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PG AND RESEARCH DEPARTMENT OF BIOCHEMISTRY

E-NOTES

SUBJECT NAME: PHYSIOLOGY AND NUTRITION

SUBJECT CODE : CBC53

SYLLABUS

UNIT – III

RESPIRATORY AND EXCRETORY SYSTEM

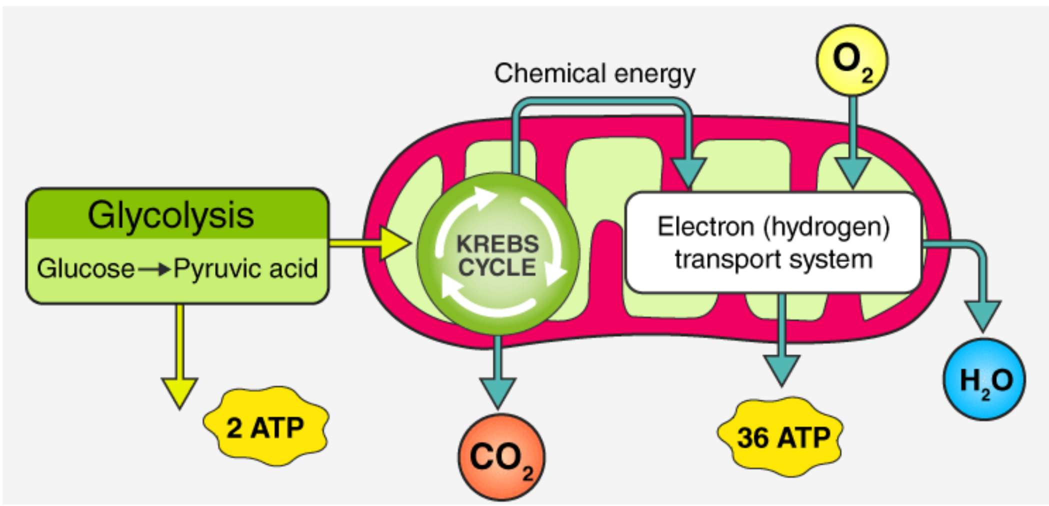
Respiratory system -Types of respiration, Transport of O2and CO2, Role of Hemoglobin in of O2 and CO2 transport. Oxygen Dissociation curve, Bohr Effect, Chloride shift.Oxygen toxicity& therapy, Artificial respiration.Structure and function of kidney and nephron, Mechanism of urine formation

Respiratory System

When we breathe, the respiratory system takes in oxygen and sends out carbon dioxide. The cells in our bodies need fresh oxygen to stay alive. As cells do their jobs, they make and give off carbon dioxide. This exchange of oxygen and carbon dioxide is called respiration.

Aerobic and Anaerobic Respiration

Aerobic Respiration



cellular respiration can be of two types: aerobic and anaerobic. Aerobic means “with air”. Therefore, aerobic respiration is the process of cellular respiration that uses oxygen to produce energy from food. This type of respiration is common in most plants and animals, including humans, birds and other mammals.

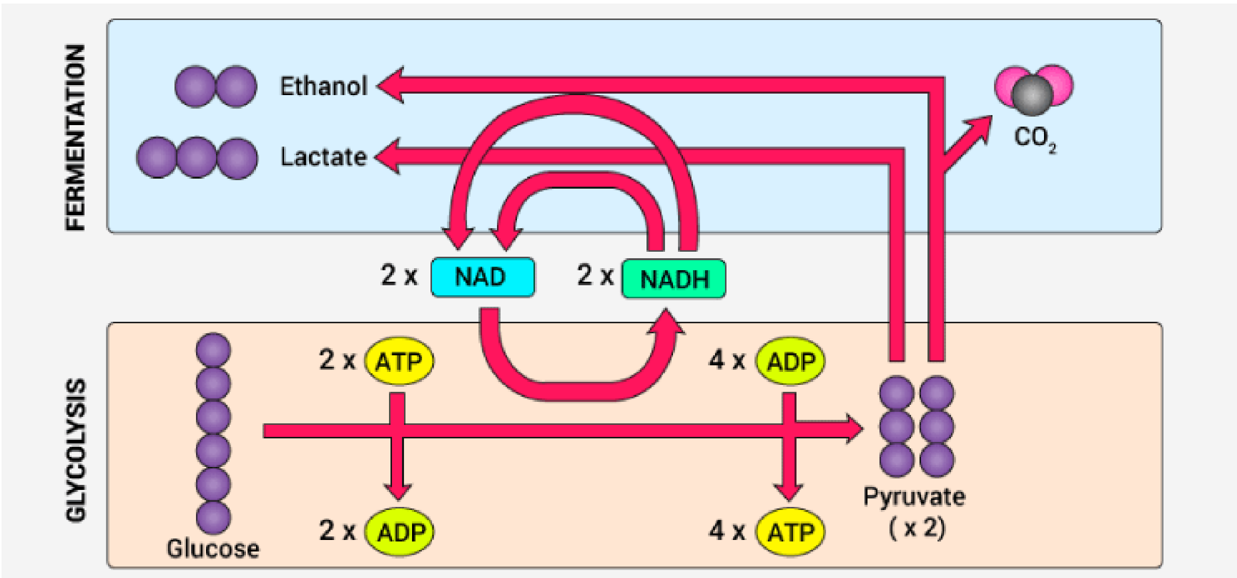
While breathing, we inhale air that contains oxygen and we exhale air rich in carbon dioxide. As we breathe in, the oxygen-rich air is transported to all the parts of our body and ultimately to each cell. Inside the cell, the food, which contains glucose, is broken down into carbon dioxide and water with the help of oxygen. The process of breaking down the food particles releases energy, which is then utilized by our body. The energy released via aerobic respiration helps plants and animals, including us, grow.

The process can be simply explained with the help of the following equation:

Glucose + Oxygen → Carbon dioxide + Water + Energy

Aerobic respiration is a continuous process and it happens all the time inside the cells of animals and plants

Anaerobic Respiration



Anaerobic means "without air". Therefore, this type of cellular respiration does not use oxygen to produce energy. Sometimes there is not enough oxygen around for some organisms to respire, but they still need the energy to survive. Due to lack of oxygen, they carry out respiration in the absence of oxygen to produce the energy they require, which is referred to as anaerobic respiration. Anaerobic respiration usually occurs in lower plants and microorganisms. In the absence of oxygen, the glucose derived from food is broken down into alcohol and carbon dioxide along with the production of energy.

Glucose → Alcohol + Carbon dioxide + Energy

Anaerobic respiration is also used by multi-cellular organisms, like us, as a temporary response to oxygen-less conditions. During heavy or intensive exercise such as running, sprinting, cycling or weight lifting, our body demands high energy. As the supply of oxygen is limited, the muscle cells inside our body resort to anaerobic respiration to fulfil the energy demand.

How do you feel when you exercise too much? Have you ever wondered why you get those muscle cramps when you run very fast? Anaerobic respiration is the culprit to be blamed. Cramps occur when muscle cells respire anaerobically. Partial breakdown of glucose, due to lack of oxygen, produces lactic acid and the accumulation of lactic acid causes muscle cramps. That is why a hot shower after heavy sports relieves the cramps as it improves blood circulation in the body, which in turn enhances the supply of oxygen to the cells.

Glucose → Lactic acid + Energy

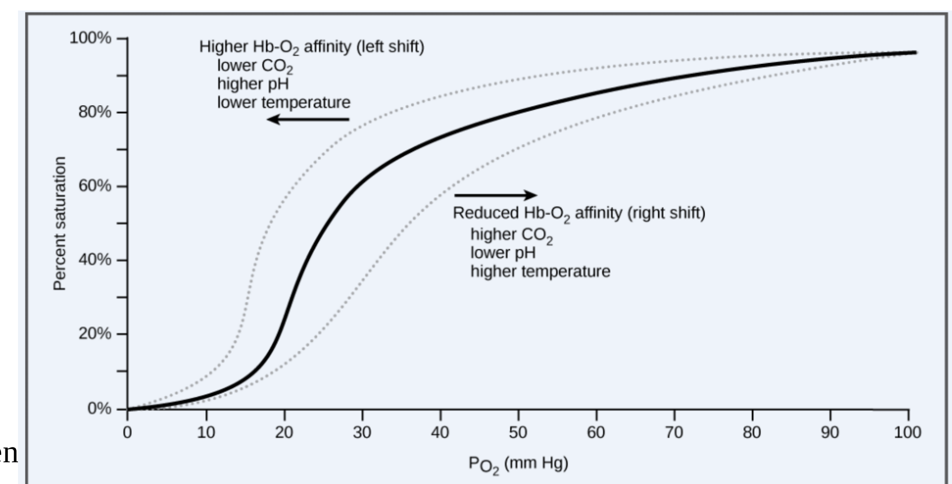
Anaerobic respiration produces a relatively lesser amount of energy as compared to aerobic respiration, as glucose is not completely broken down in the absence of oxygen.

Transport of Oxygen in the Blood

Hemoglobin

Hemoglobin, or Hb, is a protein molecule found in red blood cells (erythrocytes) made of four subunits: two alpha subunits and two beta subunits. Each subunit surrounds a central heme group that contains iron and binds one oxygen molecule, allowing each hemoglobin molecule to bind four oxygen molecules. Molecules with more oxygen bound to the heme groups are brighter red. As a result, oxygenated arterial blood where the Hb is carrying four oxygen molecules is bright red, while venous blood that is deoxygenated is darker red.

It is easier to bind a second and third oxygen molecule to Hb than the first molecule. This is because the hemoglobin molecule changes its shape, or conformation, as oxygen binds. The fourth oxygen is then more difficult to bind. The binding of oxygen to hemoglobin can be plotted as a function of the partial pressure of oxygen in the blood (x-axis) versus the relative Hb-oxygen saturation (y-axis). The resulting graph—an oxygen dissociation curve—is sigmoidal, or S-shaped (Figure 20.20). As the partial pressure of oxygen increases, the hemoglobin becomes increasingly saturated with oxygen.



The oxygen n increases, more oxygen shift to the left or the right depending on environmental conditions.

The kidneys are responsible for removing excess H+ ions from the blood. If the kidneys fail, what would happen to blood pH and to hemoglobin affinity for oxygen?

Factors That Affect Oxygen Binding

The oxygen-carrying capacity of hemoglobin determines how much oxygen is carried in the blood. In addition to P_{O2}, other environmental factors and diseases can affect oxygen carrying capacity and delivery.

Carbon dioxide levels, blood pH, and body temperature affect oxygen-carrying capacity. When carbon dioxide is in the blood, it reacts with water to form bicarbonate (HCO^{-}_{3}) and hydrogen ions (H^{+}). As the level of carbon dioxide in the blood increases, more H^{+} is produced and the pH decreases. This increase in carbon dioxide and subsequent decrease in pH reduce the affinity of hemoglobin for oxygen. The oxygen dissociates from the Hb molecule, shifting the oxygen dissociation curve to the right. Therefore, more oxygen is needed to reach the same hemoglobin saturation level as when the pH was higher. A similar shift in the curve also results from an increase in body temperature. Increased temperature, such as from increased activity of skeletal muscle, causes the affinity of hemoglobin for oxygen to be reduced.

Diseases like sickle cell anemia and thalassemia decrease the blood’s ability to deliver oxygen to tissues and its oxygen-carrying capacity. In sickle cell anemia, the shape of the red blood cell is crescent-shaped, elongated, and stiffened, reducing its ability to deliver oxygen (Figure 20.21). In this form, red blood cells cannot pass through the capillaries. This is painful when it occurs. Thalassemia is a rare genetic disease caused by a defect in either the alpha or the beta subunit of Hb. Patients with thalassemia produce a high number of red blood cells, but these cells have lower-than-normal levels of hemoglobin. Therefore, the oxygen-carrying capacity is diminished.

Transport of Carbon Dioxide in the Blood

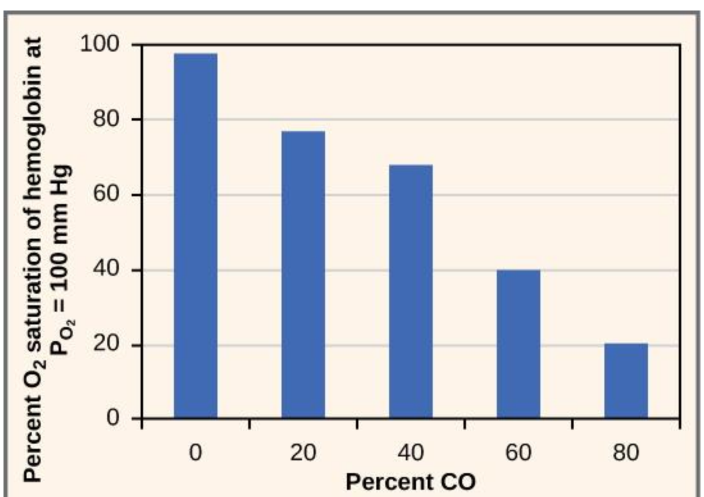
Carbon dioxide molecules are transported in the blood from body tissues to the lungs by one of three methods: dissolution directly into the blood, binding to hemoglobin, or carried as a bicarbonate ion. Several properties of carbon dioxide in the blood affect its transport. First, carbon dioxide is more soluble in blood than oxygen. About 5 to 7 percent of all carbon dioxide is dissolved in the plasma. Second, carbon dioxide can bind to plasma proteins or can enter red blood cells and bind to hemoglobin. This form transports about 10 percent of the carbon dioxide. When carbon dioxide binds to hemoglobin, a molecule called carbaminohemoglobin is formed. Binding of carbon dioxide to hemoglobin is reversible. Therefore, when it reaches the lungs, the carbon dioxide can freely dissociate from the hemoglobin and be expelled from the body.

Third, the majority of carbon dioxide molecules (85 percent) are carried as part of the bicarbonate buffer system. In this system, carbon dioxide diffuses into the red blood cells. Carbonic anhydrase (CA) within the red blood cells quickly converts the carbon dioxide into carbonic acid (H_2CO_3). Carbonic acid is an unstable intermediate molecule that immediately dissociates into (HCO^{-}_{3}) and hydrogen (H^{+}) ions. Since carbon dioxide is quickly converted into bicarbonate ions, this reaction allows for the continued uptake of carbon dioxide into the blood down its concentration gradient. It also results in the production of H^+ ions. If too much H^+ is produced, it can alter blood pH. However, hemoglobin binds to the free H^+ ions and thus limits shifts in pH. The newly synthesized bicarbonate ion is transported out of the red blood cell into the liquid component of the blood in exchange for a chloride ion (Cl^-); this is called the bicarbonate (HCO−3) ion. When the blood reaches the lungs, the bicarbonate ion is transported back into the red blood cell in exchange for the chloride ion. The H^+ ion dissociates from the hemoglobin and binds to the bicarbonate ion. This produces the carbonic acid intermediate, which is converted back into carbon dioxide through the enzymatic action of CA. The carbon dioxide produced is expelled through the lungs during exhalation.

The benefit of the bicarbonate buffer system is that carbon dioxide is "soaked up" into the blood with little change to the pH of the system. This is important because it takes only a small change in the overall pH of the body for severe injury or death to result. The presence of this bicarbonate buffer system also allows for people to travel and live at high altitudes: When the partial pressure of oxygen and carbon dioxide change at high altitudes, the bicarbonate buffer system adjusts to regulate carbon dioxide while maintaining the correct pH in the body.

Carbon Monoxide Poisoning

While carbon dioxide can readily associate and dissociate from hemoglobin, other molecules such as carbon monoxide (CO) cannot. Carbon monoxide has a greater affinity for hemoglobin than oxygen. Therefore, when carbon monoxide is present, it binds to hemoglobin preferentially over oxygen. As a result, oxygen cannot bind to hemoglobin, so very little oxygen is transported through the body (Figure 20.22). Carbon monoxide is a colorless, odorless gas and is therefore difficult to detect. It is produced by gas-powered vehicles and tools. Carbon monoxide can cause headaches, confusion, and nausea; long-term exposure can cause brain damage or death. Administering 100 percent (pure) oxygen is the usual treatment for carbon monoxide poisoning. Administration of pure oxygen speeds up the separation of carbon monoxide from hemoglobin.



As percent CO increases, the oxygen saturation of hemoglobin decreases.

Bohr Effect

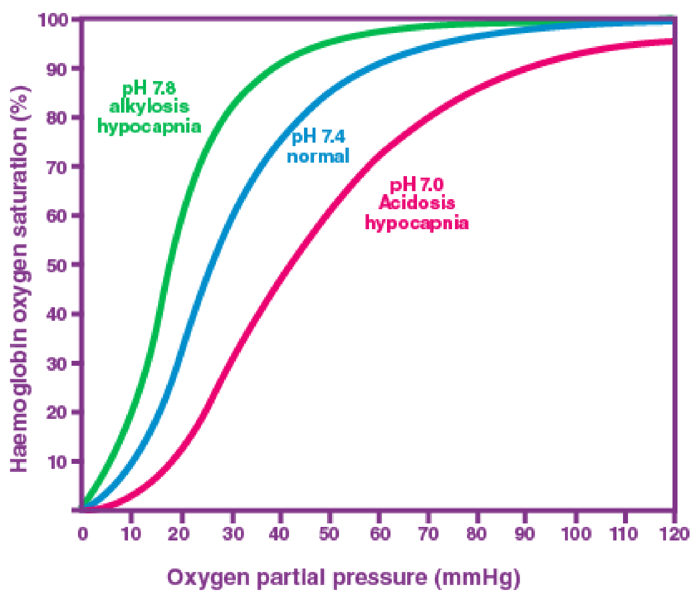
The Bohr effect explains red blood cells' ability to adjust to changes in their biochemical climate, maximizing haemoglobin-oxygen binding potential in the lungs while enhancing oxygen delivery to the most demanding tissues.

The Bohr effect was first described in 1904 by Christian Bohr, a Danish physiologist. The oxygen binding affinity of haemoglobin is inversely related to acidity and carbon dioxide concentration. The Bohr effect explains how low pH (acidity) decreases haemoglobin's affinity for oxygen, making haemoglobin more likely to offload oxygen in areas of low pH, which tissues in need of oxygen appear to have for reasons I'll explain later. And haemoglobin does not simply reclaim what it has dumped.

Experimental Discovery of Bohr Effect

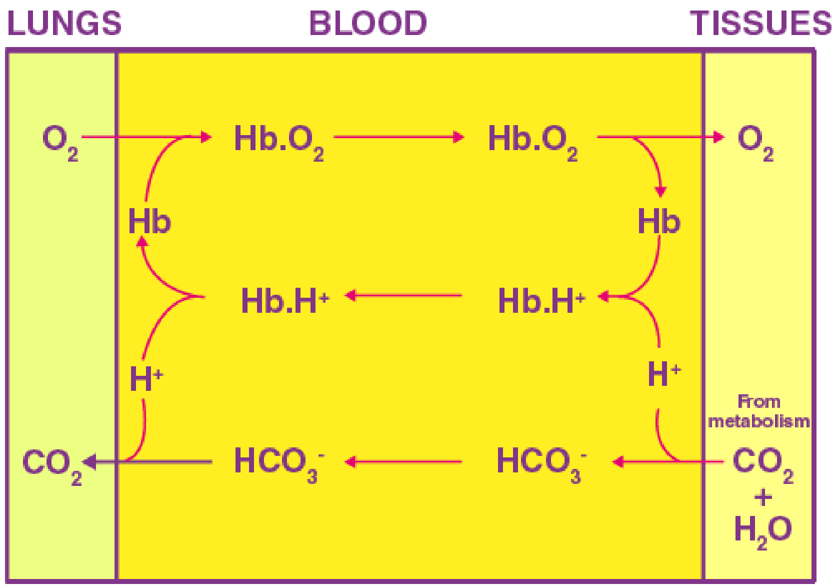
The first explanation of the Bohr effect included dissociation curves from Bohr's experiments, which showed a decrease in oxygen affinity as the partial pressure of carbon dioxide increased. One of the first examples of cooperative linking can be found here.

The Bohr effect is important because it improves oxygen supply to muscles and tissues where metabolism and carbon dioxide production occur. This aids in the delivery of oxygen to the areas where it is most needed.



The Bohr Effect allows for better oxygen unloading in metabolically active peripheral tissues like skeletal muscle during exercise. Increased skeletal muscle activity causes localized increases in carbon dioxide partial pressure, which lowers the local blood pH.

In 1903, he began collaborating with Karl Hasselbalch and August Krogh, two of his university colleagues, in an effort to recreate Gustav von Hüfner's work using whole blood rather than haemoglobin solution. The oxygen-haemoglobin binding curve had been proposed by Hüfner to be hyperbolic, but the Copenhagen group determined that it was sigmoidal after extensive testing.



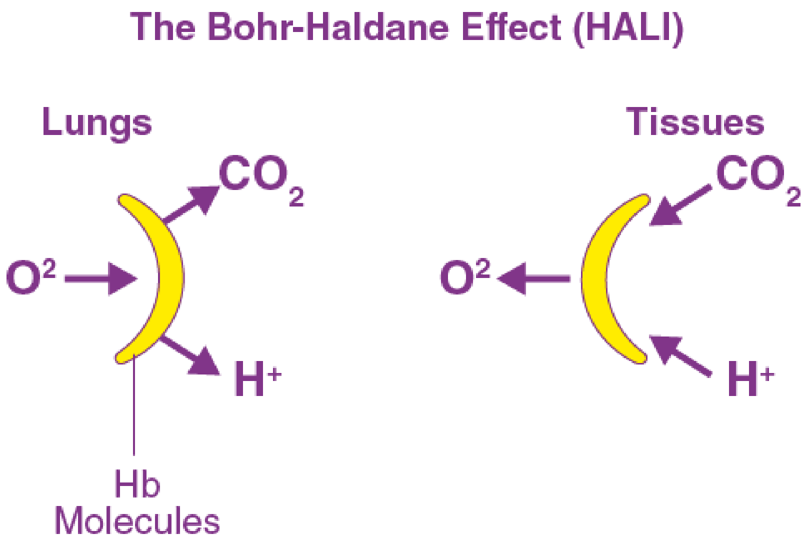
Bohr Effect Mechanism – Allosteric interactions

The solution of allosteric coefficients with only one Bohr variable is suggested by a heterotropic Bohr equation, which clarifies the biophysical symmetry in allostery. The allosteric Bohr effects should have been chosen by nature to adjust haemoglobin to cope with the quick dynamics of gas exchange, according to the Bohr equation. The discovery of the Bohr element in the Bohr equation casts doubt on haemoglobin's orthosteric cooperatively.

Because of its chemical versatility, nature chose phosphate to change proteins [1]. By taking into account allosteric and universal posttranslational modifications. The centennial paradox caused by the orthosteric Hill coefficient was solved by applying the biophysical rule of symmetry. Haemoglobin is discovered to be non-orthosteric, and the descriptive Hill equation is transformed into a quantitative Bohr equation. In the misunderstood Hill equation with prejudiced perceptiveness, the Monod-Wyman-Changeux (MWC) model eliminated the allosteric Bohr results.

Bohr Effect vs Haldane Effect

The Haldane effect is a haemoglobin property first described by John Scott Haldane in which oxygenation of blood in the lungs displaces carbon dioxide from haemoglobin, raising carbon dioxide removal. The Haldane Effect is a term that explains how oxygen affects CO2 transport. The Haldane Effect (along with the Bohr Effect) makes it easier for O2 to be released from tissues and absorbed into the lungs.



The Haldane effect explains how oxygen concentrations influence haemoglobin’s carbon dioxide affinity. The change in carbon dioxide levels is caused by oxygen in both cases. The Bohr effect, on the other hand, explains how carbon dioxide and hydrogen ions influence haemoglobin’s oxygen affinity.

The key difference between the Bohr and Haldane effects is that the Bohr effect is the decrease of haemoglobin’s oxygen binding capacity with an increase in carbon dioxide concentration or a decrease in pH, while the Haldane effect is the decrease of haemoglobin’s carbon dioxide binding capacity with an increase in oxygen concentration.

The Bohr effect helps the metabolizing tissues release oxygen from oxyhemoglobin, while the Haldane effect helps the lungs release carbon dioxide from carboxyhemoglobin. Haemoglobin has two properties: the Bohr effect and the Haldane effect. Dependent on the physiological conditions of their ultimate destination, they aid in the dissociation of respiratory gases from the haemoglobin molecule.

Artificial Respiration

Artificial respiration is also known as artificial ventilation. This is a metabolic process that stimulates or assists respiration. This is a process where a complete exchange of gases is observed via external respiration, internal respiration, and pulmonary ventilation. This process is based on facilitating manual air to a person who is not able to breathe or sufficient respiration efforts cannot be handled by him. This may also be defined as mechanical ventilation where usage of the mechanical ventilator is involved to move the air out and into the lungs (the person is not able to breathe on his own). For instance, at the time of surgery, in a coma, in trauma, or a general anaesthesia condition, this therapy is used.

It means breathing induced by some of the manipulative techniques. When the natural respiration has been stopped and the heart is running or flattering, artificial respiration is applied quickly and properly to prevent people from dying due to drowning, choking, strangulation, suffocation, carbon monoxide poisoning, or electric shock. Machines of artificial respiration are also known as artificial lung ventilation machines.

Artificial respiration mainly consists of two actions, primarily to maintain and establish an open-air passage from the upper respiratory tract to the lungs, and then the exchange of air and carbon dioxide in the terminal air sac of the lungs, while the heart is still functioning.

Different Methods of Artificial Respiration

Some of the important artificial respiration methods are Schaffer's method and Sylvester's method.

Schaffer's Method

In this method, the victim is made to lay on his belly, with one arm extended directly overhead and the other arm bent at the elbow. The face is turned outward and resting on the forearm. In this position, the nose and mouth are free for breathing. Now, the doctor kneels to the patient's waist and puts his palm on the patient's loin. The first step will be to apply the pressure by bending forward, then the doctor pushes the abdominal viscera to bring about the expiration. Pressing forward expiration takes place and the bending backwards inspiration takes place. According to some rough calculations, expiration lasts for 3 seconds and the inspiration lasts for 2 seconds. Some of the advantages of this method are its prone position~~,~~ so that water from the abdomen and lungs can be easily drained~~,~~; it is a very simple method, non-tiring, and it can be continued for a long time.

This method can be applied~~,~~ if there are injuries to the thorax or back. The main disadvantage of this method are that inspiration is passive and the expiration is active, which is not physiological. This method is not applied to patients with injuries in the abdomen.

Sylvester's Method

It is the supine position, in which the pillow is given below the shoulder and the neck is fully extended. During this method, the doctor will kneel near the patient’s head, facing towards the patient. The doctor will catch the patient's wrist and by bending the doctor will pull the patient’s arms up, this will result in inspiration. Then bending forward the doctor will put deep pressure on the chest with the patient’s hand, this will cause expiration. In this method, inspiration should last for 3 seconds and expire for 2 seconds.

The main advantages of this method are that both inspiration and expiration are active, so good ventilation is obtained. And the disadvantage of this method is that there is no drainage of water from the lungs, due to the supine position of the patient, so this method should not be used in cases of drowning. This method is quite tiring, so assistance is required for this and if there is rib fracture or thorax this method cannot be applied.

Mouth to Mouth Respiration

This is one of the best methods of the artificial method of respiration. In this method, the doctor kneels near the patient’s neck facing toward him. And a pillow is placed below the patient’s shoulder so that the neck is extended fully. With the left- hand doctor closes the patient’s nostril and places the handkerchief on the patient’s mouth, and then the doctor will blow the expired air in the patient’s mouth, this will cause inspiration. When the mouth is taken away, expiration occurs passively.

The main advantage of this method is giving expired air containing carbon dioxide, which stimulates the patient’s respiratory centre, and in this good ventilation is obtained.

Artificial Respiration Machine

An artificial respiration machine is also known as a breathing machine or artificial ventilation machine. Some of the patients require help to breathe~~,~~; in such situations, this kind of machine is used to assist the function of the lungs.

The main purpose of the ventilator is to blow the air into the lungs, helping to maintain the level of oxygen in the blood. To use the mechanical ventilator, the medical team needs some form of access to the patient’s lungs. Like a tube is inserted into the mouth or nose to reach the lungs, this process is called intubation. Or, even a tube can be inserted into the opening of the windpipe, medically known as the trachea and this process is called a tracheostomy.

Artificial Breathing Devices

Once you have comprehended the introduction, definition, and methods in a detailed way, then it is time to get to know the devices used for artificial breathing devices. The reason behind it is that all these devices have a key role to play in following artificial respiration.

Different types of artificial respiration devices are used to treat different respiratory diseases according to the symptoms and condition of the patient. Some of the artificial breathing devices are mentioned below:-

- Chest compression system
- CPAP
- CPR devices
- CPR pocket mask
- Demand valves and aspirators
- Humidifiers
- Nebulizers
- Oxygen delivery devices
- Oxygen regulator
- Oxygen fittings
- Oxygen flowmeters and selector valves

Kidney

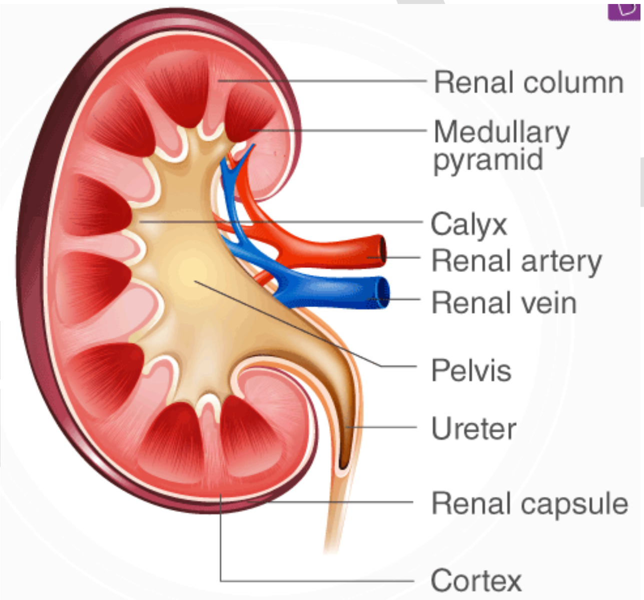
The structure of human kidney can be seen as two reddish bean-shaped organs that are located below the rib cage on each side of the spine. They are almost a fistful in size, measuring around 10-12cm. Kidneys are the main organs in the human excretory system, which takes part in the filtration of the blood before the urine is formed. Let us look at the structure of the organ for a better understanding.

External and Internal Features of Kidney

- It has a convex and concave border.
- Towards the inner concave side, a notch called the hilum is present through which the renal artery enters the kidney and the renal vein and ureter leave.

- The outer layer of the kidney is a tough capsule.
- On the inside, the kidney is divided into an outer renal cortex and an inner renal medulla.
- The hilum extends inside the kidney into a funnel-like space called the renal pelvis.
- The renal pelvis has projections called calyces(sing: calyx).
- The medulla is divided into medullary pyramids, which project into the calyces.
- Between the medullary pyramids, the cortex extends as renal columns called Columns of Bertini.
- The kidney is made up of millions of smaller units called nephrons which are also the functional units.

A simple structure of kidney can be understood by the following diagram:



Function

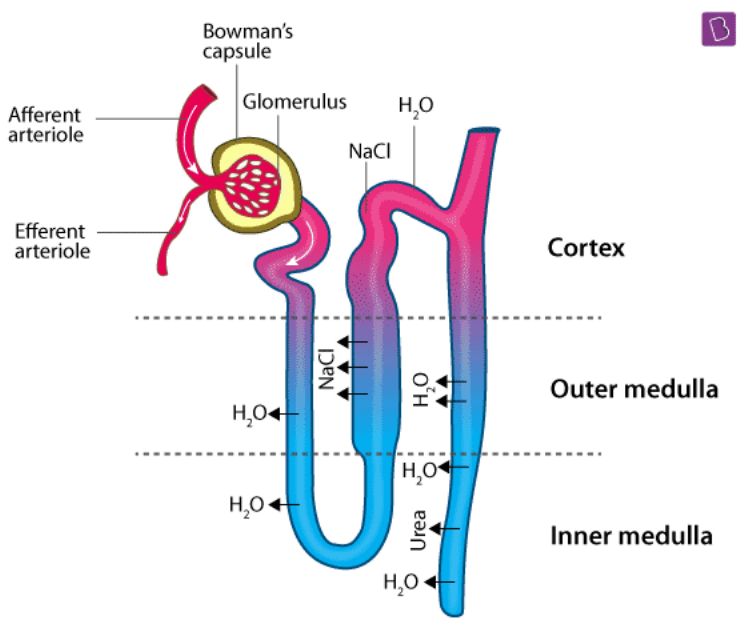
- The most important function of the kidney is to filter the blood for urine formation.
- It excretes metabolic wastes like urea and uric into the urine.
- It secretes a number of hormones and enzymes such as:
    - Erythropoietin: It is released in response to hypoxia
    - Renin: It controls blood pressure by regulation of angiotensin and aldosterone
    - Calcitriol: It helps in the absorption of calcium in the intestines
- It maintains the acid-base balance of the body by reabsorbing bicarbonate from urine and excreting hydrogen ions and acid ions into the urine.
- It also maintains the water and salt levels of the body by working together with the pituitary gland.

Nephron

A nephron is the basic structural and functional unit of the kidney. They are the microscopic structure composed of a renal corpuscle and a renal tubule. The word nephron is derived from the Greek word – nephros, meaning kidney. There are about millions of nephrons in each human kidney.

Structure of Nephron

The mammalian nephron is a long tube-like structure, its length varying from 35–55 mm long. At one end, the tube is closed, folded and expanded, into a double-walled, a cuplike structure called the Bowman's capsule or renal corpuscular capsule, which encloses a cluster of microscopic blood vessels called the glomerulus. This capsule and glomerulus together constitute the renal corpuscle.



Nephron

The structure of nephron comprises two major portions:

1. Renal Tubule
2. Renal Corpuscle

Renal Tubule

The renal tubule is a long and convoluted structure that emerges from the glomerulus and can be divided into three parts based on function.

- The first part is called the proximal convoluted tubule (PCT) due to its proximity to the glomerulus; it stays in the renal cortex.
- The second part is called the loop of Henle, or nephritic loop because it forms a loop (with descending and ascending limbs) that goes through the renal medulla.
- The third part of the renal tubule is called the distal convoluted tubule (DCT) and this part is also restricted to the renal cortex.

The capillaries of the glomerulus are enclosed by a cup-like structure called Bowman's capsule. This structure extends to form highly coiled tubules called PCT. PCT continues to form the loop of Henle which ascends to DCT, which in turn opens into the collecting duct.

The major function of tubules is reabsorption and the process can either be through active transport or passive transport. In addition, secretions by tubules help in the urine formation without affecting the electrolyte balance of the body.

- **Proximal Convoluted Tubule (PCT)**

The blood brought by the renal artery is filtered by the glomerulus and then passed to the PCT. Maximum reabsorption takes place in PCT of the nephron.PCT is the region of renal tubule where reabsorption of essential substances like glucose, proteins, amino acids, a major portion of electrolytes and water takes place. The surface area for reabsorption is facilitated by the lining of the simple cuboidal epithelium in them. Reabsorption takes place at the expense of energy, i.e., the process is active.PCT selectively secretes ions such as hydrogen, ammonia, and potassium into the filtrate and absorbs $HCO_3^-$from it. Thus, PCT maintains the electrolyte and acid-base balance of the body fluids.

- **Henle's Loop**

Henle's loop has a descending and an ascending limb. Being parts of the same loop, both the descending and ascending limbs show different permeability. The descending limb is permeable to water but impermeable to an electrolyte, while the ascending limb is permeable to electrolytes but impermeable to water. Since the electrolytes get reabsorbed at the ascending loop of Henle, the filtrate gets diluted as it moves towards the ascending limb. But reabsorption is limited in this segment.

- **Distal Convoluted Tubule (DCT)**

The DCT, which is the last part of the nephron, connects and empties its contents into collecting ducts that line the medullary pyramids. The collecting ducts amass contents from multiple nephrons and fuse together as they enter the papillae of the renal medulla.

Similar to PCT, DCT also secretes ions such as hydrogen, potassium, and NH_3 into the filtrate while reabsorbing the $HCO_3^-$from the filtrate. Conditional reabsorption of sodium ions and water takes place in DCT. Thus, it maintains the pH and sodium-potassium level in the blood cells.

Collecting Duct

Collecting duct is a long, straight tube where H+ and K+ ions are secreted to maintain the electrolyte balance of the blood. This is also the region where the maximum reabsorption of water takes place to produce concentrated urine.

Renal Corpuscle

The renal corpuscle consists of a glomerulus surrounded by a Bowman's capsule. The glomerulus arises from an afferent arteriole and empties into an efferent arteriole. The smaller diameter of an efferent arteriole helps to maintain high blood pressure in the glomerulus.

The Bowman's capsule is divided into three layers:

1. Outer Parietal layer: It is made up of epithelial cells with minute pores of diameter 12nm.
2. Middle Basement membrane: This layer is selectively permeable.
3. Inner Visceral Layer: It consists of large nucleated cells called podocytes which bear finger-like projections called podocel.

Types of Nephron

There are two types of nephron:

- **Cortical nephron**

These are the nephrons present within the cortex. These are short and comprise about 80% of the total nephrons.

- **Juxtamedullary nephron**

These have long loops of Henle and extend into the medulla. These are about 20%.

Functions of Nephron

The primary function of nephron is removing all waste products including the solid wastes, and other excess water from the blood, converting blood into the urine, reabsorption, secretion, and excretion of numerous substances.

As the blood passes through the glomerulus with high pressure, the small molecules are moved into the glomerular capsules and travel through a winding series of tubules.

The cell present in each tube absorbs different molecules excluding the glucose, water, and other beneficial molecules which are called as the ultrafiltrate. As the ultrafiltrate molecules travel down the tubules they become more and more hypertonic, which results in more amount of water to be extracted from the ultrafiltrate before it exits the nephrons.

The blood surrounding the nephron travels back into the body through the renal blood vessels, which are free of toxins and other excess substances. The obtained ultrafiltrate is urine, which travels down via the collecting duct to the bladder, where it will be stored and released through the urethra.

Though excretion in human beings takes place through lungs, skin, liver, the kidneys are the main organs of the human excretory system. They are bean-shaped organs, which weigh between 150 to 170 gms and their length ranges from 4 – 5 inches long.

The kidneys are located in the retroperitoneal space in the abdominal cavity, just below the rib cage and present in the opposite direction or facing each other on both the left and right side of the body. The right kidney is slightly smaller and lower than the left kidney.

Compared to males, the total area, size and the weight of the kidneys are smaller in females. Therefore, both male and female should be careful during their kidney transplantation.

The major functions of the kidneys are to:

1. Maintains the body's pH
2. Reabsorption of nutrients
3. Regulates blood pressure
4. Excretion of wastes from the body
5. Removal of excess fluid from the body
6. Secret hormones that help in the production of red blood cell, acid regulation, etc.

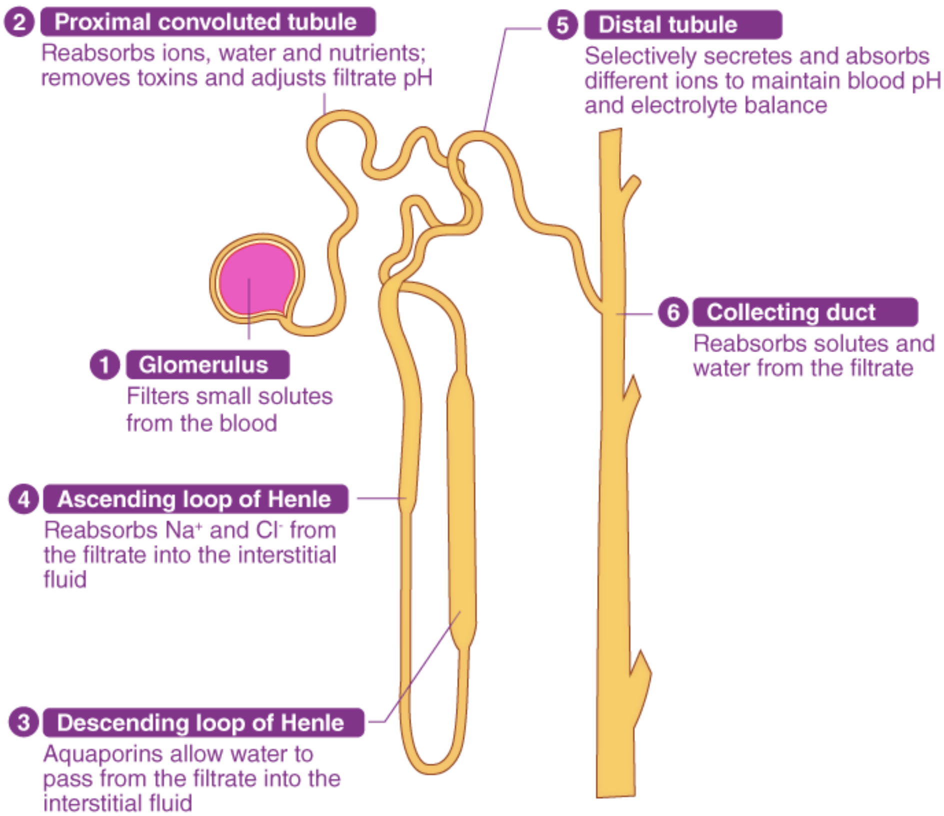
The functional unit of the kidney is the nephron. Each kidney consists of millions of nephron which plays a significant role in the filtration and purification of blood. The nephron is divided into two portions, namely, the glomerulus and the renal tubule and helps in the removal of excess waste from the body.

Urine Formation

Waste is excreted from the human body, mainly in the form of urine. Our kidneys play a major role in the process of excretion. Constituents of normal human urine include 95 per cent water and 5 per cent solid wastes. It is produced in the nephron, which is the structural and functional unit of the kidney. Urine formation in our body is mainly carried out in three phases namely

1. Glomerular filtration
2. Reabsorption
3. Secretion

Mechanism of Urine Formation



The mechanism of urine formation involves the following steps:

Glomerular Filteration

Glomerular filtration occurs in the glomerulus where blood is filtered. This process occurs across the three layers- the epithelium of Bowman's capsule, the endothelium of glomerular blood vessels, and a membrane between these two layers.

Blood is filtered in such a way that all the constituents of the plasma reach the Bowman's capsule, except proteins. Therefore, this process is known as ultrafiltration.

Reabsorption

Around 99 per cent of the filtrate obtained is reabsorbed by the renal tubules. This is known as reabsorption. This is achieved by active and passive transport.

Secretion

The next step in urine formation is tubular secretion. Here, tubular cells secrete substances like hydrogen ions, potassium ions, etc into the filtrate. Through this process, the ionic, acid-base and the balance of other body fluids are maintained. The secreted ions combine with the filtrate and form urine. The urine passes out of the nephron tubule into a collecting duct.

Urine

The urine produced is 95% water and 5% nitrogenous wastes. Wastes such as urea, ammonia, and creatinine are excreted in the urine. Apart from these, the potassium, sodium and calcium ions are also excreted.

Osmoregulation

Osmoregulation is the process of regulating body fluids and their compositions. It maintains the osmotic pressure of the blood and helps in homeostasis. This is why it is recommended to consume more water about 2-3 litres, which helps in the proper functioning of our kidneys. For example, we consume lots of water during summers, but still, we urinate fewer times in summers than in winters and the concentration of the urine is also more. The reason is that we lose lots of water from our body in summer through sweating. Thus, to maintain the fluid balance in the body our kidneys reabsorb more water.

Key Points on Urine Formation and Osmoregulation

- Urine is formed in three main steps- glomerular filtration, reabsorption and secretion.
- It comprises 95 % water and 5% wastes such as ions of sodium, potassium and calcium, and nitrogenous wastes such as creatinine, urea and ammonia.
- Osmoregulation is the process of maintaining homeostasis of the body.
- It facilitates the diffusion of solutes and water across the semi-permeable membrane thereby maintaining osmotic balance.
- The kidney regulates the osmotic pressure of blood through filtration and purification by a process known as osmoregulation.