ATP, while the formation of ammonia does not consume ATP. Actually the formation of ammonia from certain sources increases the supply of ATP. Eg. The formation of ammonia from glutamine releases ATP.



2. Ionic Regulation

The second bonus of ammonia excretion is associated with the trading of this surplus, toxic ion for physiologically indispensable ions, particularly sodium. In this way cations of the body may be conserved or salt may be acquired from the surroundings.

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2. Ureotelic Animals

The animals excreting urea are called ***ureotelic animals.*** The process of excretion of urea is called ***ureotelism.*** Urea is formed from ammonia through ***ornithine cycle.***

As the urea is less toxic, the ureotelic animals have the advantage of concentrating their blood by retaining urea. Elasmobranch can retain 2 to 2.5% urea in the blood. It excretes 80% of nitrogenous wastes as urea.

Urea is the excretory product of semi-terrestrial animals. Eg. *Amphibians, mammals.* In such animals, the availability of water is not plenty.

When *Protopterus* is in water it excretes plenty of ammonia. But it excretes large amount of urea under dry conditions.

$$CO_2 + 2NH_3 \longrightarrow C{=}O\begin{matrix}NH_2\\NH_2\end{matrix} + H_2O$$

When ***earthworms*** are immersed in water they become ammonotelic (***Delaunay,*** 1934). But when they are kept under moist air, they produce more urea than ammonia (***Bahl,*** 1945).

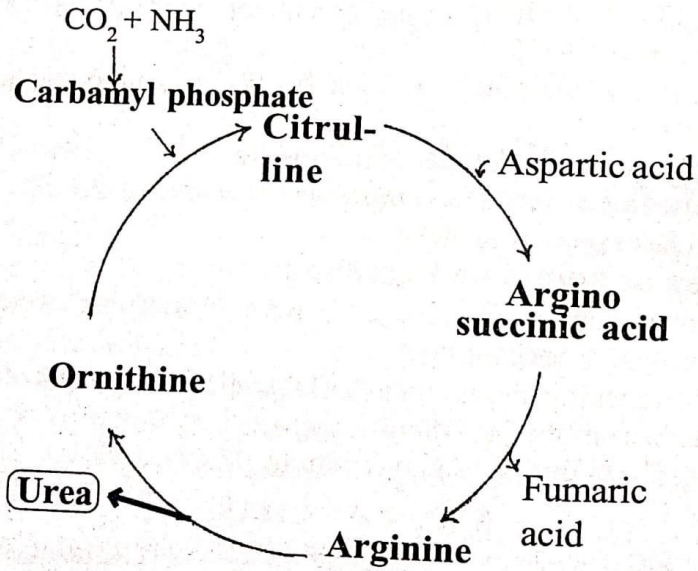

Fig.38.7: Krebs urea cycle.

Xenopus is ammonotelic in water, but becomes ureotelic during desiccation (***Janssens,*** 1972).

Amphibian ***tadpoles*** are ammonotelic. They excrete 40% of nitrogen as ammonia. After metamorphosis ammonia excretion is reduced to 12.5% and urea excretion increases proportionately.

All mammals including prototheria are ureotelic. The urea excretion in mammals

is associated with placentation. The foetal urea is transported to the maternal blood for excretion through placenta.

Chemically, urea consists of two molecules of ammonia united to one molecule of CO_2.

Urea is formed from ammonia through ornithine cycle (Please refer above), from amino acid (arginine) and from purine metabolism.

3. Uricotelic Animals

Animals excreting uric acid are called ***uricotelic animals.*** The process of excretion of uric acid is called ***uricotelism.*** All terrestrial animals are uricotelic. Eg. *Insects, reptiles* and *birds.*

Uric acid is excreted as thick ***pastes*** or ***pellets***. Uric acid is ***insoluble*** in water. Hence it does not require water for excretion. So uricotelism is exhibited by animals which require water conservation.

Water conservation is essential for desert animals and those which live in dry places. Eg. *Insects, land snails, reptiles* and *birds.*

Uric acid is synthesized from ***liver*** and ***Malpighian tubules***. It is formed as an end product of ***purine*** metabolism.

The formation of uric acid is more important in the development. All uricotelic organisms produce ***cleidoic eggs*** (shelled egg). The embryo completes its entire development in the egg. But the eggs contain only limited amount of water. So if they excrete soluble excretory products as ammonia and urea, they will poison the small amount of water available in the egg. Hence they excrete insoluble uric acid.

Insects and land snails excrete solid pellets of uric acid. In insects, the rectum and ***Malpighian tubules*** effectively absorb water from both faecal and excretory products. In this aspect reptiles and birds are not so efficient since they void uric acid in the form of pastes.

Crocodile is ***ammonotelic***. But when it is kept out of water, there is an increase in the amount of urea and uric acid excretion.

Environmental Influence

39 Kidney of Man

Man has two kidneys. They are the ***metanephros*** or advanced kidneys. They are located in the abdomen one on either side of the vertebral column.

The two kidneys are not located at the same level; the right kidney is slightly lower than the left one. This is because the right side of abdomen is occupied by the liver.

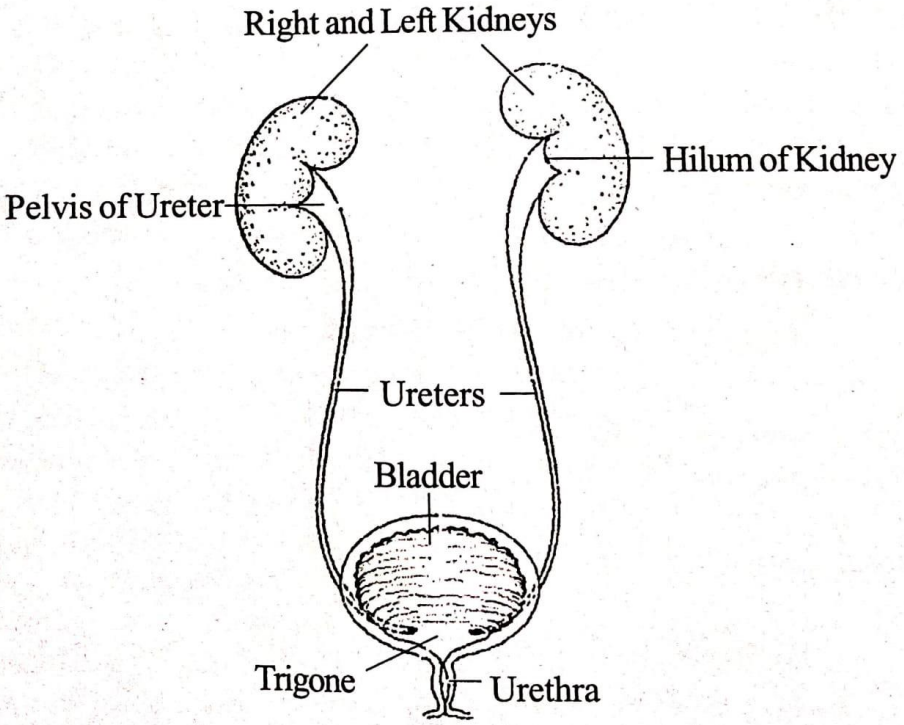

Fig.39.1: Urinary system of Man.

It is ***bean shaped***. The outer surface is convex and inner surface is concave. The inner surface has a deep notch called ***hilus.*** The ureters, renal artery, renal vein and nerves enter the kidney through the hilus.

In a section of the kidney, the peripheral portion appears dark reddish brown and the central portion appears light red. The peripheral area is called ***cortex*** and the central area is called ***medulla.***

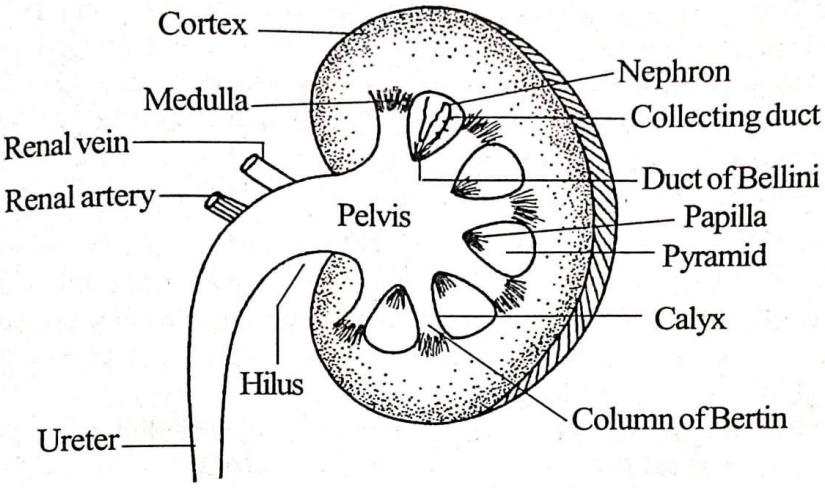

Fig.39.2: Kidney of man.

The ureter entering the hilus expands to form a funnel- like structure called ***pelvis.*** The pelvis is produced into a number of cup-like structures called ***calyces*** (calyx,

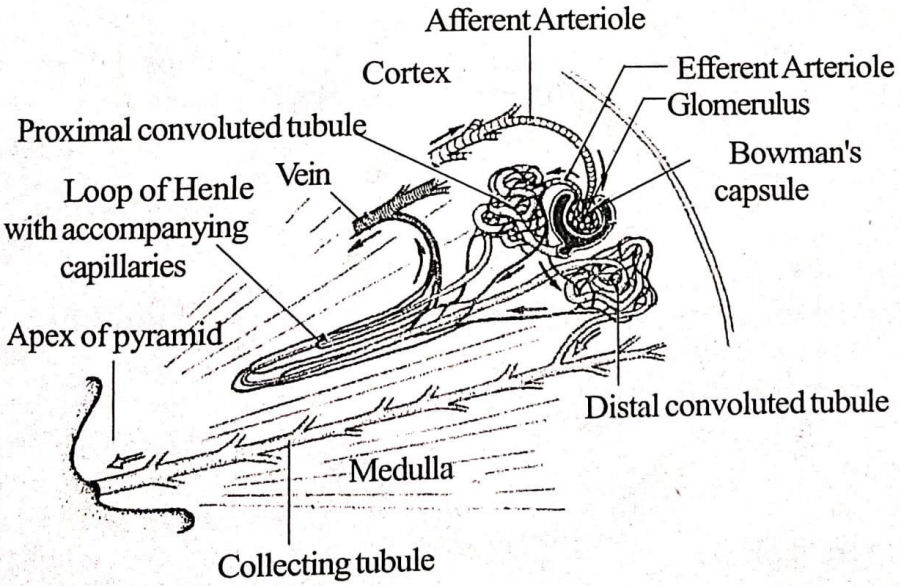

Fig.39.3: A Nephron

sing). The cavity of each calyx is occupied by a cone-like structure called ***pyramid.*** The apex of the pyramid is called ***papilla*** or ***area eribrosa.*** It projects into the cavity of the calyx.

Each kidney contains 10 to 15 pyramids. The pyramids are separated by the projections of cortex called ***renal columns of Bertin.***

Each pyramid has thousands of tubules called ***uriniferous tubules*** or ***nephroi*** and blood vessels. This gives a striated appearance to the pyramid. In each pyramid many uriniferous tubules join together to form a common tubule called ***collecting tubule*** or ***collecting duct***. It is straight and tree-like receiving many ***nephroi.***

Finally this straight duct called ***duct of Bellini*** opens at the apex of pyramid. The apex of the pyramid has a number of perforations. Through these openings the ducts of Bellini open into the pelvis which passes into the ureter.

Nephron

Nephron is *the structural and functional unit of the kidney.* It is also called ***uriniferous tubule.*** A nephron consists of a twisted tubule closed at one end, open at the other end and a network of associated blood vessels. Each kidney of man is formed of about one to 1.3 million nephrons.

Each ***nephron*** has a length of ***4 cm***. The total length of all nephrons (2 to 2.6 millions) will be about ***65 km***.

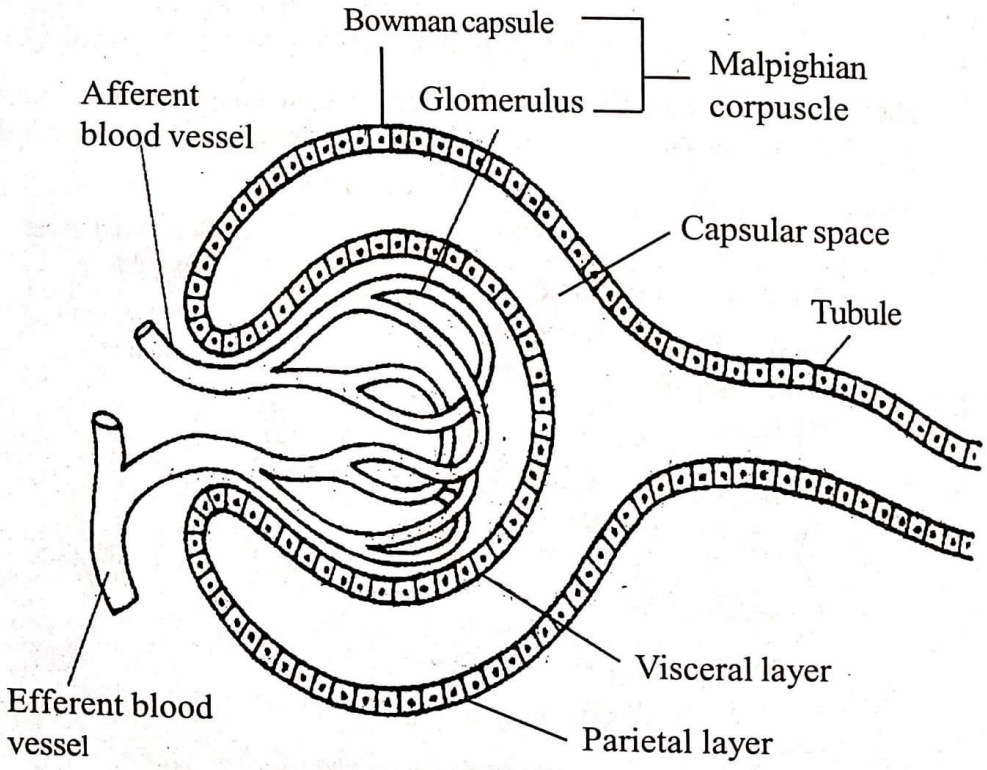

Fig.39.4: Malpighian corpuscle.

The number of nephrons decreases after 45 to 50 year at the rate of 1% every year.

Human kidney has two types of nephrons. They are:

1. *Cortical nephrons* - The Malpighian corpuscles are in the outer cortex. 85% of nephrons are this type.
2. *Juxtamedullary nephrons* - The Malpighian corpuscles remain in the inner cortex near the medulla.

Each nephron consists of two parts namely :

1. *Malpighian corpuscle*
2. *Renal tubule.*

The Malpighian corpuscle is a globular structure located at one end of the nephron. It is also called ***renal corpuscle***.

It is the ***filtration unit*** of the nephron.

It is located in the ***cortex*** of the kidney.

The Malpighian corpuscle is formed of two components, namely

1. *Bowman capsule*
2. *Glomerulus.*

Bowmans capsule is a double-walled cup. The inner wall is called ***visceral layer*** and the outer wall is called ***parietal layer***. The visceral layer contains ***pores***. The space lying between the two walls is called ***capsular space.*** The capsular space of the Bowman capsule is continuous with the lumen of the tubule.

The Bowman capsule can be compared to a ***funnel with a filter paper***.

The cavity of the cup contains a ***network of capillaries*** called ***glomerulus.***

The glomerulus receives blood through a small arteriole called ***afferent vessel.*** Similarly, the blood comes out from the glomerulus through another arteriole called ***efferent vessel.***

The glomerulus and Bowman capsule are together called ***Malpighian corpuscle.***

The Bowman capsule leads into the tubular portion.

The renal tubule is formed of three components.

1. *Proximal convoluted tubule*
2. *Henle's loop*
3. *Distal convoluted tubule.*

The proximal portion of the tubule arising from the ***Bowmans capsule*** is thrown into many coils called ***proximal convoluted tubule.***

It leads into an ***U shaped*** portion called ***Henle's loop.*** It has three regions, namely a proximal ***descending limb,*** a middle ***hair pin bend*** and a distal ***ascending limb.***

The descending limb is made up of two components namely,

Thick descending segment

Thin descending segment.

Thick descending segment is the direct continuation of the proximal convoluted tubule.

The ***thin descending segment*** connects the thick descending segment and th hair-pin bend.

The ***ascending limb*** is made up of two components namely,

1. *Thin ascending segment*
2. *Thick ascending segment.*

Thin ascending segment is the continuation of hairpin bend and it leads int the ***thick ascending segment*** of ascending limb.

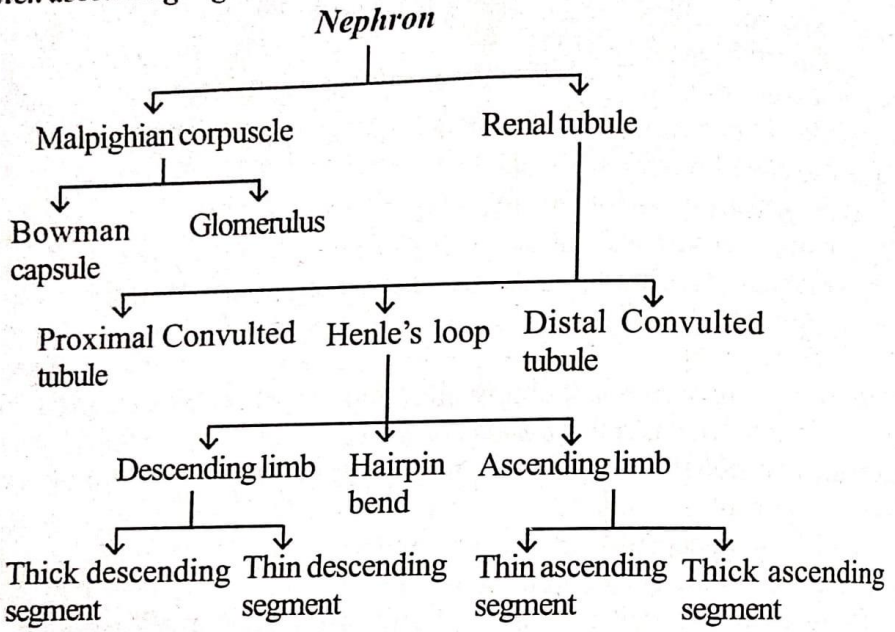

Fig.39.5: Components of a nephron.

The thick ascending limb continues into the ***distal convoluted tubule.***

A group of ***collecting ducts*** unite to form a ***duct of Bellini.***

The ducts of Bellini open into a ***pyramid.***

The pyramids opens into the ***minor calyx.*** Three or four minor calyces unite to form a ***major calyx.***

The major calyces open into the ***pelvis.*** The pelvis leads into the ***ureter.***

The ureter opens into the ***urinary bladder.*** The urinary bladder opens out through the ***urethra.***

The Henle's loop alone remains in the ***medulla.*** The remaining portions of the nephrons remain in the ***cortex.***

Each kidney receives arterial blood through a ***renal artery*** and the venous blood leaves the kidney through ***renal vein.*** The artery divides and redivides to form ***arterioles.*** Most of these arterioles supply the glomerulus as ***afferent vessels.*** They leave the glomerulus as ***efferent vessels.*** The efferent vessels, after leaving the glomerulus, break up into small capillaries which envelope the whole uriniferous tubule. The blood vessels then converge and form a system of veins that merge to form renal vein by which blood leaves the kidney.

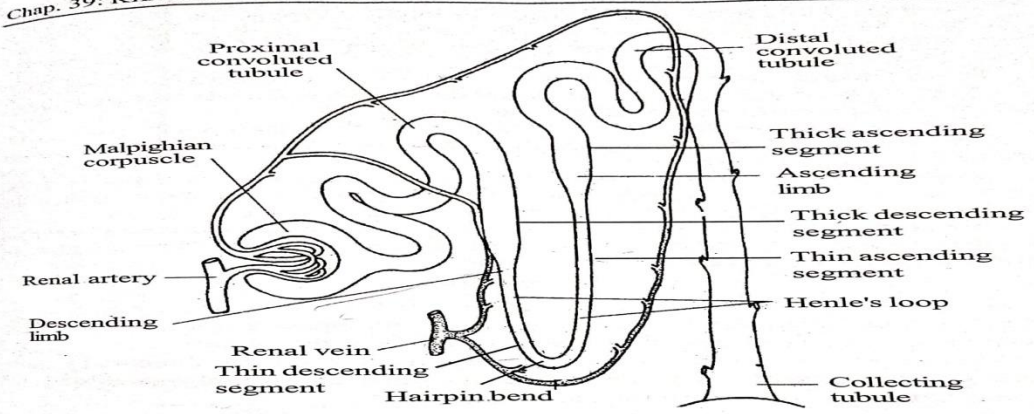

Fig. 39.6: Nephron.

Hormonal Regulation of Kidney

41 Formation of Urine

Urine is the excretory fluid eliminated by the kidney. Formation of urine is a highly sensitive and complex process. It involves three steps. They are,

1. *Ultrafiltration*
2. *Reabsorption* and
3. *Secretion*

1. Ultrafiltration

The straining of blood by the Malpighian corpuscle for minute particles is called ***ultrafiltration.*** *It is the first step in urine formation.*

Malpighian corpuscle functions as the ***filtering apparatus***. The Bowman capsule is like a ***funnel with filter paper***. The ***glomerulus*** provides the ***blood*** for filtering.

The blood and the capsular space of the Bowman capsule are separated by capillary ***endothelium,*** a ***basement membrane*** and capsular ***epithelium.*** Arterial blood flows in the glomerulus. This blood is filtered by the Bowman capsule and it enters the capsular space. The fluid present in the capsular space is called ***glomerular filtrate.***

The glomerular filtrate exactly resembles a ***cell free*** and ***protein*** free blood. The constituents of glomerular filtrate remain in the same ratio as those of the blood.

In 24 hours, ***180 litres*** of glomerular filtrate is formed. ie. ***125ml/*** minute.

Ultrafiltration is facilitated by the following factors :

- *Pores present in the Malpighian corpuscles.*
- *Blood pressure.*
- *Renal blood flow.*

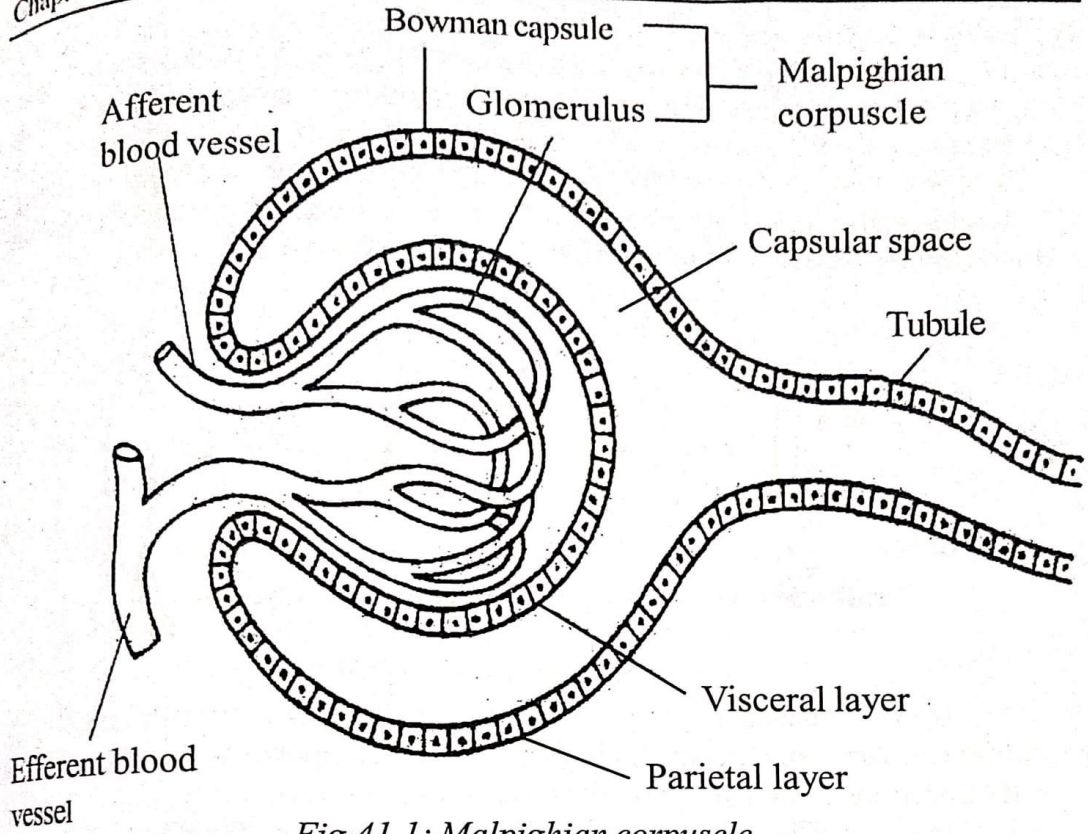

Fig.41.1: Malpighian corpuscle.

- *Osmotic pressure.*
- *Hydrostatic pressure.*
- *Constriction of glomerular arterioles.*
- *Sympathetic stimulation.*
- *Hormonal factors.*

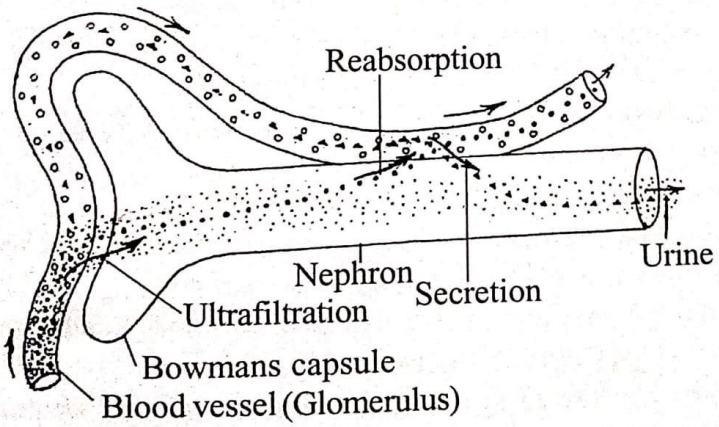

Fig.41.2: Mechanism of urine formation showing ultrafiltration, reabsorption and secretion.

2. Reabsorption

Reabsorption is the intake of useful substances into the blood from the glomerular filtrate. Every day about 180 litres of glomerular filtrate are formed. But a normal man excretes only 1 to 1.5 litres of urine, i.e about 1% of the glomerular filtrate.

The remaining bulk i.e 99% of glomerular filtrate is reabsorbed into the blood.

Reabsorption is ***selective reabsorption*** because useful substances are reabsorbed and the wastes are retained in the glomerular filtrate.

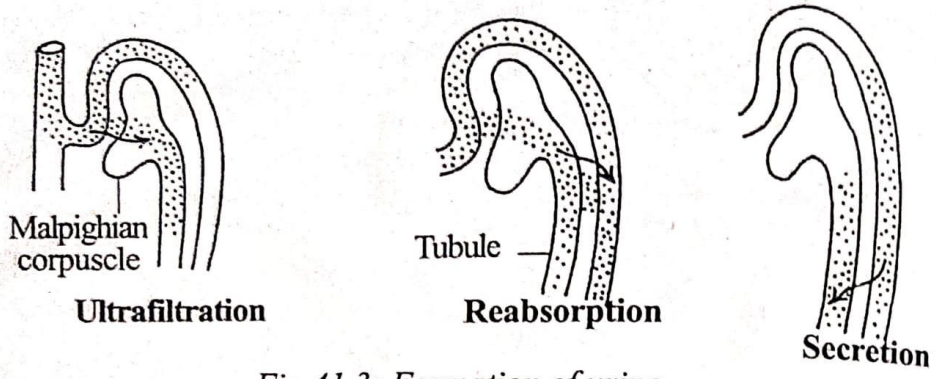

Fig.41.3: Formation of urine.

The useful substances of glomerular filtrate are reabsorbed into the blood by the way of the capillary network enveloping the uriniferous tubule.

Reabsorption is the function of the renal tubule.

The following substances are reabsorbed from the glomerular filtrate of the uriniferous tubule:

1. The ***amino acids, glucose, protein*** and ***phosphate*** are reabsorbed in the first part of the proximal tubule.
2. ***Sodium chloride*** and ***bicarbonates*** are absorbed along the proximal tubule and the distal tubule.
3. ***Potassium*** is reabsorbed in the proximal tubule.
4. ***Water*** is reabsorbed from the distal tubules and collecting duct.
5. ***Sodium*** is reabsorbed from the ascending limb.

The rate of reabsorption varies from 100% to negligible amounts.

1. The reabsorption of glucose is 100%.
2. The reabsorption of water and sodium is 99%.
3. ***Urea, uric acid, creatine***, etc. are reabsorbed in negligible amount.

As the renal fluid moves into the collecting duct, the renal fluid is called ***urine.***

At the end of the duct, the urine is more concentrated than the original glomerular filtrate and is also ***hypertonic*** to plasma.

Thus out of the 180 litres of glomerular filtrate about 179 litres are reabsorbed.

Water reabsorption occurs by osmosis which is a ***passive*** and non-energy requiring process. But the absorption of glucose, amino acids and vitamins is an ***active process.***

The cleaning of the blood by the kidney can be compared to the housewife who wants to clean up a dirty room. To get a clear wash she empties the room of all its portable furniture (table, chairs, pictures and so on) as well as the waste materials. Once the waste has been disposed off all the furnitures are returned to the room again.

3. Secretion

Secretion is *the release of unwanted materials from the blood into the nephron.* The concentration of certain substances in the final urine is higher than that present in the glomerular filtrate. Again urine contains certain additional substances which are not present in the glomerular filtrate. This shows that the urinary epithelium secretes some substances into the lumen of the urinary tubule.

This secretion mainly occurs in the convoluted tubules.

Aminohippuric acid, an excretory product is secreted into the proximal convoluted tubule.

K^+ and H^+ ions are secreted by the distal convoluted tubules.

Potassium, ammonia, urea are also secreted into the tubules.

Creatinine and ***phosphates*** are other substances secreted.

Moreover, a number of foreign substances introduced into the body for therapeutic or diagnostic purposes are also removed from the plasma mainly by the tubular epithelium. Such substances include ***penicillin, phenolsulphonaphthalein,*** etc.

Hair-pin Counter Current

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