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BIO-ZOOLOGY

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VOLUME - II

Untouchability is Inhuman and a Crime

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CONTENTS

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UNIT III | Chapter 8

Excretion

Chapter Outline

Seabirds have no problem in drinking sea water

Learning Objectives:

- *Understands different modes of excretion in animals.*
- *Learns the structure of the human excretory system.*
- *Understands the structure of a nephron, mechanism of urine formation - glomerular filtration reabsorption and secretion from the renal tubules.*
- *Visualizes the blood supply to the kidney including the nephrons*
- *Learns about the possible kidney related diseases.*

6MERK5

Earliest animal life forms arose around 700 million years ago. They were marine organisms like the modern sponges. Each cell of a modern sponge is surrounded by sea water, but it maintains an intracellular ionic composition different from that of the sea water. Evolution led to changes in the organisation of the tissue layers followed by formation of specialized external tissue layers. This provided a barrier between the external environment and internal fluid resulting in the formation of extracellular fluid. Major changes in osmoregulation and ionic regulation occurred during the evolution of chordates. The ability to control extracellular fluid composition was essential for the diversification of animals to inhabit brackish water, fresh water and land. Animals that invaded land had the risk of desiccation and were unable to excrete metabolic waste directly into the water; hence there was a need for an alternate pathway to dispose the nitrogenous wastes.

Most animals rely on kidneys to control ionic and water balance. Some

animals depend on external tissues such as the gills, skin and digestive mucosa to collectively regulate three homeostatic processes namely, osmotic regulation, ionic regulation and nitrogen excretion. Osmotic regulation is the control of tissue osmotic pressure which acts as a driving force for movement of water across biological membranes. Ionic regulation is the control of the ionic composition of body fluids. The process by which the body gets rid of the nitrogenous waste products of protein metabolism is called excretion. Nitrogen excretion is the pathway by which animals excrete ammonia, the toxic nitrogenous end product of protein catabolism. The removal of ammonia or other metabolic alternatives such as urea and uric acid is linked to ionic and osmotic homeostasis.

Fresh water vertebrates maintain higher salt concentrations in their body fluids; marine vertebrates maintain lower salt concentrations in their body fluids and terrestrial animals have more water in their body than the surrounding hence tend to lose water by evaporation. Osmoconformers are able to change their internal osmotic concentration with change in external environment as in marine molluscs and sharks. Osmoregulators maintain their internal osmotic concentration irrespective of their external osmotic environment (example: Otters). Depending on the ability to tolerate changes in the external environment, animals are classified as stenohaline and euryhaline. The stenohaline animals can tolerate only narrow fluctuations in the salt concentration (example: Gold fish), whereas the euryhaline animals are able to tolerate wide fluctuations in the salt concentrations eg., *Artemia, Tilapia* and salmons.

The major nitrogenous waste products are ammonia, urea and uric acid. Other waste products of protein metabolism are trimethyl amine oxide (TMO) in marine teleosts, guanine in spiders, hippuric acid, allantonin, allantoic acid, ornithuric acid, creatinine, creatine, purines, pyramidines and pterines.

8.1 Modes of Excretion

Excretory system helps in collecting nitrogenous waste and expelling it into the external environment. Animals have evolved different strategies to get rid of these nitrogenous wastes. Ammonia produced during amino acid breakdown is toxic hence must be excreted either as ammonia, urea or uric acid. The type of nitrogenous end product an animal excretes depends upon the habitat of the animal. Ammonia requires large amount of water for its elimination, whereas uric acid, being the least toxic can be removed with the minimum loss of water, and urea can be stored in the body for considerable periods of time, as it is less toxic and less soluble in water than ammonia.

Animals that excrete most of its nitrogen in the form of ammonia are called **ammonoteles.** Many fishes, aquatic amphibians and aquatic insects are ammonotelic. In bony fishes, ammonia diffuses out across the body surface or through gill surface as ammonium ions. Reptiles, birds, land snails and insects excrete uric acid crystals, with a minimum loss of water and are called **uricoteles**. In terrestrial animals, less toxic urea and

Animals	Most aquatic animals	Mammals, most amphibians, sharks, reptiles and terrestrial invertebrates	Birds and most reptiles, insects and land snails
Nitrogenous wastes	Ammonia	Urea	Uric acid

Figure 8.1 Excretory products in different groups of animals.

uric acid are produced to conserve water. Mammals and terrestrial amphibians mainly excrete urea and are called **ureoteles**. Earthworms while in soil are ureoteles and when in water are ammonoteles. Figure 8.1 shows the excretory products in different groups of animals.

The animal kingdom presents a wide variety of excretory structures. Most invertebrates have a simple tubular structure in the form of primitive kidneys called **protonephridia** and **metanephridia.** Vertebrates have complex tubular organs called kidneys. Protonephridia are excretory structures with specialized cells in the form of **flame cells** (cilia) in Platyhelminthes (example tapeworm) and **Solenocytes** (flagella) in *Amphioxus*. Nematodes have **rennette cells, Metanephridia** are the tubular excretory structures in annelids and molluscs. **Malpighian tubules** are the excretory structures in most insects. **Antennal glands** or **green glands** perform excretory function in crustaceans like prawns. Vertebrate kidney differs among taxa in relation to the environmental conditions. Nephron is the structural and functional unit of kidneys. Reptiles have reduced glomerulus or lack glomerulus and Henle's loop and hence produce very little hypotonic urine, whereas mammalian kidneys produce concentrated (hyperosmotic) urine due to the presence of long Henle's loop. The Loop of Henle of the nephron has evolved to form hypertonic urine. Aglomerular kidneys of marine fishes produce little urine that is isoosmotic to the body fluid. Amphibians and fresh water fish lack Henle's loop hence produce dilute urine (hypoosmotic).

DO YOU KNOW?

The average bladder holds between 300ml and 600ml of urine. If the urinary system is healthy, urine may stay in the bladder for up to about 5 hours before excretion, depending on the amount of liquid consumed. Nerves send signals to the brain when the bladder needs to be emptied, with this indication one will feel the urge to empty the bladder. The muscle in the bladder wall is called the 'detrusor' muscle. One may suffer from stress if the muscles supporting the bladder are weakened. Pelvic floor exercise helps to strengthen these muscles.

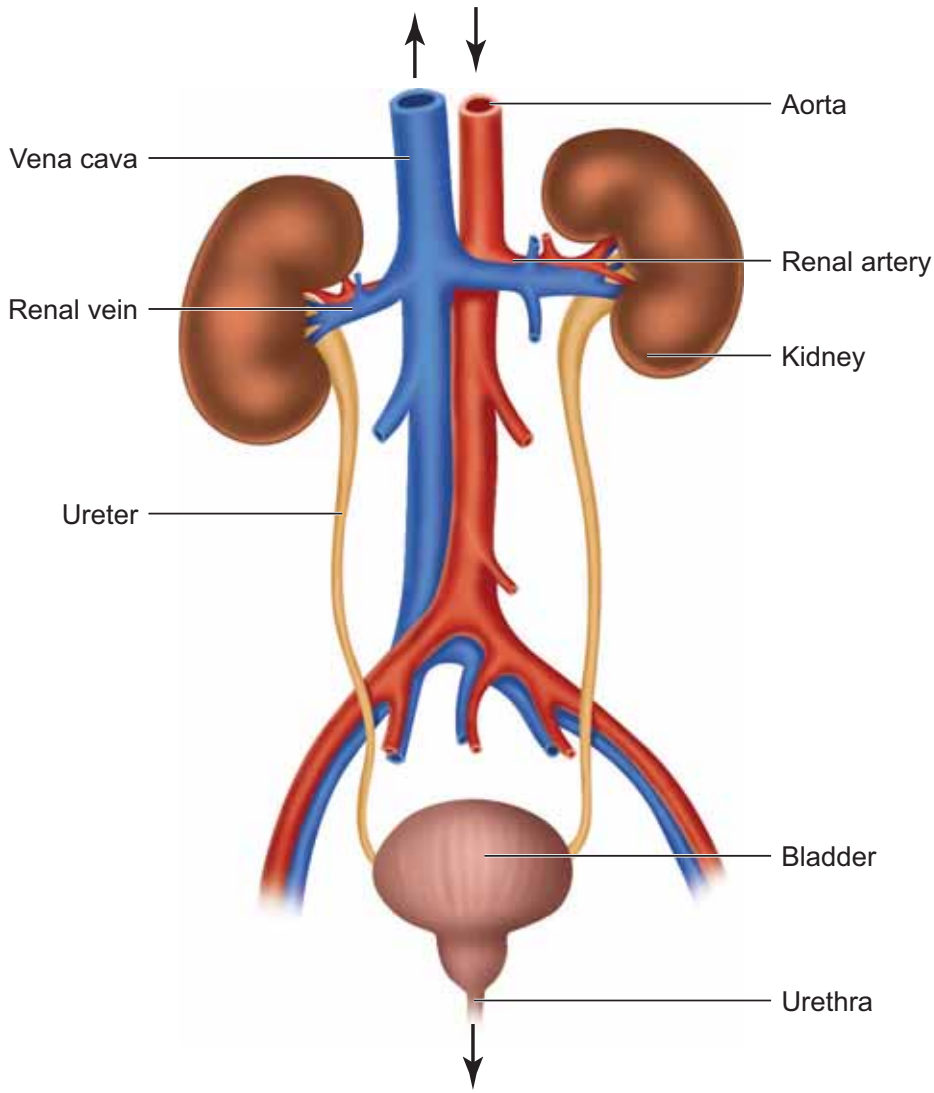


Figure 8.2 Human excretory system

8.2 Human excretory system

8.2.1 Structure of kidney

Excretory system in human consists of a pair of kidneys, a pair of ureters, urinary bladder and urethra (Figure. 8.2). Kidneys are reddish brown, bean shaped structures that lie in the superior lumbar region between the levels of the last thoracic and third lumber vertebra close to the dorsal inner wall of the abdominal cavity. The right kidney is placed slightly lower than the left kidney. Each kidney weighs an average of 120-170 grams. The outer layer of the kidney is covered by three layers of supportive tissues namely, renal fascia, perirenal fat capsule and fibrous capsule.

The longitudinal section of kidney (Figure. 8.3) shows, an outer cortex, inner medulla and pelvis. The medulla is divided into a few conical tissue masses called medullary pyramids or renal pyramids. The part of cortex that extends in between the medullary pyramids is the renal columns of **Bertini.** The centre of the inner concave surface of the kidney has a notch called the renal **hilum,** through which ureter, blood vessels and nerves innervate. Inner to the hilum is a broad funnel shaped space called the renal pelvis with projection called calyces. The

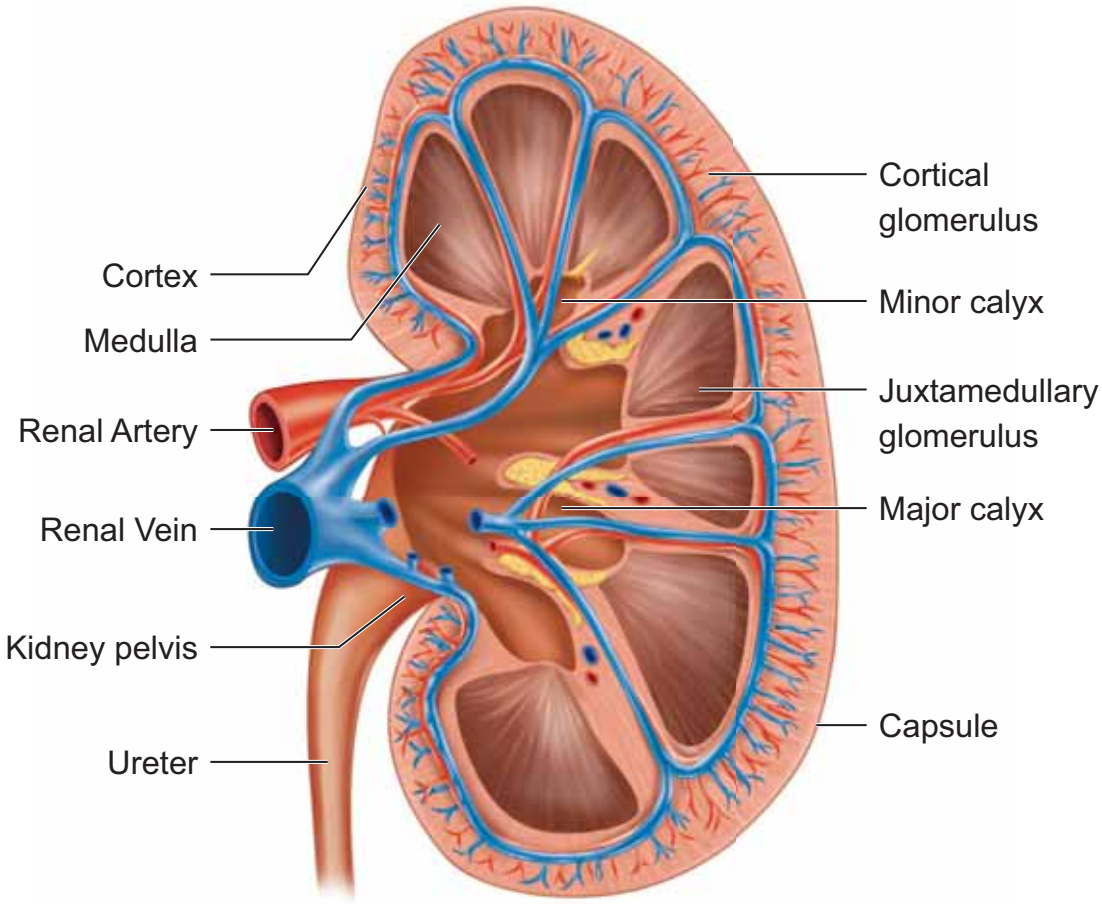


Figure 8.3 L S of kidney

renal pelvis is continuous with the ureter once it leaves the hilum. The walls of the calyces, pelvis and ureter have smooth muscles which contracts rhythmically. The calyces collect the urine and empties into the ureter, which is stored in the urinary bladder temporarily. The urinary bladder opens into the urethra through which urine is expelled out.

8.2.2 Structure of a nephron

Each kidney has nearly one million complex tubular structures called nephron (Figure 8.4). Each nephron consists of a filtering corpuscle called renal corpuscle (malpighian body) and a renal tubule. The renal tubule opens into a longer tubule called the collecting duct. The renal tubule begins with a double walled cup shaped structure called the Bowman's capsule, which encloses a ball of capillaries that delivers fluid to the tubules, called the glomerulus (Figure 8.4). The Bowman's capsule and the glomerulus together constitute the **renal corpuscle.** The endothelium of glomerulus has many pores (fenestrae). The external parietal layer of the Bowman's capsule is made up of simple squamous epithelium and the visceral layer is made of epithelial cells called podocytes. The podocytes end in foot processes which cling to the basement membrane of the glomerulus. The openings between the foot processes are called filtration slits.

The renal tubule continues further to form the proximal convoluted tubule

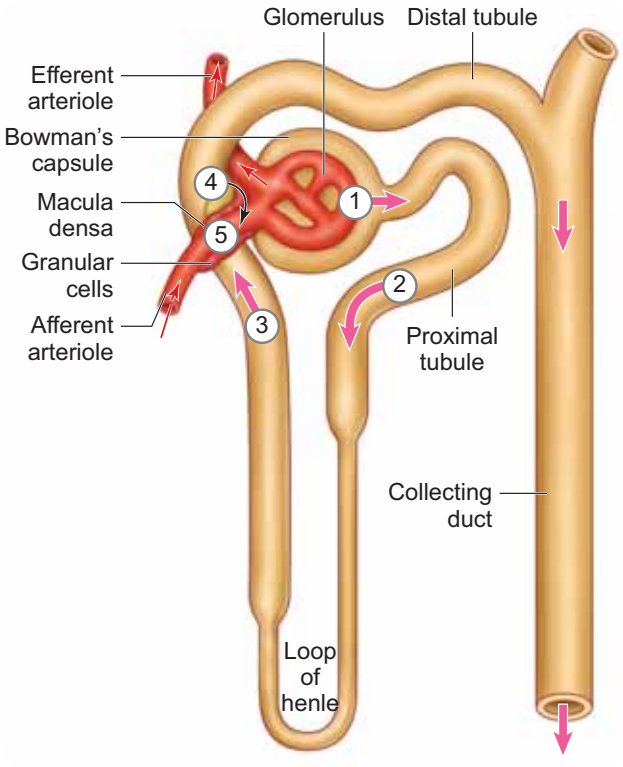


Figure 8.4 Structure of a Nephron

[PCT] followed by a U-shaped loop of Henle (Henle's loop) that has a thin descending and a thick ascending limb. The ascending limb continues as a highly coiled tubular region called the distal convoluted tubule [DCT]. The DCT of many nephrons open into a straight tube called collecting duct. The collecting duct runs through the medullary pyramids in the region of the pelvis. Several collecting ducts fuse to form papillary duct that delivers urine into the calyces, which opens into the renal pelvis.

In the renal tubules, PCT and DCT of the nephron are situated in the cortical region of the kidney whereas the loop of Henle is in the medullary region. In majority of nephrons, the loop of Henle is too short and extends

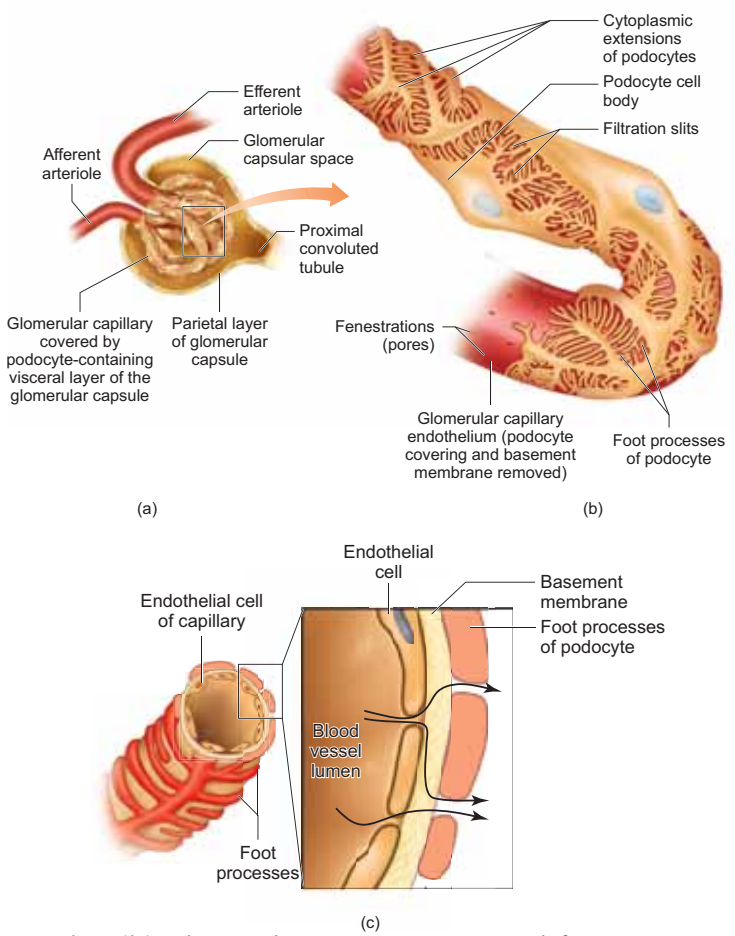


Figure 8.5 (a) Glomerulus (b) The podocytes gives several foot processes that form filtration slits (c) interacts with the basement membrane to create a filter that retains blood cells and large protein in the plasma while permitting the passage of fluids through the filtration slit.

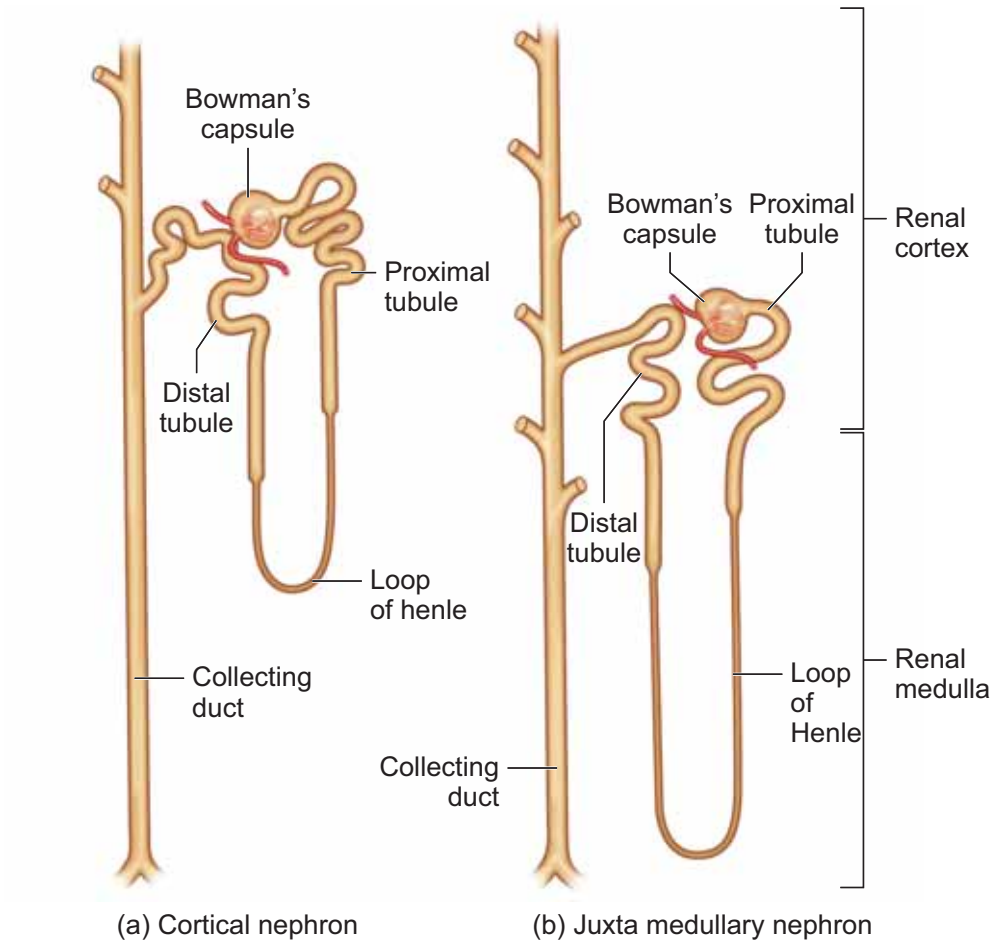


Figure 8.6 (a) Cortical nephrons are located predominantly in the outer cortex. (b) Juxtamedullary nephrons are mainly located in the inner medulla.

only very little into the medulla and are called **cortical nephrons.** Some nephrons have very long loop of Henle that run deep into the medulla and are called **juxta medullary nephrons (JMN)** (Figure 8.6 a and b)

The capillary bed of the nephrons- First capillary bed of the nephron is the glomerulus and the other is the peritubular capillaries. The glomerular capillary bed is different from other capillary beds in that it is supplied by the afferent and drained by the efferent arteriole. The efferent arteriole that comes out of the glomerulus forms a fine capillary network around the renal tubule called the peritubular capillaries. The efferent arteriole serving the juxta medullary nephron forms

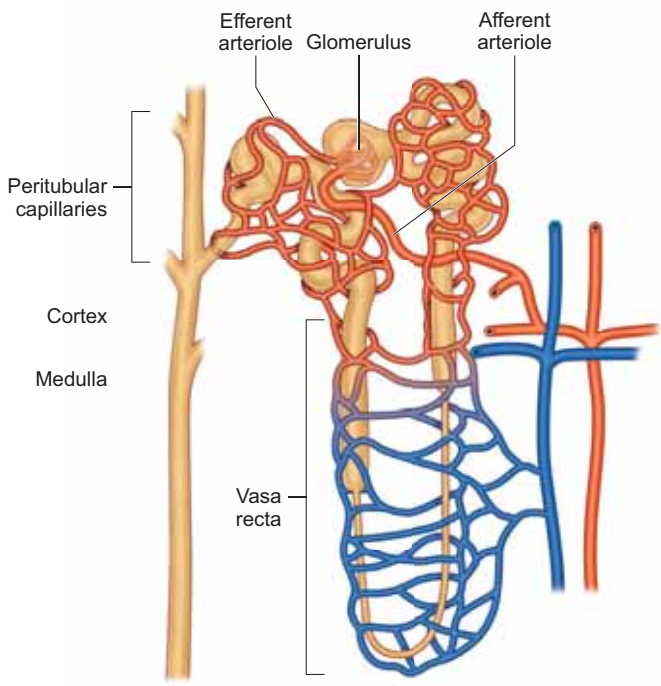
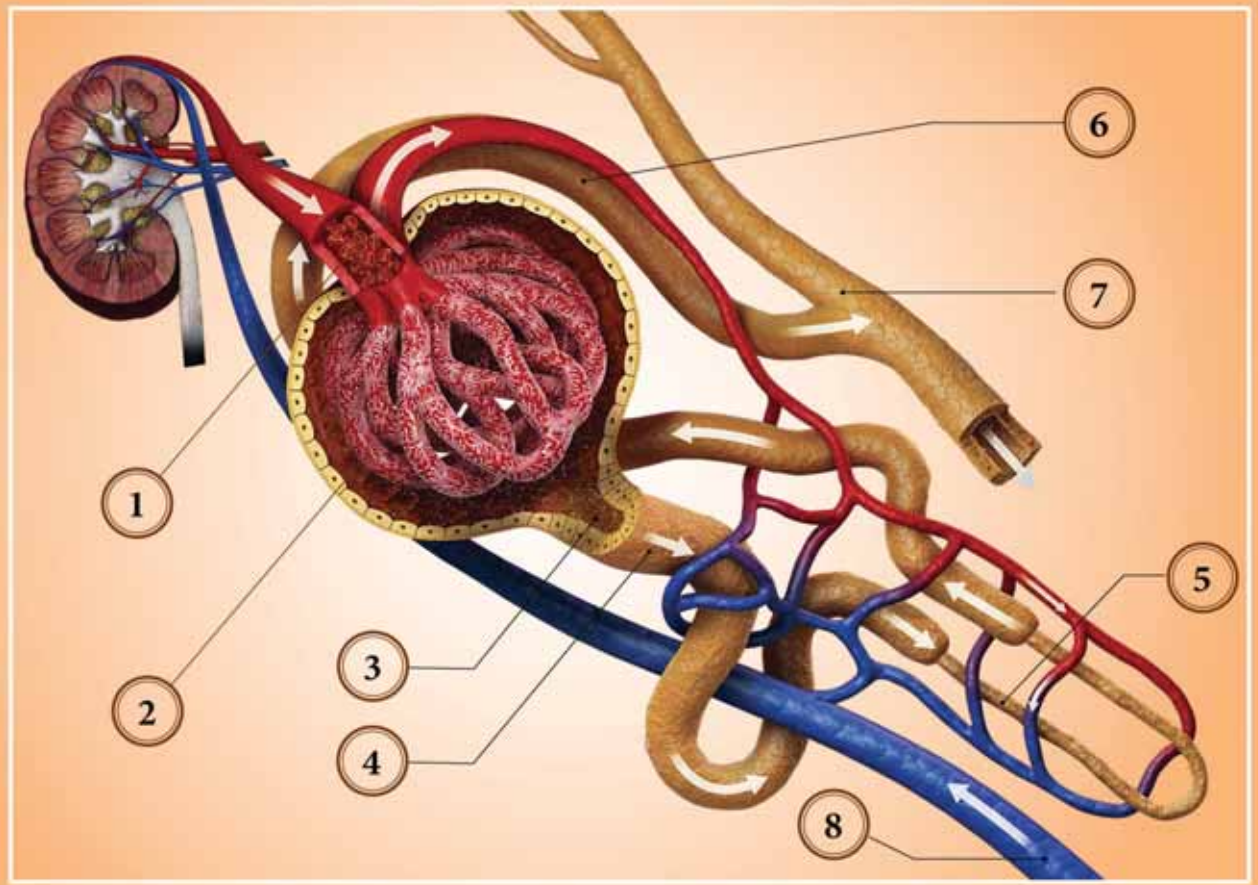


Figure 8.7 Blood vessels of the nephron.

Filtration in the Kidneys



INSIDE A KIDNEY, EACH MICROSCOPIC NEPHRON IS A COMPLEX NETWORK OF COILED CAPILLARIES AND WINDING TUBES. DOZENS OF SUBSTANCES MOVE TO AND FRO TO ELIMINATE WASTES AND FINE-TUNE URINE COMPOSITION.

1 BLOOD ENTERS THE GLOMERULUS

Blood flows from a renal arteriole into the knot of capillaries. It enters at high pressure, which will force water and other substances out of the capilaries into the capsule space.

2 CAPILLARY TO CAPSULE

Blood cells and most blood proteins are too big to cross the capsular membrane into the capsule space. But the membrane's slits and pores allow through water, mineral salts, polypeptides, and other small molecules, including wastes such as urea ammonia and creatinine.

3 PROXIMAL TUBULE

Proximal (near) to its capsule, this region allows much water to be reabsorbed into the capillaries and surrounding fluids, as well as glucose, mineral salts, and other useful substances.

4 PERITUBULAR CAPILLARIES

Also called the vasa recta, this network reabsorbs up to 99 per cent of the water in the tubule, as well as various other substances. Using active pumps, it also moves sodium from the blood to the tubule.

5 HENLE'S LOOP

As the loop of Henle dips into the renal dulla, more water moves from the tubule into the blood, as well as small amounts of mineral salts and some urea and creatinine. Some acids and amines may move into the tubule, while ammonia can go in either direction.

6 DISTAL TUBULE

Distal to (far from) its capsule, this region may see water go in or out of the tubule, depending on the concentration of water already in the tubule, while hydrogen and potassium ions move to regulate both blood and urine pH. Acids, amines, and ammonia compounds may also be transported into the tubule.

7 COLLECTING DUCT

Fine adjustment of urine composition continues into the collecting-duct system. About 5 per cent of all the water and sodium being reabsorbed into the blood is recovered here.

8 VENOUS FLOW

Blood flowing away from the nephrons carries 99 per cent of its original water, 98 per cent of its sodium, calcium, and chloride, and about 40 per cent of its urea.

bundles of long straight vessel called vasa recta and runs parallel to the loop of Henle. Vasa recta is absent or reduced in cortical nephrons (Figure 8.7).

What is the importance of having a long loop of Henle and short loop of Henle in a nephron?

8.3 Mechanism of urine formation in human

The nitrogenous waste formed as a result of breakdown of amino acids is converted to urea in the liver by the Ornithine cycle or urea cycle (Figure 8.8).

Urine formation involves three main processes namely, glomerular filtration, tubular reabsorption and tubular secretion.

i) **Glomerular Filtration**: Blood enters the kidney from the renal artery, into the glomerulus. Blood is composed of large quantities of water, colloidal proteins, sugars, salts and nitrogenous end product. The first step in urine formation is the filtration of blood that takes place in the glomerulus. This is called glomerular filtration which is a passive process. The fluid that leaves the glomerular capillaries and enters the Bowman's capsule is called the glomerular filtrate. The glomerular membrane has a large surface area and is more permeable to water and small molecules present in the blood plasma. Blood enters the glomerulus

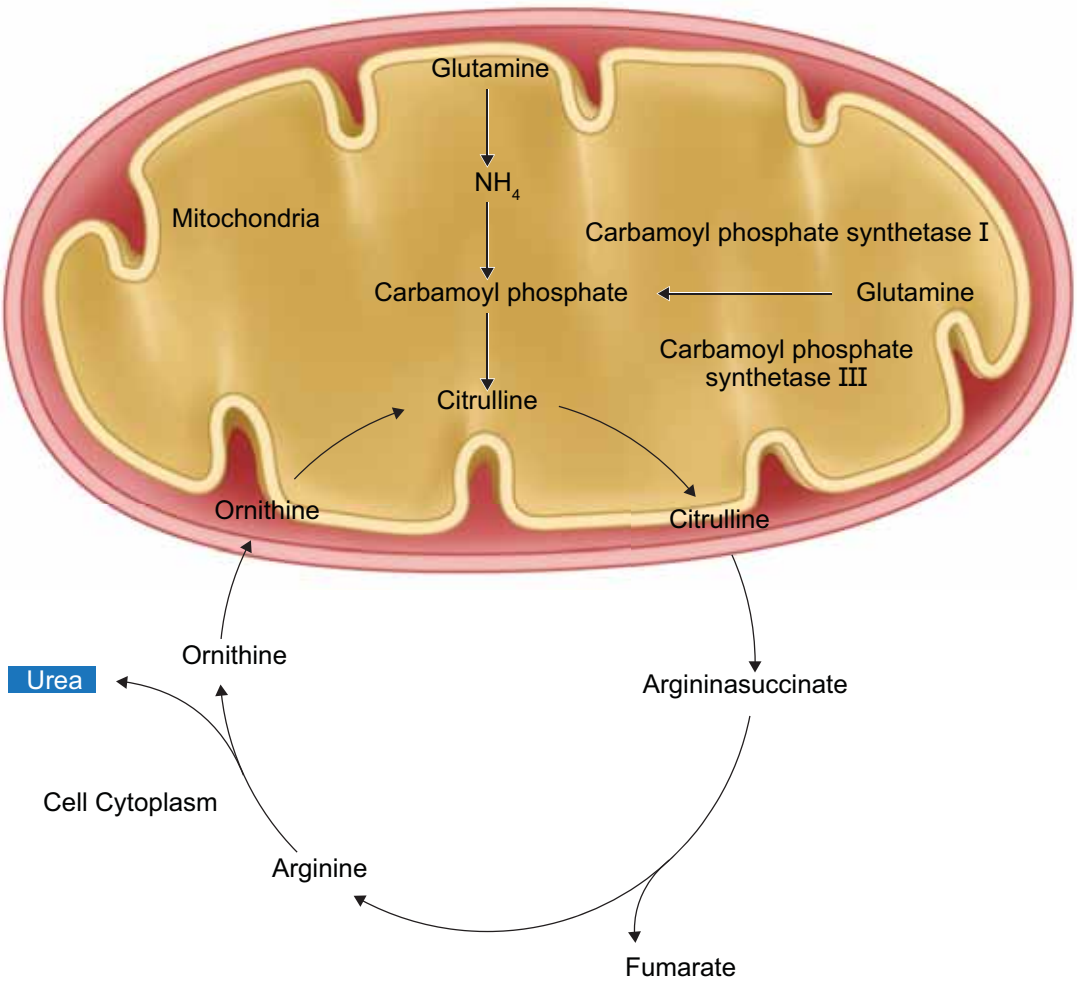


Figure 8.8 Ornithine cycle

faster with greater force through the afferent arteriole and leaves the glomerulus through the efferent arterioles, much slower. This force is because of the difference in sizes between the afferent and efferent arteriole (afferent arteriole is wider than efferent arteriole) and glomerular hydrostatic pressure which is around 55mm Hg.

Kidneys produce about 180L of glomerular filtrate in 24 hours. The molecules such as water, glucose, amino acids and nitrogenous substances pass freely from the blood into the glomerulus. Molecules larger than 5nm are barred from entering the tubule. Glomerular pressure is the chief force that pushes water and solutes out of the blood and across the filtration membrane. The glomerular blood pressure (approximately 55 mmHg) is much higher than in other capillary beds. The two opposing forces are contributed by the plasma proteins in the capillaries. These includes, colloidal osmotic pressure (30 mmHg) and the capsular hydrostatic pressure (15 mmHg) due to the fluids in the glomerular capsule. The net filtration pressure of 10 mmHg is responsible for the renal filtration.

Net filtration Pressure = Glomerular hydrostatic pressure − (Colloidal osmotic pressure + Capsular hydrostatic pressure).

Net filtration pressure = 55 mmHg − (30 mmHg + 15 mmHg)= 10mmHg

The effective glomerular pressure of 10 mmHg results in **ultrafiltration.** Glomerular filtration rate (GFR) is the volume of filtrate formed min^{-1} in all nephrons (glomerulus) of both the kidneys. In adults the GFR is approximately 120-125mL/min. Blood from the glomerulus is passed out through the efferent arteriole. The smooth muscle of the efferent arteriole contract resulting in vasoconstriction. Table 8.1 shows the relative concentrations of substances in the blood plasma and the glomerular filtrate. The glomerular filtrate is similar to blood plasma except that there are no plasma proteins.

Renal clearance is a parameter that reflects the amount of solute passing from the plasma to the urine in a given period of time. If the renal clearance is equal to the GFR it means that there is efficient filtration with little reabsorption and secretion. It is one of the parameters used to identify the efficiency of the kidney.

Table 8.1 Concentration of substances in the blood plasma and in the glomerular filtrate

Substance	Concentration in blood Plasma/g dm^{-3}	Concentration in glomerular filtrate/g dm^{-3}
Water	900	900
Proteins	80.0	0.05
Aminoacids	0.5	0.5
Glucose	1.0	1.0
Urea	0.3	0.3
Uric acid	0.04	0.04
Creatinine	0.01	0.01
Inorganic ions (mainly Na^+, K^+ and Cl^-)	7.2	7.2

A person with cirrhosis of the liver has lower than normal levels of plasma proteins and higher than normal GFR. Explain why a decrease in plasma protein would increase GFR.

In cortical nephrons, blood from efferent arteriole flows into peritubular capillary beds and enters the venous system carrying with it recovered solutes and water from the interstitial fluid that surrounds the tubule.

6MNMLS

ii) Tubular Reabsorption

This involves movement of the filtrate back into the circulation. The volume of filtrate formed per day is around 170-180 L and the urine released is around 1.5 L per day, i.e., nearly 99% of the glomerular filtrate that has to be reabsorbed by the renal tubules as it contains certain substances needed by the body. This process is called selective reabsorption. Reabsorption takes place by the tubular epithelial cells in different segments of the nephron either by active transport or passive transport, diffusion and osmosis.

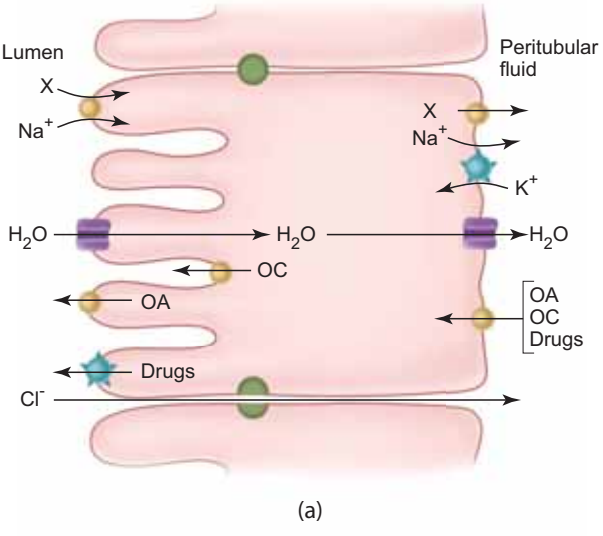


Figure 8.9 (a) Transport in the proximal convoluted tubule cells
(OA: Organic anion. OC: Organic cation).

Proximal convoluted Tubule (PCT)- Glucose, lactate, amino acids, Na^+ and water in the filtrate is reabsorbed in the PCT. Sodium is reabsorbed by active transport through sodium- potassium (Na^+ K^+) pump in the PCT. Small amounts of urea and uric acid are also reabsorbed.

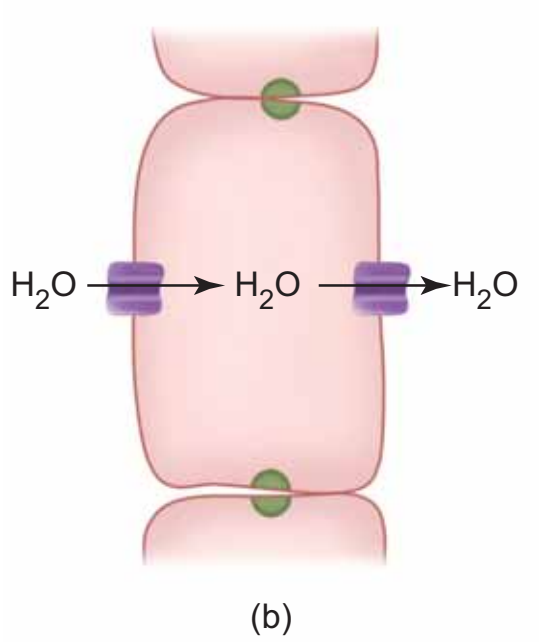


Figure 8.9 (b) Thin descending limb

Figure 8.9 (a) shows the transport in the proximal convoluted tubule cells.

Descending limb of Henle's loop is permeable to water due the presence of aquaporins, but not permeable to salts. Water is lost in the descending limb, hence Na^+ and Cl^- gets concentrated in the filtrate (Figure 8.9(b)).

Ascending limb of Henle's loop is impermeable to water but permeable to solutes such as Na^+, Cl^- and K^+ (Figure 8.9(c)).

The **distal convoluted tubule** recovers water and secretes potassium into the tubule. Na^+, Cl^- and water remains in

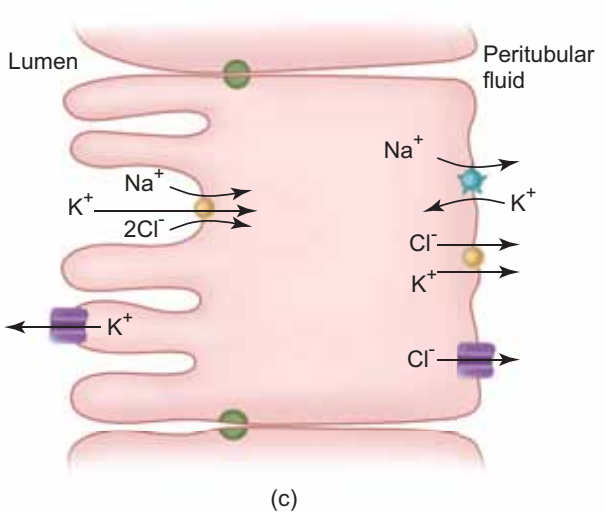


Figure 8.9 (c) Thick ascending limb

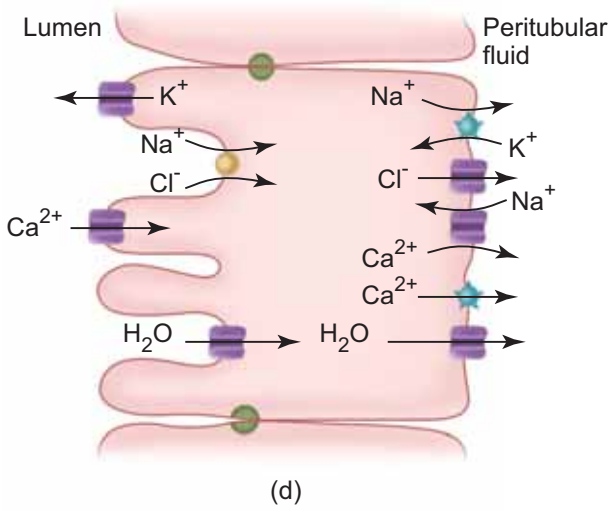


Figure 8.9 (d) Transport in the distal tubule

the filtrate of the DCT (Figure 8.9(d)). Most of the reabsorption from this point is dependent on the body's need and is regulated by hormones. Reabsorption of bicarbonate (HCO_3^-) takes place to regulate the blood pH. Homeostasis of K^+ and Na^+ in the blood is also regulated in this region.

Aquaporins are water–permeable channels (membrane transport proteins) that allow water to move across the epithelial cells in relation to the osmotic difference from the lumen to the interstitial fluid.

Collecting duct is permeable to water, secretes K^+ (potassium ions are actively transported into the tubule) and reabsorbs Na^+ to produce concentrated urine. The change in permeability to water is due to the presence of number of water-permeable channels called **aquaporins**.

Tubular secretion- Substances such as H^+, K^+, NH_4^+, creatinine and organic acids move into the filtrate from the peritubular capillaries into the tubular fluid. Most of the water is absorbed in the proximal convoluted tubule and Na^+ is exchanged for water in the loop of Henle. Hypotonic fluid enters the distal convoluted tubule and substances such as urea and salts pass from peritubular blood into the cells of DCT. The urine excreted contains both filtered and secreted substances. Once it enters the collecting duct, water is absorbed and concentrated hypertonic urine is formed. For every H^+ secreted

Osmolarity-(Thesoluteconcentration of a solution of water is known as the solutions osmolarity, expressed as milliosmoles /liter (mOsm/L)

into the tubular filtrate, a Na^+ is absorbed by the tubular cell. The H^+ secreted combines with HCO_3^-, HPO_3^- and NH_3^- and gets fixed as $H_2CO_4^+$, $H_2PO_4^+$ and NH_4^+ respectively. Since H^+ gets fixed in the fluid, reabsorption of H^+ is prevented.

Formation of concentrated urine Formation of concentrated urine is accomplished by kidneys using counter

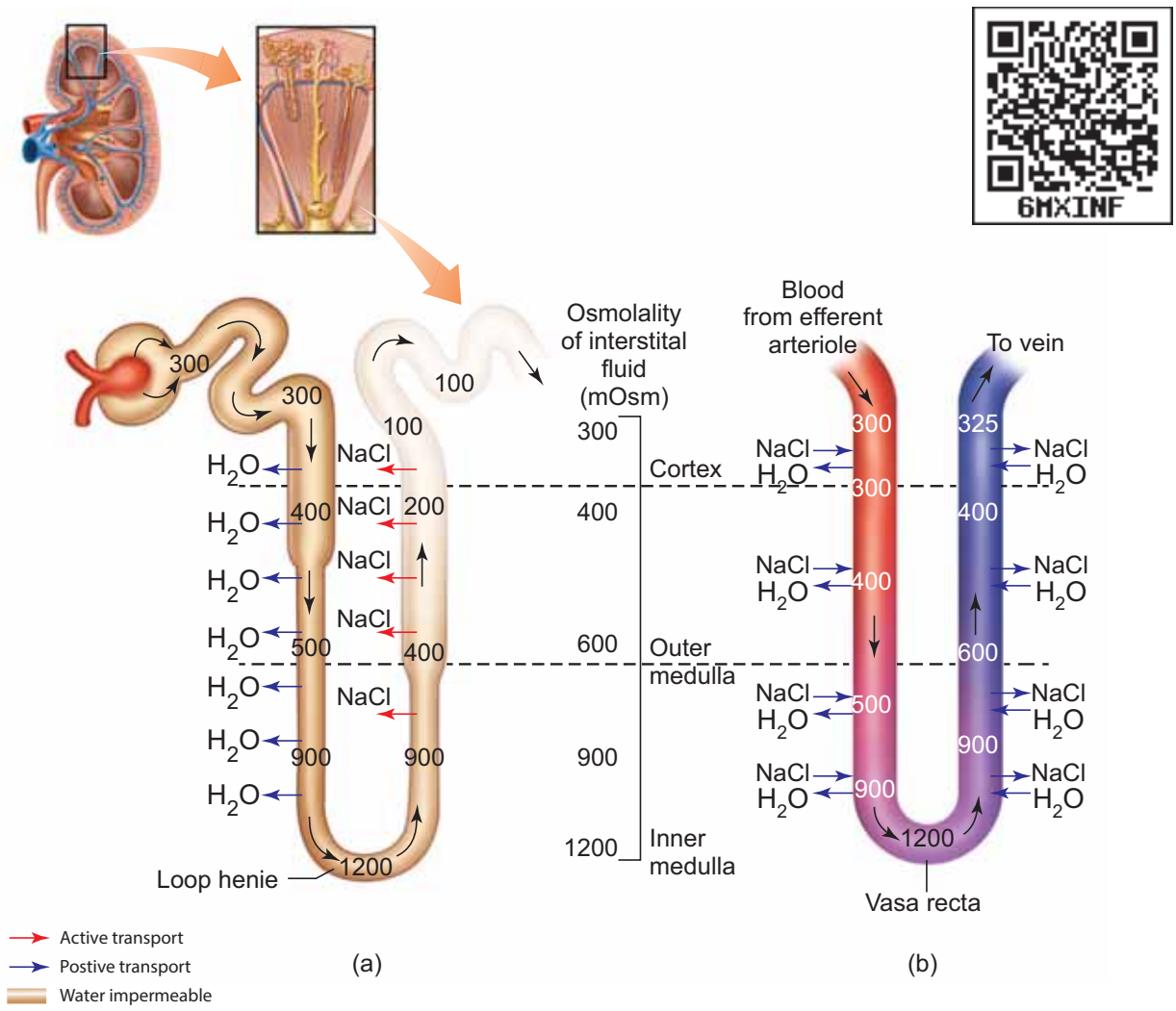


Figure 8.10 (a) Counter current multiplier – the long loops of Henle of the juxtamedullary nephrons create the medullary osmotic gradient (b) Counter current exchanger – Vasa recta preserves the medullary gradient while removing reabsorbed water and solutes.

current mechanisms. The major function of Henle's loop is to concentrate Na^+ and Cl^-. There is low osmolarity near the cortex and high osmolarity towards the medulla. This osmolarity in the medulla is due to the presence of the solute transporters and is maintained by the arrangement of the loop of Henle, collecting duct and vasa recta. This arrangement allows movement of solutes from the filtrate to the interstitial fluid. At the transition between the proximal convoluted tubule and the descending loop of Henle the osmolarity of the interstitial fluid is similar to that of the blood – about 300mOsm. Ascending and descending limbs of Henle, create a **counter current multiplier** (interaction between flow of filtrate through the limbs of Henle's and JMN) by active transport. Figure 8.10 (a) shows the counter current multiplier created by the long loops of Henle of the JM nephrons which creates medullary osmotic gradient. As the fluid enters the descending limb, water moves from the lumen into the interstitial fluid and the osmolarity decreases. To counteract this dilution the region of the

ascending limb actively pumps solutes from the lumen into the interstitial fluid and the osmolarity increases to about 1200mOsm in medulla. This mismatch between water and salts creates osmotic gradient in the medulla. The osmotic gradient is also due to the permeability of the collecting duct to urea.

The vasa recta, maintains the medullary osmotic gradient via **counter current exchanger** (the flow of blood through the ascending and descending vasa recta blood vessels) by passive transport. Figure 8.10 (b) shows counter current exchanger where the vasa recta preserves the medullary gradient while removing reabsorbed water and solutes. This system does not produce an osmotic gradient, but protects the medulla by removal of excess salts from the interstitial fluid and removing reabsorbed water. The vasa recta leave the kidney at the junction between the cortex and medulla. The interstitial fluid at this point is iso-osmotic to the blood. When the blood leaves the efferent arteriole and enters vasa recta the osmolarity in the medulla increases (1200mOsm) and results in passive uptake of solutes and loss of water. As the blood enters the cortex, the osmolarity in the blood decreases (300mOsm) and the blood loses solutes and gains water to form concentrated urine (hypertonic). Human kidneys can produce urine nearly four times concentrated than the initial filtrate formed.

List the pathways involved in the homeostatic compensation in case of severe dehydration.

8.4 Regulation of kidney function

ADH and Diabetes insipidus

The functioning of kidneys is efficiently monitored and regulated by hormonal feedback control mechanism involving the hypothalamus, juxta glomerular apparatus and to a certain extent the heart. Osmoreceptors in the hypothalamus are activated by changes in the blood volume, body fluid volume and ionic concentration. When there is excessive loss of fluid from the body or when there is an increase in the blood pressure, the osmoreceptors of the hypothalamus respond by stimulating the neurohypophysis to secrete the antidiuretic hormone (ADH) or vasopressin (a positive feedback). ADH facilitates reabsorption of water by increasing the number of aquaporins on the cell surface membrane of the distal convoluted tubule and collecting duct. This increase in aquaporins causes the movement of water from the lumen into the interstitial cells, thereby preventing excess loss of water by diuresis. When you drink excess amounts of your favourite juice, osmoreceptors of the hypothalamus is no longer stimulated and the release of ADH is suppressed from the neurohypophysis (negative feedback) and the aquaporins of the collecting

Angiotensin Converting Enzyme inhibitors (ACE inhibitors) are used to treat high blood pressure. Using a flow chart, explain why these drugs are helpful in treating hypertension.

ducts move into the cytoplasm. This makes the collecting ducts impermeable to water and the excess fluid flows down the collecting duct without any water loss. Hence dilute urine is produced to maintain the blood volume. Vasopressin secretion is controlled by positive and negative feedback mechanism. Defects in ADH receptors or inability to secrete ADH leads to a condition called diabetes insipidus, characterized by excessive thirst and excretion of large quantities of dilute urine resulting in dehydration and fall in blood pressure.

Consider how different foods affect water and salt balance, and how the excretory system must respond to maintain homeostasis.

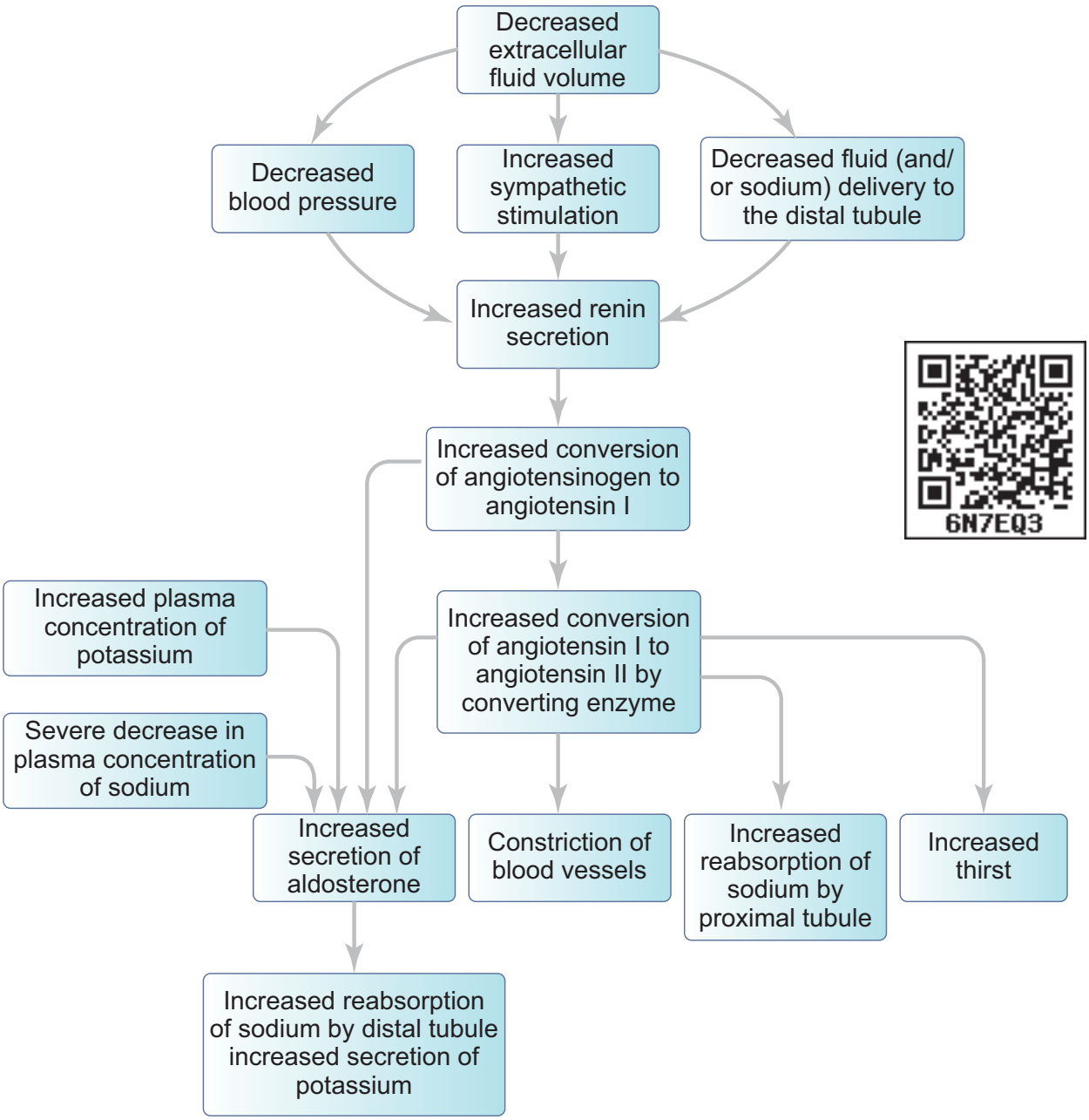


Figure 8.11 Schematic representations of the various hormones in the regulation of body fluid concentration

Renin angiotensin

Juxta glomerular apparatus (JGA) is a specialized tissue in the afferent arteriole of the nephron that consists of macula densa and granular cells. The macula densa cells sense distal tubular flow and affect afferent arteriole diameter, whereas the granular cells secrete an enzyme called renin. A fall in glomerular blood flow, glomerular blood pressure and glomerular filtration rate, can atctivate JG cells to release renin which converts a plasma protein, angiotensinogen (synthesized in the liver) to angiotensin I. Angiotensin converting enzyme (ACH) converts angiotensin I to angiotensin II. Angiotensin II stimulates Na^+ reabsorption in the proximal convoluted tubule by vasoconstriction of the blood vessels and increases the glomerular blood pressure. Angiotensin II acts at different sites such as heart, kidney, brain, adrenal cortex and blood vessels. It stimulates adrenal cortex to secrete aldosterone that causes reabsorption of Na^+, K^+ excretion and absorption of water from the distal convoluted tubule and collecting duct. This increases the glomerular blood pressure and glomerular filtration rate. This complex mechanism is generally known as **Renin- Angiotensin-Aldosterone System** (RAAS). Figure 8.11 shows the schematic representation of the various hormones in the regulation of body fluid concentration.

Atrial natriuretic factor

Excessive stretch of cardiac atrial cells cause an increase in blood flow to the atria of the heart and release Atrial Natriuretic Peptide or factor (ANF) travels to the kidney where it increases Na^+ excretion and increases the blood flow to the glomerulus, acting on the afferent glomerular arterioles as a vasodilator or on efferent arterioles as a vasoconstrictor. It decreases aldosterone release from the adrenal cortex and also decreases release of renin, thereby decreasing angiotensin II. ANF acts antagonistically to the renin-angiotensin system, aldosterone and vasopressin.

8.5 Micturition

The process of release of urine from the bladder is called micturition or urination. Urine formed by the nephrons is ultimately carried to the urinary bladder where it is stored till it receives a voluntary signal from the central nervous system. The stretch receptors present in the urinary bladder are stimulated when it gets filled with urine. Stretching of the urinary bladder stimulates the CNS via the sensory neurons of the parasympathetic nervous system and brings about contraction of the bladder. Simultaneously, somatic motor neurons induce the sphincters to close. Smooth muscles contracts resulting in the opening of the internal sphincters passively and relaxing the external sphincter. When the stimulatory and inhibitory controls exceed the threshold, the sphincter opens and the urine is expelled out.

An adult human on an average excretes 1 to 1.5 L of urine per day. The urine formed is a yellow coloured watery fluid which is slightly acidic in nature (pH 6.0), Changes in diet may cause pH to vary between 4.5 to 8.0 and has a characteristic odour. The yellow colour of the urine is due to the presence of a pigment,

Hypotonic urine is formed when osmotic pressure of the body fluid is decreased due to water retention or solute loss when ADH secretion is lowered. If you drink large volume of water without eating anything salty, the total body fluid volume increases quickly and the osmolarity decreases. The kidneys increases the volume of urine excreted. The reverse happens when you eat salty food without drinking water.

urochrome. On an average, 25-30 gms of urea is excreted per day. Various metabolic disorders can affect the composition of urine. Analysis of urine helps in clinical diagnosis of various metabolic disorders and the malfunctioning of the kidneys. For example the presence of glucose (glucosuria) and ketone bodies (ketonuria) in the urine are indications of diabetes mellitus.

8.6 Role of other organs in excretion

Apart from kidneys, organs such as lungs, liver and skin help to remove wastes. Our lungs remove large quantities of carbon dioxide (18 L/day) and significant quantities of water every day. Liver secretes bile containing substances like, bilirubin and biliverdin, cholesterol, steroid hormones, vitamins and drugs which are excreted out along with the digestive wastes.

Sweat and sebaceous glands in the skin eliminate certain wastes through their secretions. Sweat produced by the sweat glands primarily helps to cool the body and secondarily excretes Na^+ and Cl^-, small quantities of urea and lactate. Sebaceous glands eliminate certain substances like sterols, hydrocarbons and waxes through sebum that provides a protective oily covering for the skin. Small quantities of nitrogenous wastes are also excreted through saliva.

8.7 Disorders related to the Excretory System

Urinary tract infection

Female's urethra is very short and its external opening is close to the anal opening, hence improper toilet habits can easily carry faecal bacteria into the urethra. The urethral mucosa is continuous with the urinary tract and the inflammation of the urethra (urethritis) can ascend the tract to cause bladder inflammation (cystitis) or even renal inflammation (pyelitis or pyelonephritis). Symptoms include dysuria (painful urination), urinary urgency, fever and sometimes cloudy or blood tinged urine. When the kidneys are inflammed, back pain and severe headache often occur. Most urinary tract infections can be treated by antibiotics.

Renal Failure (Kidney Failure)- Failure of the kidneys to excrete wastes may lead to accumulation of urea with marked reduction in the urine output. Renal failure are of two types, Acute and chronic renal failure. In acute renal failure the kidney stops its function abruptly, but there are chances for recovery of kidney functions. In chronic renal failure there is a progressive loss of function of the

nephrons which gradually decreases the function of kidneys.

Females are prone to recurring urinary tract infections as they have shorter urethras. With age prostate in males may enlarge which forces urethra to tighten restricting a normal urinary flow.

Uremia - Uremia is characterized by increase in urea and other non-protein nitrogenous substances like uric acid and creatinine in blood. Normal urea level in human blood is about 17-30mg/100mL of blood. The urea concentration rises as 10 times of normal levels during chronic renal failure.

Renal calculi- Renal calculi, also called renal stone or kidney stone or nephrolithiasis, is the formation of hard stone like masses in the renal tubules of renal pelvis. It is mainly due to the accumulation of soluble crystals of salts of sodium oxalates and certain phosphates. This result in severe pain called "renal colic pain" and can cause scars in the kidneys. Renal stones can be removed by techniques like pyleothotomy or lithotripsy.

Glomerulonephritis- It is also called Bright's disease and is characterized by inflammation of the glomeruli of both kidneys and is usually due to post-streptococcal infection that occurs in children. Symptoms are haematuria, proteinuria, salt and water retention, oligouria, hypertension and pulmonary oedema.

8.8 Haemodialysis

Malfunctiong of the kidneys can lead to accumalation of urea and other toxic substances, leading to kidney failure. In such patients toxic urea can be removed from the blood by a process called haemodialysis. A dialyzing machine or an artificial kidney is connected to the patient's body. A dialyzing machine consists of a long cellulose tube surrounded by the dialysing fluid in a water bath. The patient's blood is drawn from a conveinent artery and pumped into the dialysing unit after adding an anticoagulant like heparin. The tiny pores in the dialysis tube allows small molecules such as glucose, salts and urea to enter into the water bath,

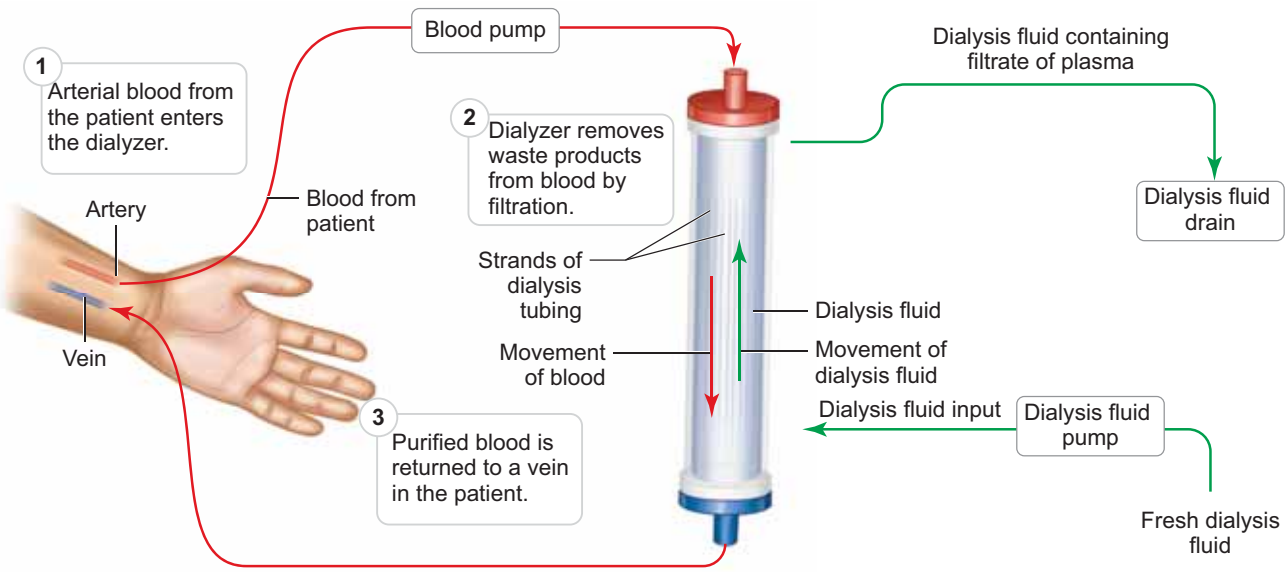


Figure 8.12 Simplified diagram of hemodialysis

whereas blood cells and protein molecules do not enter these pores. This stage is similar to the filtration process in the glomerulus. The dialysing liquid in the water bath consists of solution of salt and sugar in correct proportion in order to prevent loss of glucose and essential salts from the blood. The cleared blood is then pumped back to the body through a vein.

Kidney Transplantation

It is the ultimate method for correction of a acute renal failures. This involves transfer of healthy kidney from one person (donor) to another person with kidney failure. The donated kidney may be taken from a healthy person who is declared brain dead or from sibling or close relatives to minimise the chances of rejection by the immune system of the host. Immunosuppressive drugs are usually administered to the patient to avoid tissue rejection.

Activity

Visit a nearby health center to observe the analysis of urine. Dip strips can be used to test urine for a range of different factors such as pH, glucose, ketones and proteins. Dip sticks for detecting glucose contain two enzymes namely, glucose oxidase and peroxidase. These two enzymes are immobilized on a small pad at one end of the stick. The pad is immersed in urine. If the urine contains glucose, a brown coloured compound is produced. The resulting colour pad is matched against a colour chart. The colour does not indicate the current blood glucose concentrations.

The world's first successful human kidney transplantation was performed from one twins to antoher by Joseph E. Murray and his colleagues at Peter Bent Brigham Hospital, Boston in 1954. The first ever human kidney transplant performed in India was done at the King Edward Memorial Hospital at Mumbai in May 1965, using a cadaver donor in a non-renal failure patient who had had hypernephroma. The first successful live donor kidney transplant in India was done at Christian Medical College Hospital, Vellore in January 1971 by Dr. Johnny and Dr. Mohan Rao.

Summary

Epithelial tissues are the interface between internal fluids and the external environment, creating osmotic barriers in lower organisms. Other specialized epithelial tissues that mediate osmotic and ionic regulation are gills, digestive tract and specialized excretory tissues in different animal groups. Animals remove toxic ammonia to less toxic forms by excretion. Three main strategies of nitrogen excretion are ammonoteles (ammonium), Uricoteles (uric acid) and Ureotelism (Urea). Most aquatic animals are ammonotelic, whereas terrestrial animals are uricotelic (reptiles and birds) or ureoteles (mammals). Urea is produced by the Ornithine cycle/Urea cycle in the liver.

Invertebrates have primitive kidneys such as protonephridia and metanephridia. Water balance in insects is regulated by Malphigian tubules. Ion and water regulation in vertebrates are carried out by the kidneys. The functional units of kidney is the nephron. Urine is formed by 3 processes, Glomerular filtration, tubular reabsorption and tubular secretion. Filtration occurs at the glomerulus, a ball of capillaries surrounded by the Bowman's capsule. From the Bowman's capsule the primary urine enters the proximal tubule, and proceeds to the loop of Henle, with its ascending and descending limbs. The hypertonic fluid then flows to the distal tubule and through the collecting duct into the ureters, the urinary bladder, after a short storage it is sent out of the urethra. Central to the nephron is the counter current system set up between the loop of Henle and the collecting duct along with the capillaries that serve the nephron.

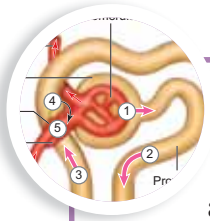
Kidney function is regulated at different levels. GFR is affected by colloidal osmotic pressure and capsular hydrostatic pressure between the glomerulus and Bowman's capsule, surface area available for filtration are the factors that affect filtration pressure. The kidneys act only on the plasma, yet the extra cellular fluid consists of both plasma and interstitial fluid. The interstitial fluid is the true internal fluid environment of the body. Interstitial fluid is the only component that comes in direct contact with the cells. Thus by performing regulatory and excretory roles on the plasma, the kidneys maintains the proper interstitial fluid environment for optimum cell functioning.

Various hormones control diuresis. Vasopressin alters the permeability of the collecting duct, the renin- angiotensin system, sympathetic system and aldosterone act together to regulate $Na^{+,}$ K^{+}, water and pressure balance.

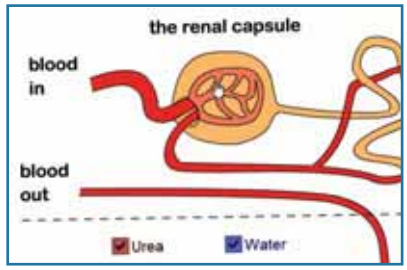
Both the kidneys of Ravi (28 years) were not functioning and he was undergoing dialysis. He was admitted to a hospital with renal failure. His mother Suganthi (47 years) was willing to donate one of her kidneys to her son after she was given counseling. Their blood groups were matching and later approval was obtained from transplant committee and technical committee. Operation was performed for 5 hrs. He was administered with immunosuppressive drugs and anti inflammatory drugs. He recovered from the operation and returned home.

1. Name the disease Ravi was suffering from.
2. What relation is the donor of the kidney
3. Name the type of matching done to perform the transplant.
4. Why approval has to be got from transplant committee and technical committee?
5. What do you think about Suganthi donating her kidney?

Let go away



Let's explore the Biomed Heads-Kidney and understand the **functions of the nephron**.



Step – 1

Use the URL to land in 'Biomed heads-Kidney' page. Click 'Continue' button near the kidney diagram to download an interactive flash file.

Step – 2

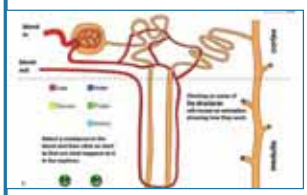
Open the flash file and then click 'Continue' button to start the interactive activity.

Step – 3

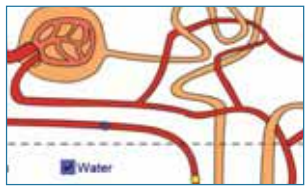
By selecting the molecules given in the list, you can understand how the nephrons process these molecules in accordance to their properties.

Step – 4

Use the drop-down menu on the top right corner of the window to understand the parts of the nephron and their functions.



Step 1



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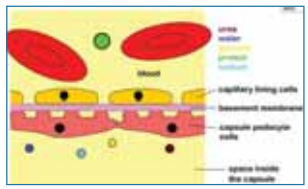
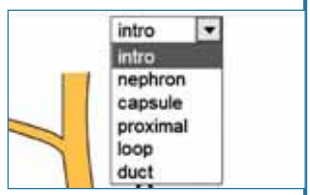


Step 3



Step 4

Biomed heads-Kidney function's URL:

http://www.biomedheads.com/kidney--nephrons.html

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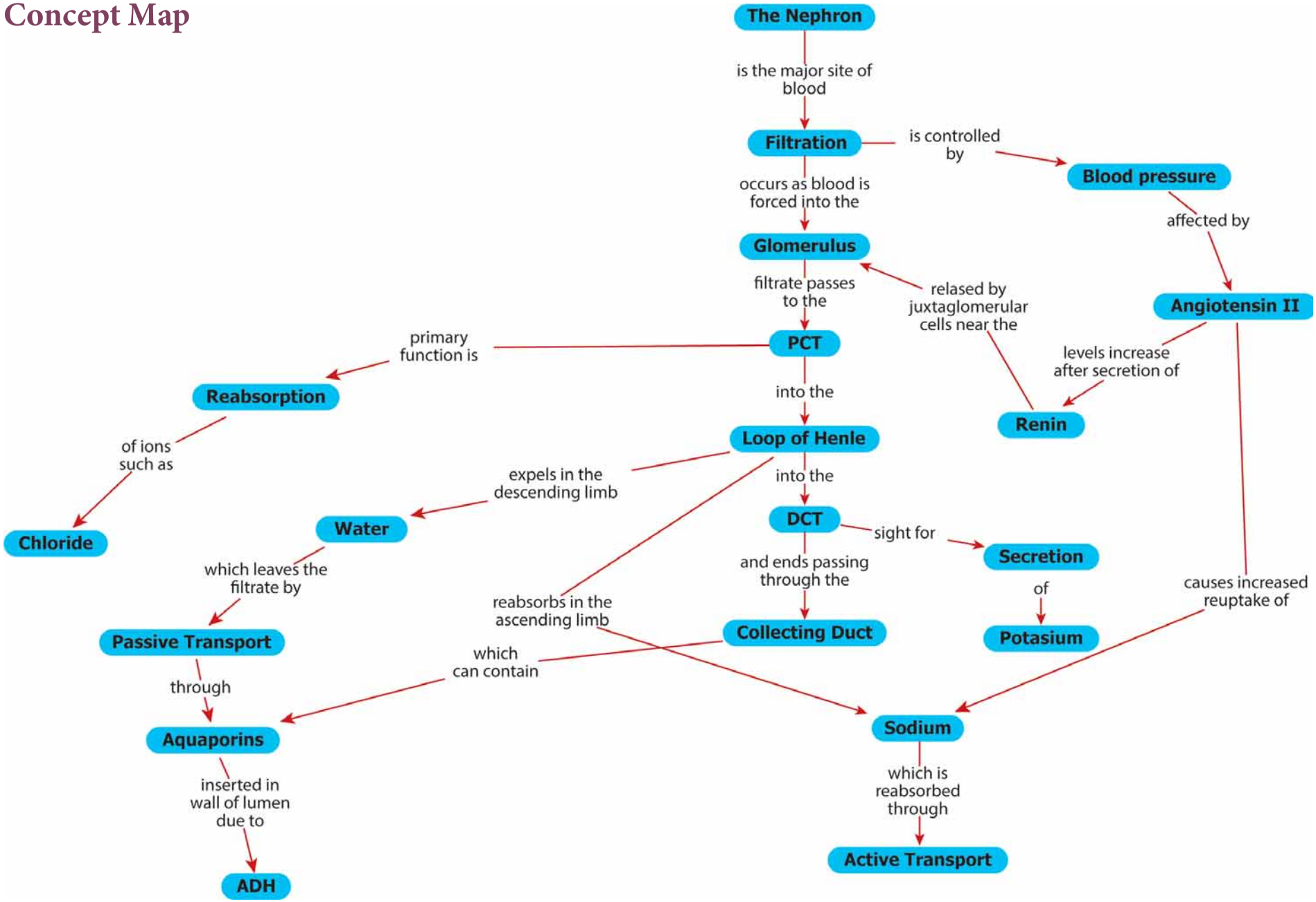
* Pictures are indicative only

Concept Map


The Nephron
is the major site of blood
Filtration
is controlled by
Blood pressure
occurs as blood is forced into the
affected by
Glomerulus
filtrate passes to the
relased by juxtaglomerular cells near the
Angiotensin II
primary function is
PCT
levels increase after secretion of
Reabsorption
into the
Renin
of ions such as
Loop of Henle
expels in the descending limb
into the
Water
DCT
sight for
Chloride
which leaves the filtrate by
and ends passing through the
Secretion
reabsorbs in the ascending limb
of
causes increased reuptake of
Passive Transport
Collecting Duct
Potasium
which can contain
through
Sodium
Aquaporins
which is reabsorbed through
inserted in wall of lumen due to
Active Transport
ADH

Glossary

Atrial natriuretic peptide – is a polypeptide hormone released by atrial myocytes (muscle cells) from the granules of the atria of the heart in response to high blood pressure, hypervolemia and exercise. It is involved in the homeostatic control of body water and sodium.

Aquaporins – or water channels are formed by specific plasma membrane proteins in the tubular cells. These water channels of the proximal convoluted tubules are always open accounting for the high water permeability in this region. In contrast the water channels in the distal convoluted tubule are regulated by the hormone vasopressin accounting for the variable water re-absorption in that region.

Bowman's capsule hydrostatic pressure – The pressure exerted by the fluid in the Bowman's capsule. This pressure tends to push fluid out of Bowman's capsule, opposes the filtration of fluid from the glomerulus into Bowman's capsule.

Cortical nephrons – All nephrons originate in the cortex, but the glomeruli of the cortical nephrons lie in the outer layer of the cortex. Peri tubular capillaries do not form vasa recta.

Glomerular filtration – this is the first step in urine formation where 20% of the plasma that enters the glomerulus is filtered. The glomerular filtrate that comes out of the glomerulus into the Bowman's capsule is the protein – free plasma.

Glomerular capillary pressure – It is the fluid pressure exerted by the blood within the glomerular capillaries.

Glomerulus – a tuft of capillaries that filters protein – free plasma into the tubular component

Juxtaglomerular apparatus – The ascending limb of Henle returns to the glomerular region of its own nephron, where it passes through the fork formed by the afferent and efferent arterioles. Both the tubular and vascular cells at this point are specialized to form juxtaglomerular apparatus that lie next to the glomerulus. (Juxta means "next to").

Juxtamedullary nephrons – the glomeruli of the juxtaglomerular nephrons lie in the inner layer of cortex next to the medulla and the loops of Henle plunges through the entire depth of the medulla Concentrated urine is formed in these nephrons.

Filtration slits - The narrow slits between adjacent foot process that provides a pathway through which the fluid leaving the glomerular capillaries can enter the lumen of Bowman's capsule.

Peritubular capillaries -supply the renal tissue, involved in exchanges with the fluid in the tubular region.

Podocytes – The glomerular membrane consists of octopus like cells called podocytes that entangles the glomerular tuft. Each podocyte bears many foot processes.

Vasa recta – (straight vessels) The peritubular capillaries of the juxtaglomerular nephrons forms vascular loops which run in close association with the loops of Henle.

Evaluation

1. Arrange the following structures in the order that a drop of water entering the nephron would encounter them.
   a. Afferent arteriole
   b. Bowman's capsule
   c. Collecting duct
   d. Distal tubule
   e. Glomerulus
   f. Loop of Henle
   g. Proximal tubule
   h. Renal pelvis

2. Name the three filtration barriers that solutes must come across as they move from plasma to the lumen of Bowman's capsule. What components of the blood are usually excluded by these layers?
3. What forces promote glomerular filtration? What forces opposes them? What is meant by net filtration pressure?
4. Identify the following structures and explain their significance in renal physiology?
   a. Juxtaglomerular apparatus
   b. Podocytes
   c. Sphincters in the bladder
   d. Renal cortex
5. In which segment of the nephron most of the re-absorption of substances takes place?
6. When a molecule or ion is reabsorbed from the lumen of the nephron, where does it go? If a solute is filtered and not reabsorbed from the tubule, where does it go?

7. Match each of the following substances with its mode of transportation in proximal tubular reabsorption.

a. Na^+	-	simple diffusion
b. Glucose	-	primary active transport
c. Urea	-	indirect active transport
d. Plasma	-	paracellular movement
e. proteins	-	facilitated diffusion
f. Water	-	endocytosis

8. Which segment is the site of secretion and regulated reabsorption of ions and pH homeostasis?
9. What solute is normally present in the body to estimate GFR in humans?
10. Which part of the autonomic nervous system is involved in micturation process?
11. Match the following terms.

a. α-receptor	- afferent arteriole
b. Autoregulation	- basal lamina
c. Bowman's capsule	- capillary blood pressure
d. Capsule fluid pressure	- colloid osmotic pressure
e. Glomerulus	- GFR
f. Podocyte	- JG cells
g. Vasoconstriction	- plasma proteins Norepinepherine

12. If the afferent arteriole of the nephron constricts, what happens to the GFR in that nephron? If the efferent arteriole constricts what happens to the GFR in that nephron? Assume that no auto regulation takes place.
13. How is the process of micturition altered by toilet training?
14. Concentration of urine depends upon which part of the nephron
    a. Bowman's capsule
    b. length of Henle's loop
    c. P.C.T.
    d. net work of capillaries arising from glomerulus
15. If Henle's loop were absent from mammalian nephron, which one of the following is to be expected?
    a. There will be no urine formation
    b. There will be hardly any change in the quality and quantity of urine formed
    c. The urine will be more concentrated
    d. The urine will be more dilute
16. A person who is on a long hunger strike and is surviving only on water, will have
    a. Less amino acids in his urine

b. Macula densa cells
c. Less urea in his urine
d. More sodium in his urine

17. What will happen if the stretch receptors of the urinary bladder wall are totally removed?
a. Micturition will continue
b. Urine will be continue to collect normally in the bladder
c. there will be micturition
d. urine will not collection the bladder

18. The end product of Ornithine cycle is
a. carbon dioxide b. uric acid
c. urea d. ammonia

19. Identify the wrong match

a. Bowman's capsule	- Glomerular filteration
b. DCT	- Absorption of glucose
c. Henle's loop	- Concentration of urine
d. PCT	- Absorption of Na^+ and K^+ ions

20. Podocytes are the cells present on the
a. Outer wall of Bowman's capsule
b. Inner wall of Bowman's capsule
c. neck of nephron
d. Wall glomerular capillaries

21. Glomerular filtrate contains
a. Blood without blood cells and proteins
b. Plasma without sugar
c. Blood with proteins but without cells
d. Blood without urea

22. Kidney stones are produced due to deposition of uric acid and
a. silicates
b. minerals
c. calcium carbonate
d. calcium ixalate

23. Animal requiring minimum amount of water to produce urine are
a. ureotelic b. ammonotelic
b. uricotelic d. chemotelic

24. Aldosterone acts at the distal convoluted tubule and collecting duct resulting in the absorption of water through
a. Aquaphorins b. spectrins
c. GLUT d. Chloride channels

25. The hormone which helps in the reabsorption of water in kidney tubules is
a. cholecystokinin
b. angiotensin II
c. antidiuretic hormone
d. pancreozymin

26. Malpighian tubules remove excretory products from
a. mouth b. oesophagus
c. haemolymph d. alimentary canal.

27. Indentfiy the biological term
Homeostasis, excretion, glomerulus,urea, glomerular filtration, ureters, urine, Bowman's capsule, urinary system, reabsorption, micturition, osmosis, glomerular capillaries via efferent arteriole, proteins.
a. A liquid which gathers in the bladder.
b. Produced when blood is filtered in a Bowman's capsule.
c. Temporary storage of urine.
d. A ball of inter twined capillaries.
e. A process that changes glomerular filtrate into urine.
f. Removal of unwanted substances from the body.
g. Each contains a glomerulus.
h. Carry urine from the kidneys to the bladder.
i. Contains urea and many useful substances.

j. Bloods is filtered through its walls into the Bowman's capsule.

k. Scientific term for urination.

l. Regulation of water and dissolved substances in blood and tissue fluid.

m. Carry urine from the kidneys to the bladder.

n. Consists of the kidneys, ureters and bladder.

o. Removal of useful substances from glomerular filtrate.

p. The process by which water is transported in the proximal convoluted tubule.

q. Where has the blood in the capillaries surrounding the proximal convoluted tubule come from?

r. What solute the blood contains that are not present in the glomerular filtrate?

28. With regards to toxicity and the need for dilution in water, how different are ureotelic and uricotelic excretions? Give examples of animals that use these types of excretion?

29. Differentiate protonephridia from metanephridia

30. What is the nitrogenous waste produced by amphibian larvae and by the adult animal?

31. How is urea formed in the human body?

32. Differentiate cortical from medullary nephrons

33. What vessels carry blood to the kidneys? Is this blood arterial or venous?

34. Which vessels drain filtered blood from the kidneys?

35. What is tubular secretion? Name the substances secreted through the renal tubules

36. How are the kidneys involved in controlling blood volume? How is the volume of blood in the body related to arterial pressure?

37. Name the three main hormones are involved in the regulation of the renal function?

38. What is the function of antidiuretic hormone? Where is it produced and what stimuli increases or decreases its secretion?

39. What is the effect of aldosterone on kidneys and where is it produced?

40. What evolutionary hypothesis could explain the heart's role in secreting a hormone that regulates renal function? What hormone is this?

Reference

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3. Anatomy and Physiology 4th edition Elaine N. Marieb and Katja Hoehn (2011) Pearson publications.

UNIT IV | Chapter 9

Locomotion and Movement

Leaping movement is effected by the coordination of skeletal and neuromuscular systems.

Chapter Outline

6NGARQ

Learning Objectives:

- *Relates the structure of skeletal muscle with its function.*
- *Learns to identify bones of the skeletal system.*
- *Gains knowledge about the disorders related to muscular and skeletal systems.*
- *Understands the benefits of regular exercise.*

Have you ever wondered how a dancer performs intricate dance steps or how a swimmer skillfully does a butterfly stroke? The muscles of our body work simultaneously with one another and with the skeletal system to perform the various movements. Our muscles have two functions: to generate motion and force. All these activities are controlled and coordinated by the skeletal, muscular and nervous system. The human body is capable of a wide range of movements from the gentle blinking of eye to running a 20 km marathon. Movement of organism from one place to another in search of food, shelter, mate and to escape from predators is called locomotion. Locomotion has evolutionary significance.

9.1 Types of movement

The different types of movements that occur in the cells of our body are amoeboid, ciliary, flagellar and muscular movement.

Amoeboid movement - Cells such as macrophages exhibit amoeboid movement for engulfing pathogens by pseudopodia formed by the streaming movement of the cytoplasm.

Ciliary movement - This type of movement occurs in the respiratory passages and genital tracts which are lined by ciliated epithelial cells.

Flagellar movement - This type of movement occurs in the cells which are having flagella or whip-like motile organelle. The sperm cells show flagellar movement.

Muscular movement -The movement of hands, legs, jaws, tongue are caused by the contraction and relaxation of the muscle which is termed as the muscular movement.

9.2. Types of muscles

Muscles are specialized tissues which are derived from the embryonic **mesoderm**. They are made of cells called **myocytes** and constitute 40 – 50 percent of body weight in an adult. These cells are bound together by a connective tissue to form a muscular tissue. The muscles are classified into three types, namely **skeletal, visceral** and **cardiac muscles.**

9.3 Skeletal muscle (Voluntary muscle)

Skeletal muscle is attached to the bone by a bundle of collagen fibres known as **tendon** (Figure 9.1). Each muscle is made up of bundles of **muscle fibres** called **fascicle**. Each muscle fibre contains hundreds to thousands of rod-like structures called **myofibrils** that run parallel to its length. The connective tissue covering the whole muscle is the **epimysium**, the covering around each fascicle is the **perimysium** and the muscle fibre is surrounded by the **endomysium**. They control the voluntary actions such as walking, running, swimming, writing hence termed as voluntary muscles.

9.3.1. Structure of a skeletal muscle fibre

Each muscle fibre is thin and elongated. Most of them taper at one or both ends. Muscle fibre has multiple oval nuclei just beneath its **plasma membrane** or **sarcolemma**. The cytoplasm of the muscle fibre is called the **sarcoplasm**. It contains glycosomes, myoglobin and sarcoplasmic reticulum. **Myoglobin** is a red- coloured respiratory pigment of the muscle fibre. It is similar to haemoglobin and contains iron group that has affinity towards oxygen and serves as the reservoir of oxygen. **Glycosomes** are the granules of stored glycogen that provide glucose during the period of muscle fibre activity. Actin and myosin are muscle proteins present in the muscle fibre.

Along the length of each myofibril there are a repeated series of dark and light bands (Figure 9.2). The dark **A-bands** (Anisotropic bands) and the light **I-bands** (Isotropic bands) are perfectly aligned with one another. This type of arrangement gives the cell a striated appearance. Each dark band

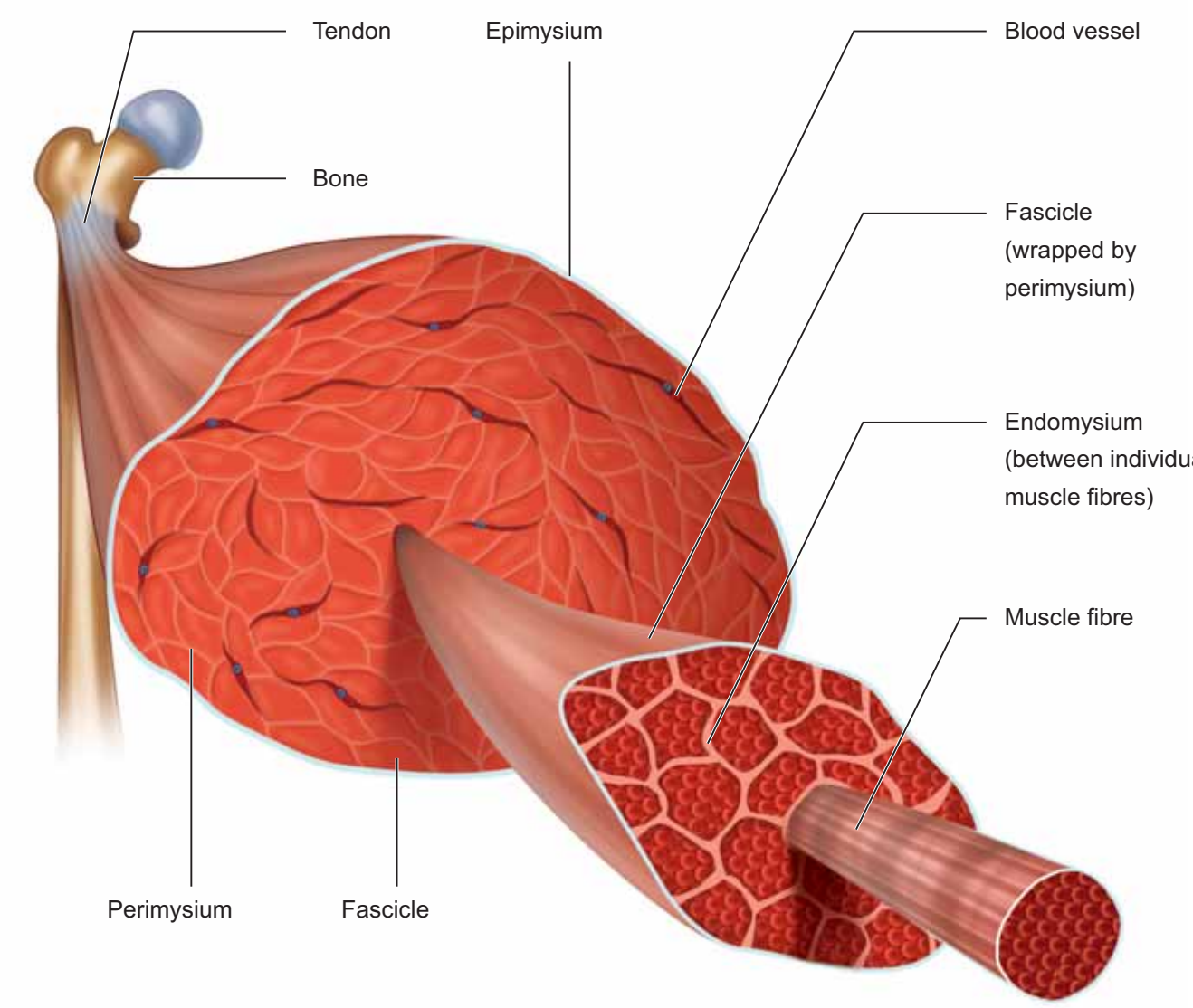


Figure 9.1 Structure of a skeletal muscle

has a lighter region in its middle called the **H-Zone** (H-helles, meaning clear). Each H-zone is bisected vertically by a dark line called the M-line (M-for middle). The light I-bands also have a darker mid line area called the **Z–disc** (from the German "Zwischenscheibe" the disc inbetween the I-bands).

The myofibrils contain the contractile element, the **sarcomere** which is the functional unit of the skeletal muscle. A Sarcomere is the region of a myofibril between two successive Z-discs. It contains an A-band with a half I-band at each end. Inside the sarcomere two types of filaments are present namely the **thick** and **thin filaments**.

The thick filaments extend the entire length of the A-band, the thin filaments extend across the I-band and partly into the A-band. The invagination of the sarcolemma forms transverse tubules **(T–tubules)** and they penetrate into the junction between the A and I-bands.

Muscle Terminology

General Term	Muscle Equivalent
Cell	Muscle fibre/ Myofibril
Plasma membrane	Sarcolemma
Cytoplasm	Sarcoplasm
Endoplasmic reticulum	Sarcoplasmic reticulum

9.4 Structure of contractile proteins

Contraction of the muscle depends on the presence of contractile proteins (Figure 9.3) such as **actin** and **myosin** in the myofilaments. The thick filaments are composed of the protein myosin which are bundled together whose heads produce at opposite ends of the filament. Each

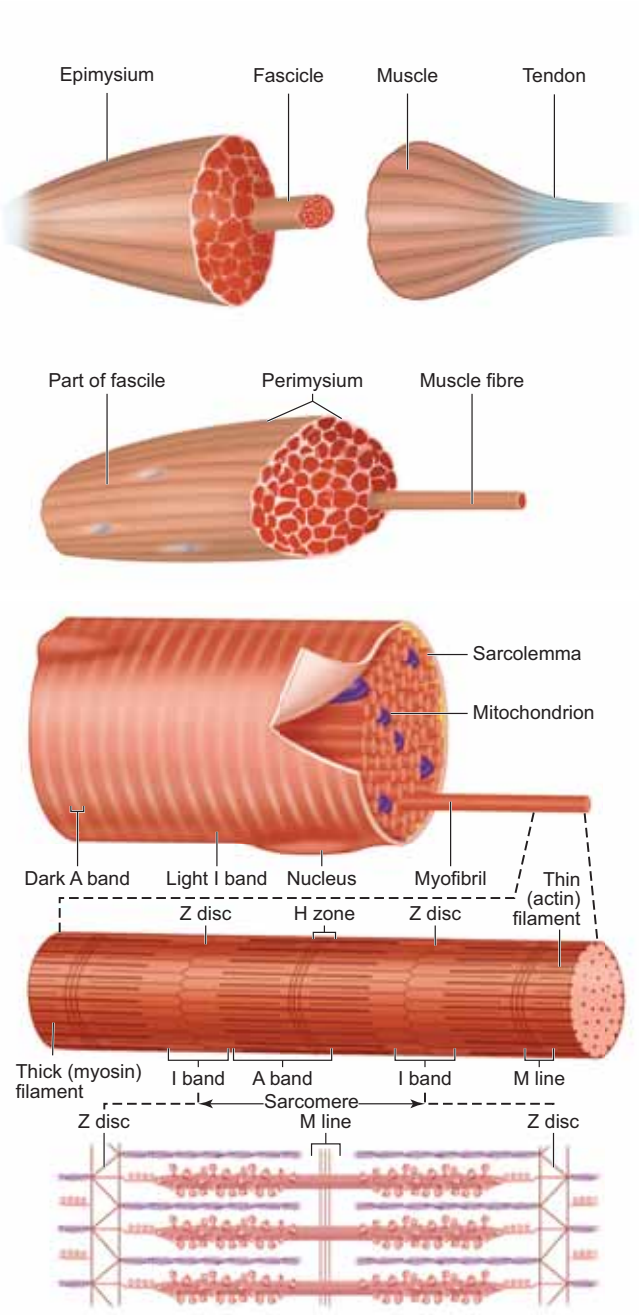


Figure 9.2 Organizational level of a skeletal muscle

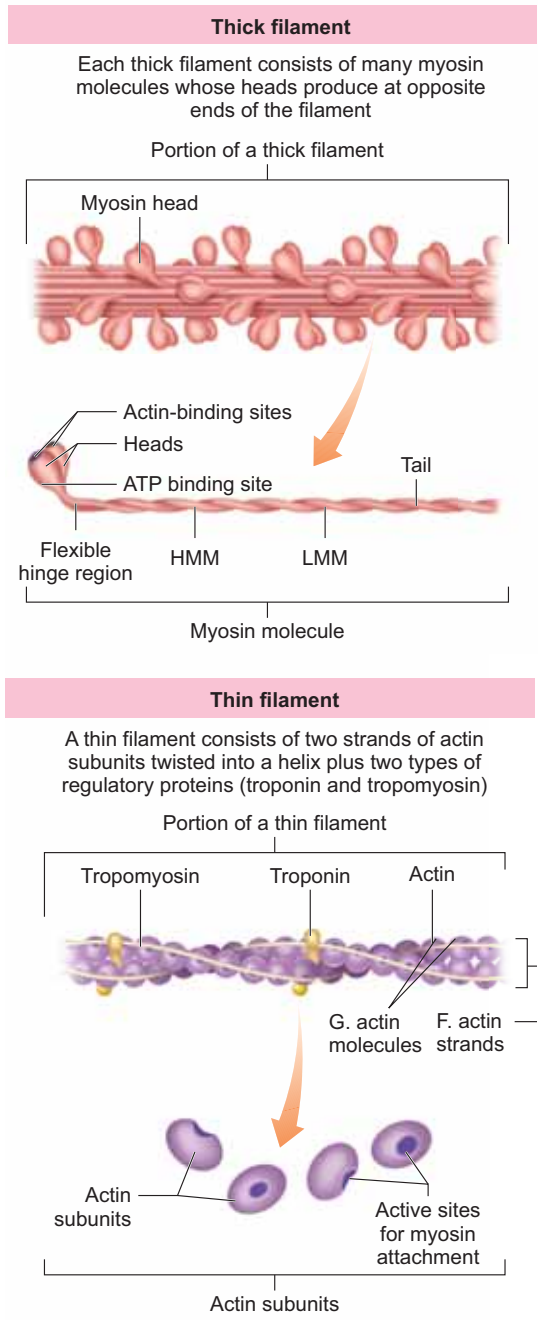
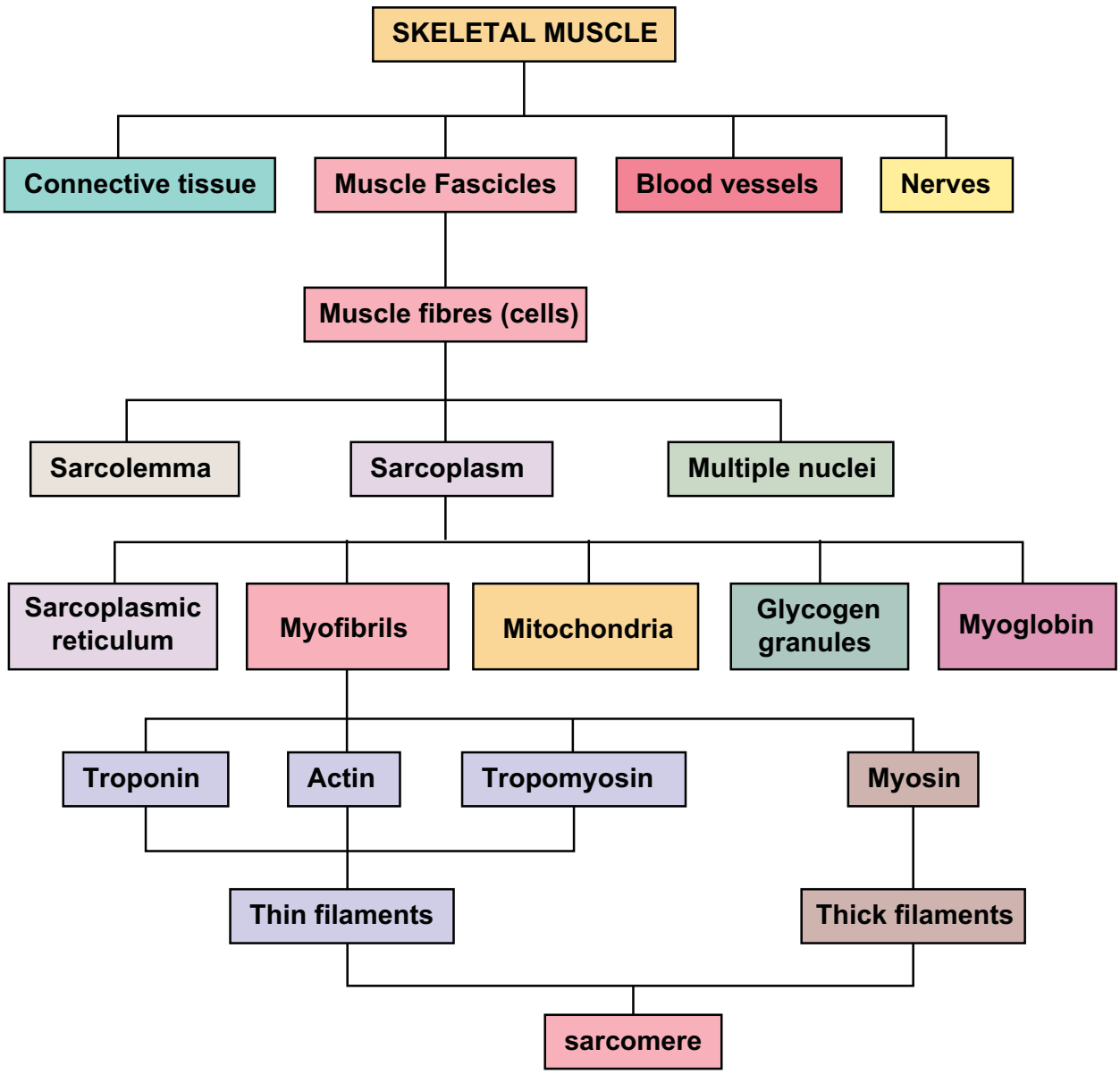


Figure 9. 3 Composition of thick and thin filaments

myosin molecule is made up of a monomer called meromyosin. The meromyosin has two regions, a globular head with a short arm and a tail. The short arm constitutes the heavy meromyosin (HMM). The tail portion forms the light meromyosin (LMM). The head bears an actin-binding site and an ATP- binding site. It also contains ATPase enzyme that split ATP to generate energy for the contraction of muscle. The thin filaments are composed of two interwined actin molecules. Actin has polypeptide subunits called globular actin or G–actin and filamentous form or F-actin. Each thin filament is made of two F-actins helically wound to each other. Each F-actin is a polymer of monomeric G-actins. It also contains a binding site for myosin. The thin filaments also contain several regulatory proteins like **tropomyosin** and **troponin** which help in regulating the contraction of muscles along with **actin** and **myosin**.

The study of muscle is called **myology.**

Schematic representation of organizational levels of skeletal muscle.



9.5 Mechanism of muscle contraction

Sliding filament theory in 1954, Andrew F. Huxley and Rolf Niedergerke proposed the sliding-filament theory to explain muscle contraction. According to this theory, overlapping actin and myosin filaments of fixed length slide past one another in an energy requiring process, resulting in muscle contraction. The contraction of muscle fibre is a remarkable process that helps in creating a force to move or to resist a load. The force which is created by the contracting muscle is called muscle tension. The load is a weight or force that opposes contraction of a muscle. Contraction is the creation of tension in the muscle which is an active process and relaxation is the release of tension created by contraction. Muscle contraction is initiated by a nerve impulse sents by the

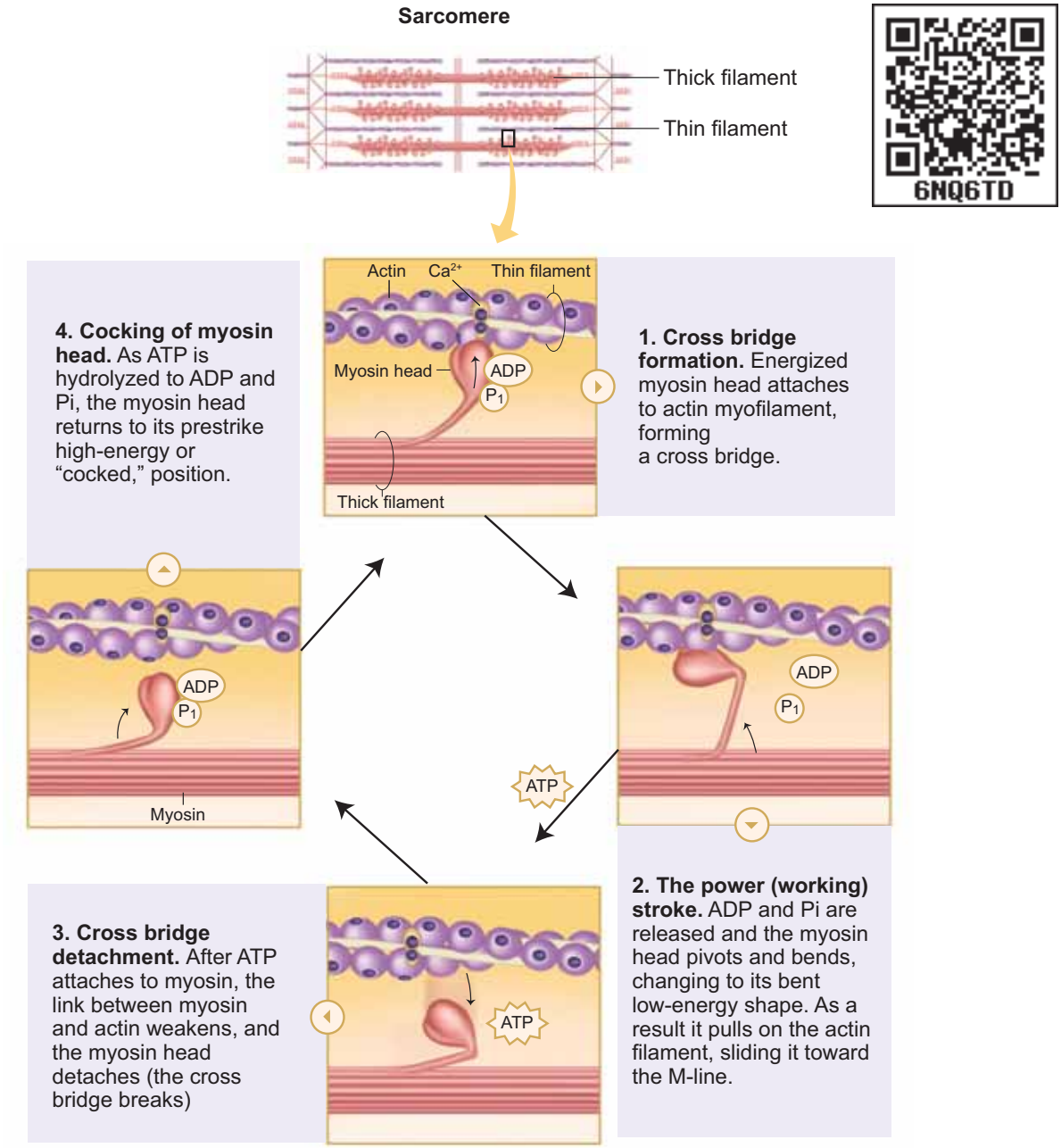


Figure 9.4 Cross-bridge cycle of muscle contraction

central nervous system (CNS) through a motor neuron. The junction between the motor neuron and the sarcolemma of the muscle fibre is called the neuromuscular junction or motor end plate. When nerve impulse reaches a neuromuscular junction, acetylcholine is released. It initiates the opening of multiple gated channels in sarcolemma. The action potential travels along the T-tubules and triggers the release of calcium ions from the sarcoplasmic reticulum. The released calcium ions bind to troponin on thin filaments. The tropomyosin uncovers the myosin-binding sites on thin filaments. Now the active sites are exposed to the heads of myosin to form a cross-bridge. During cross-bridge formation actin and myosin form a protein complex called actomyosin. Utilizing the energy released from hydrolysis of ATP, the myosin head rotates until it forms a 90° angle with the long axis of the filament. In this position myosin binds to an actin and activates a contraction – relaxation cycle which is followed by a power stroke.

The power stroke (cross-bridge tilting) begins after the myosin head and hinge region tilt from a 90° angle to a 45° angle. The cross-bridge transforms into strong, high-force bond which allows the myosin head to swivel. When the myosin head swivels it pulls the attached actin filament towards the centre of the A-band. The myosin returns back to its relaxed state and releases ADP and phosphate ion. A new ATP molecule then binds to the head of the myosin and the cross-bridge is broken. At the end of each power stroke, each myosin head detaches from actin, then swivels back and binds to a new actin molecule to start another contraction cycle. This movement is similar to the motion of an oar on a boat. At the end of each power stroke, each myosin head detaches from actin, then swivels back and binds to a new actin molecule to start another contraction cycle. The power stroke repeats many times until a muscle fibre contracts. The myosin heads bind, push and release actin molecules over and over as the thin filaments move toward the centre of the sarcomere. The repeatedly formation of

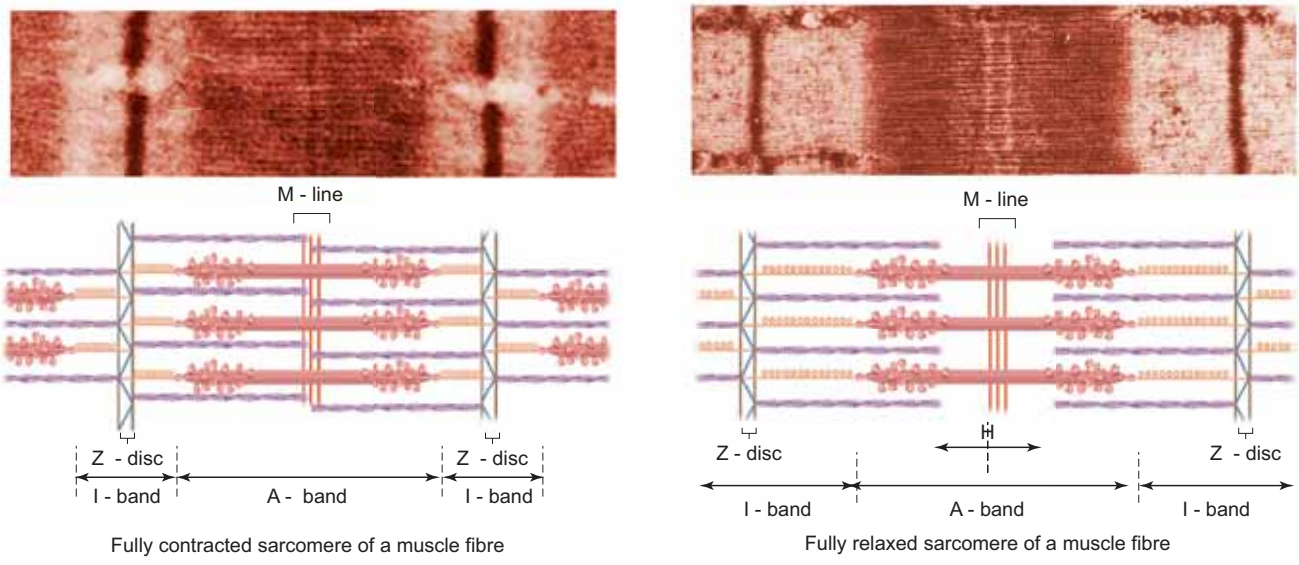


Figure 9.5 Sliding filament model of muscle contraction

cross-bridge cycles cause the sliding of the filaments only but there is no change in the lengths of either the thick or thin filaments. The Z- discs attached to the actin filaments are also pulled inwards from both the sides, causing the shortening of the sarcomere (i.e. contraction). This process continues as long as the muscle receives the stimuli and a steady flow of calcium ions. When motor impulse stops, the calcium ions are pumped back into the sarcoplasmic reticulum, results in the masking of the active sites of the actin filaments.The myosin head fails to bind with the active sites of actin and these changes cause the return of Z- discs back to their original position, i.e. relaxation.

Which myofilament has the binding sites for calcium? Name the specific molecule that binds with calcium.

Skeletal Muscle Glycogen Analysis (SMGA) –Used to measure an Athlete's sporting performance by taking muscle biopsies. It is a standard method to measure muscle glycogen. Muscle glycogen provides the main source of energy during anaerobic exercise. Furthermore, total glycogen stores within the body also contribute significantly to energy metabolism in endurance-type events lasting longer in duration. A single glycogen molecule may contain 5000 glucose units compared to that of 5000 individual glucose molecules.

Schematic Presentation of Muscle Contraction

Muscle contraction is initiated by the signal from CNS

↓

Release of acetylcholine at the neuromuscular junction

↓

Causes action potential in muscle fibre

↓

Triggers the release of calcium ions from sarcoplasmic reticulum

↓

Calcium ions combine with troponin and tropomyosin uncovers the binding sites on actin and initiates contraction

↓

Myosin binding sites on actin exposed. Myosin head binds to actin

↓

Myosin head executes power stroke

↓

Actin filament slides towards the centre of sarcomere (contraction)

↓

Signal from CNS stops; calcium ions are pumped back into the sarcoplasmic reticulum

↓

Tropomyosin masks the binding sites. Filaments pulled back to the original position (relaxation)

All muscles produce movement, but only skeletal muscle is responsible for locomotion. What is meant by this statement?

9.6. Types of skeletal muscle contraction

There are two primary types of muscle contractions. They are **isotonic contraction** and **isometric contraction**. The types of contractions depend on the changes in the length and tension of the muscle fibres at the time of its contraction.

Isotonic contraction (iso- same, ton- weight/resistance)

In isotonic contraction the length of the muscle changes but the tension remains constant. Here, the force produced is unchanged. Example: lifting dumbbells and weightlifting.

Isometric contraction (iso- same, metric-distance)

In isometric contraction the length of the muscle does not change but the tension of the muscle changes. Here, the force produced is changed. Example: pushing against a wall, holding a heavy bag.

Types of skeletal muscle fibres

The muscle fibres can be classified on the basis of their rate of shortening, either fast or slow and the way in which they produce the ATP needed for contraction, either oxidative or glycolytic. Fibres containing myosin with high ATPase activity are classified as fast fibres and with lower ATPase activity are classified as slow fibres. Fibres that contain numerous mitochondria and have a high capacity for oxidative phosphorylation are classified as **oxidative fibres**. Such fibres depend on blood flow to deliver oxygen and nutrients to the muscles. The oxidative fibres are termed as **red muscle fibres**. Fibres that contain few mitochondria but possess a high concentration of glycolytic enzymes and large stores of glycogen are called **glycolytic fibres**. The lack of myoglobin gives pale colour to the fibres, so they are termed as **white muscle fibres**.

Skeletal muscle fibres are further classified into three types based on the above classification. They are slow – oxidative fibres, fast – oxidative fibres and fast – glycolytic fibres.

1. **Slow – oxidative fibres** have low rates of myosin ATP hydrolysis but have the ability to make large amounts of ATP. These fibres are used for prolonged, regular activity such as long distance swimming. Long – distance runners have a high proportion of these fibres in their leg muscles.
2. **Fast – oxidative fibres** have high myosin ATPase activity and can make large amounts of ATP. They are particularly suited for rapid actions.
3. **Fast – glycolytic fibres** have myosin ATPase activity but cannot make as much ATP as oxidative fibres, because their source of ATP is glycolysis. These fibres are best suited for rapid, intense actions, such as short sprint at maximum speed.

9.7 Skeletal system and its function

The skeletal system is constituted by a framework of bones and cartilages. It is derived from the embryonic **mesoderm**. Muscles are attached to the bones by means of tendons and provide the necessary force required for the bones of the skeleton to operate as levers. There are three types of skeletal systems. They are,

Hydrostatic skeleton, which is found in soft-bodied invertebrates. It is a fluid filled-cavity encircled by muscles (e.g. Earth worm).

Exoskeleton, which is found in invertebrates. It is a rigid hard case present outside the body of animals (e.g. Cockroach).

Endoskeleton, which is found inside the body of vertebrates. It is composed of bones and cartilages, surrounded by muscles. (eg. Human being).

In human beings, the skeletal system is made up of 206 bones and cartilages. It is grouped into two principal divisions – the

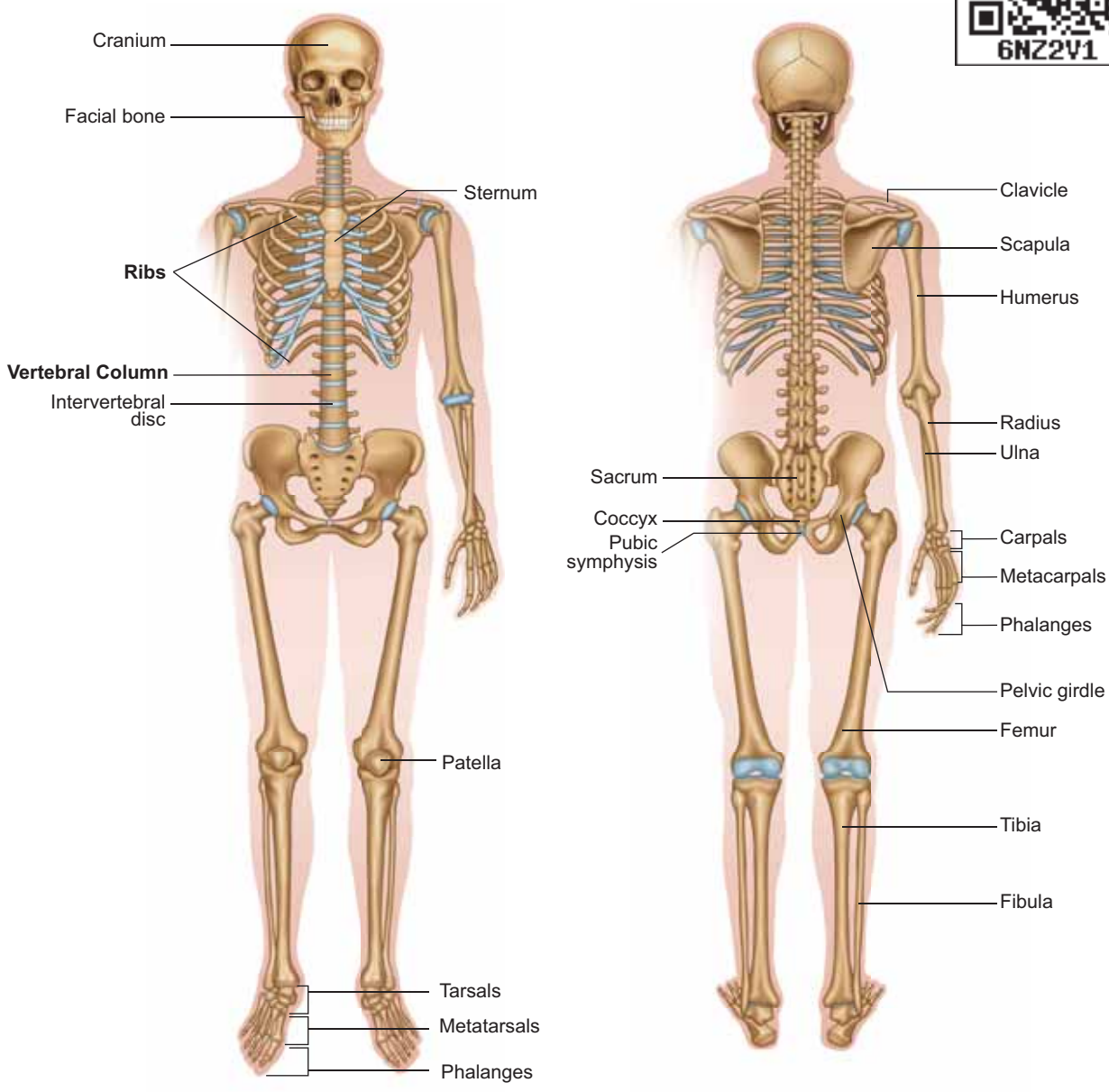


Figure 9.6 Human skeletal system

axial skeleton and the **appendicular skeleton**. The axial skeleton consists of 80 bones and the appendicular skeleton consists of 126 bones (Figure 9.6 and Table.1).

Functions of skeletal system

- Support –It forms a rigid framework and supports the weight of the body against gravity.
- Shape - It provides and maintains the shape of the body.
- Protection – It protects the delicate internal organs of the body.
- Acts as reservoir – It stores minerals such as calcium and phosphate. Fat (Triglyceride) is stored in yellow bone marrow and represents a source of stored energy for the body.
- Locomotion – It acts as lever along with the muscles attached to it.
- Strength – It can withstand heavy weight and absorbs mechanical shock.
- As a haemopoietic tissue – Red and White blood cells are produced in the bone marrow of the ribs, spongy bones of vertebrae and extremities of long bones.

9.8 The Axial skeleton

Axial skeleton forms the main axis of the body. It consists of the skull, hyoid bone, vertebral column and thoracic cage.

a) The Skull

The skull is composed of two sets of bones – cranial and facial bones. It consists of 22 bones of which 8 are cranial bones and 14 are facial bones (Figure 9.7). The cranial bones form the hard protective outer covering of the brain and called the brain box. The capacity of the cranium is 1500 cm^{3}. These bones are joined by sutures which are immovable. They are a **paired parietal, paired temporal** and **individual bones** such as the **frontal, sphenoid, occipital and ethmoid**.

The large hole in the temporal bone is the **external auditory meatus**. In the facial bones **maxilla, zygomatic, palatine, lacrimal, nasal** are paired bones whereas **mandible** or **lower jaw** and **vomer** are **unpaired bones**. They form the front part of the skull. A single U-shaped **hyoid bone** is present at the base of the buccal cavity. It is the only one bone without any joint. Each middle ear contains three tiny bones- **malleus**, **incus** and **stapes** collectively are called **ear ossicles**. The upper jaw is formed of the **maxilla** and the lower jaw is formed of the **mandible**. The upper jaw is fused with the cranium and is immovable. The lower jaw is connected to the cranium by muscles and is movable. The most prominent openings in the skull are **the orbits** and **the nasal cavity**. **Foramen magnum** is a large opening found at the posterior base of the skull**.** Through this opening the medulla oblongata of the brain descends down as the spinal cord.

b) The Vertebral Column

Vertebral column is also called the back bone. It consists of 33 serially arranged vertebrae which are interc onnected by cartilage known as intervertebral disc (Figure 9.8). The vertebral column extends from the base of the skull to the pelvis and forms the main frame work of the trunk. The vertebral column has five major regions. They are, **the Cervical**, **Thoracic**, **Lumbar**, **Sacrum** (5 sacral vertebrae found in the infant which are fused to form one bone in the adult) and **Coccyx** (4 coccygeal vertebrae found in the

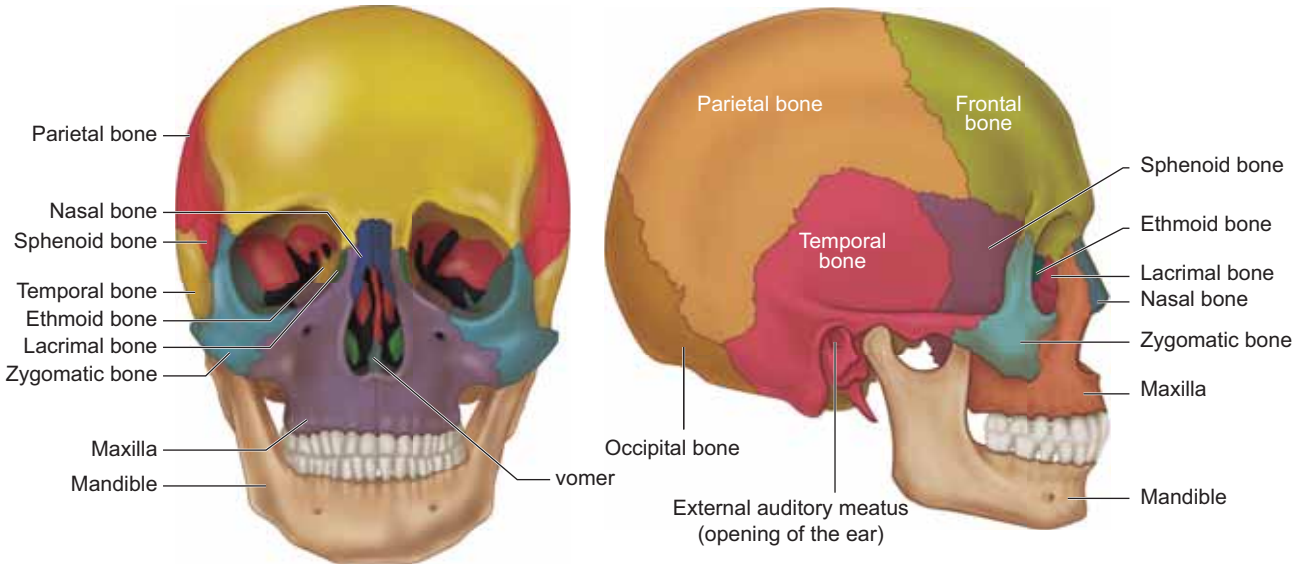


Figure 9. 7 Structure of the skull

infant which are fused to form one bone in the adult).

Each vertebra has a central hollow portion, the neural canal, through which the spinal cord passes. The first vertebra is called as **the atlas** and the second vertebra is called as **the axis**. Atlas is articulated with the occipital condyles.

The vertebral column protects the spinal cord, supports the head and serves as the point of attachment for the ribs and musculature of the back.

(c) The Sternum (Chest bone)

Sternum is a flat bone on the mid ventral line of the thorax. It provides space for the attachment of the thoracic ribs and abdominal muscles.

(d) The Rib cage

There are 12 pairs of ribs (Figure 9.9). Each rib is a thin flat bone connected dorsally to the vertebral column and ventrally to the sternum. It has two articulation surfaces on its dorsal end, hence called bicephalic. The first seven pairs of ribs are called '**true**

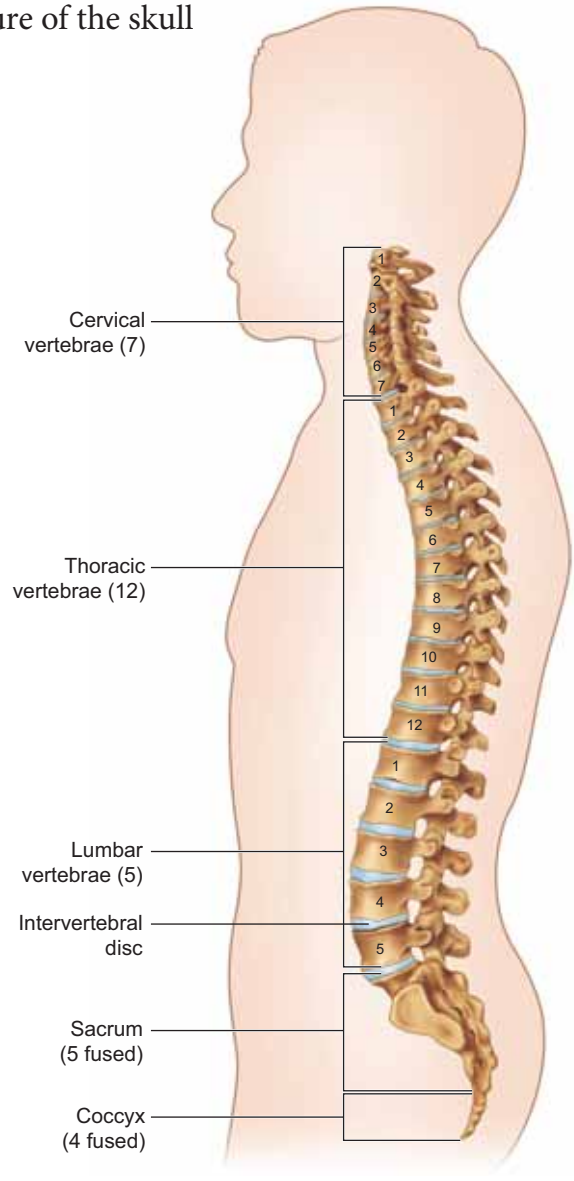


Figure 9. 8 Vertebral Column

ribs' or **vertebro–sternal ribs**. Dorsally they are attached to the thoracic vertebrae and ventrally connected to the sternum with the help of hyaline cartilages. The 8th, 9th and 10th pairs of ribs do not articulate directly with the sternum but joined with the cartilaginous (hyaline cartilage) part of the seventh rib. These are called **'false ribs'** or **vertebro-chondral ribs**. The last 11th and 12th pairs of ribs are not connected ventrally. Therefore, they are called as **'floating ribs'** or **vertebral ribs**. Thoracic vertebrae, ribs and sternum together form the ribcage.

Rib cage protects the lungs, heart, liver and also plays a role in breathing.

9.9 The Appendicular skeleton

The bones of the upper and lower limbs along with their girdles constitute the appendicular skeleton. The appendicular skeleton is composed of 126 bones.

(a) The Pectoral girdle

The upper limbs are attached to the pectoral girdles. These are very light and allow the upper limbs a degree of mobility not seen anywhere else in the body. The girdle is formed of two halves**.** Each half of the pectoral girdle (Figure 9.10) consists of **a clavicle** or **collar bone** and a **scapula**. The scapula is a large, thin, triangular

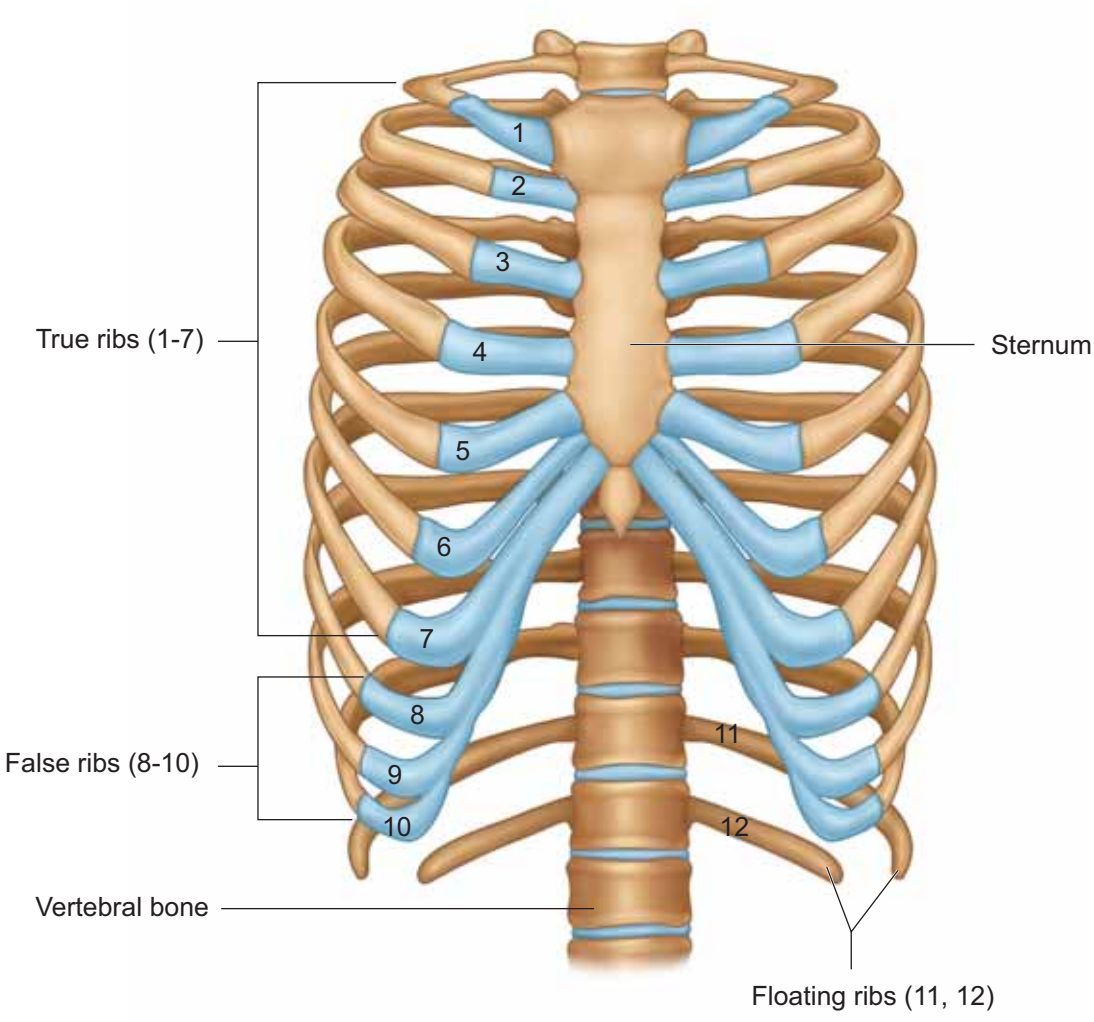


Figure 9 .9 Rib cage

bone situated in the dorsal surface of the ribcage between the second and seventh ribs. It has a slightly elevated ridge called the spine which projects as a flat, expanded process called the **acromion**. The clavicle articulates with this process. Below the acromion is a depression called the **glenoid cavity** which articulates with the head of the humerus to form the shoulder joint. Each clavicle is a long slender bone with two curvatures which lies horizontally and connects axial skeleton with appendicular skeleton.

The Upper limb

The upper limb consists of 30 separate bones and is specialized for mobility. The skeleton of the arm, the region between the shoulder and elbow is the **humerus**. The head of humerus articulates with the **glenoid cavity** of the scapula and forms the shoulder joint. The distal end of humerus articulates with the two forearm bones the **radius** and **ulna**. The forearm is the region between the elbow and the wrist. **Olecranon process** is situated at the upper end of the ulna which forms the pointed portion of the elbow.The hand consists of **carpals, metacarpals** and **phalanges.**

Carpals,the wrist bones, 8 in number are arranged in two rows of four each. The anterior surface of the wrist has tunnel-like appearance, due to the arrangement of carpals with the ligaments. This tunnel is termed as **carpal tunnel**.

Metacarpals,the palm bones are 5 in number and **phalanges** the digits bones are 14 in number.

(b) Pelvic Girdle

The pelvic girdle is a heavy structure specialized for weight bearing. It is

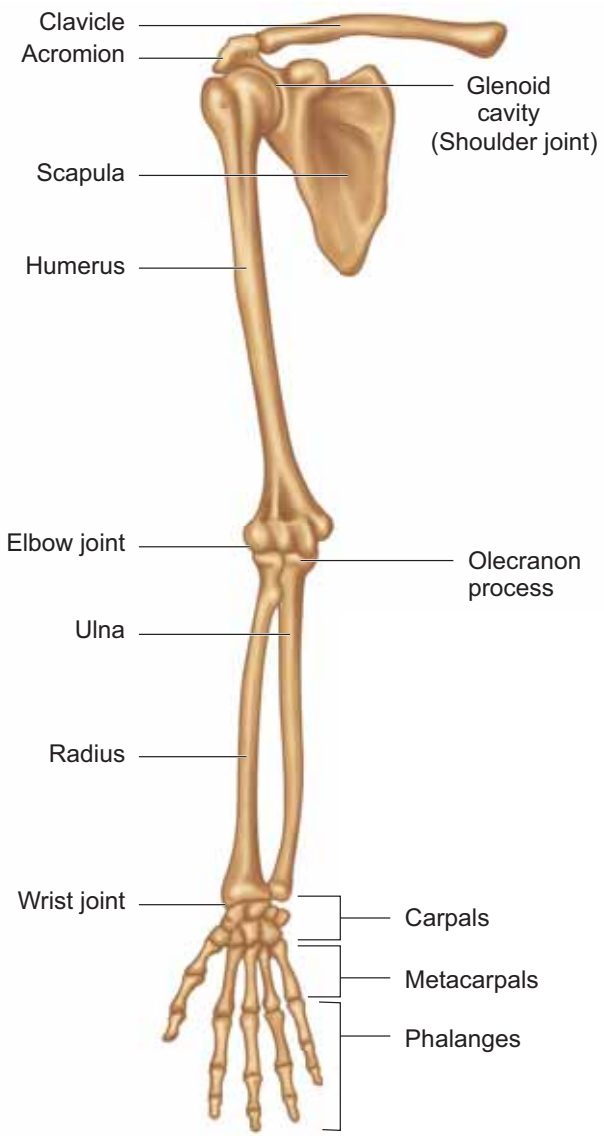


Figure 9. 10 Pectoral girdle with upper limb

composed of two hip bones called coxal bones that secure the lower limbs to the axial skeleton (Figure 9.11). Together, with the sacrum and coccyx, the hip bones form the basin-like bony pelvis.

Each coxal bone consists of three fused bones, **ilium, ischium** and **pubis**. At the point of fusion of ilium, ischium, and pubis a deep hemispherical socket called the acetabulum is present on the lateral surface of the pelvis. It receives the head of the femur or thigh bone at the hip joint and helps in the articulation

of the femur. Ventrally the two halves of the pelvic girdle meet and form the **pubic symphysis** containing fibrous cartilage.

The **ilium** is the superior flaring portion of the hip bone. Each ilium forms a secure joint with the sacrum posteriorly. The **ischium** is a curved bar of bone. The V-shaped **pubic bones** articulate anteriorly at the **pubic symphysis**. The pelvis of male is deep and narrow with larger heavier bones and the female is shallow, wide and flexible in nature, and this helps during pregnancy which is influenced by female hormones.

The Lower limb

The lower limb consists of 30 bones which carries the entire weight of the erect body and is subjected to exceptional forces when we jump or run. The bones of the lower limbs are thicker and stronger than the upper limbs. The three segments of each lower limb are **the thigh**, **the leg** or **the shank** and **the foot**. **The femur** is the single bone of the thigh. It is the largest, longest and strongest bone in the body. The head of femur articulates with **the acetabulum** of the pelvis to form the hip joint. Two parallel bones, **the tibia** and **fibula**, form the skeleton of the shank. A thick, triangular **patella** forms the knee cap, which protects the knee joint anteriorly and improves the leverage of thigh muscles acting across the knee. The foot includes the bones of ankle, **the tarsus**, **the metatarsus** and **the phalanges or toe bones**. The foot supports our body weight and acts as a lever to propel the body forward, while walking and running. **The tarsus**

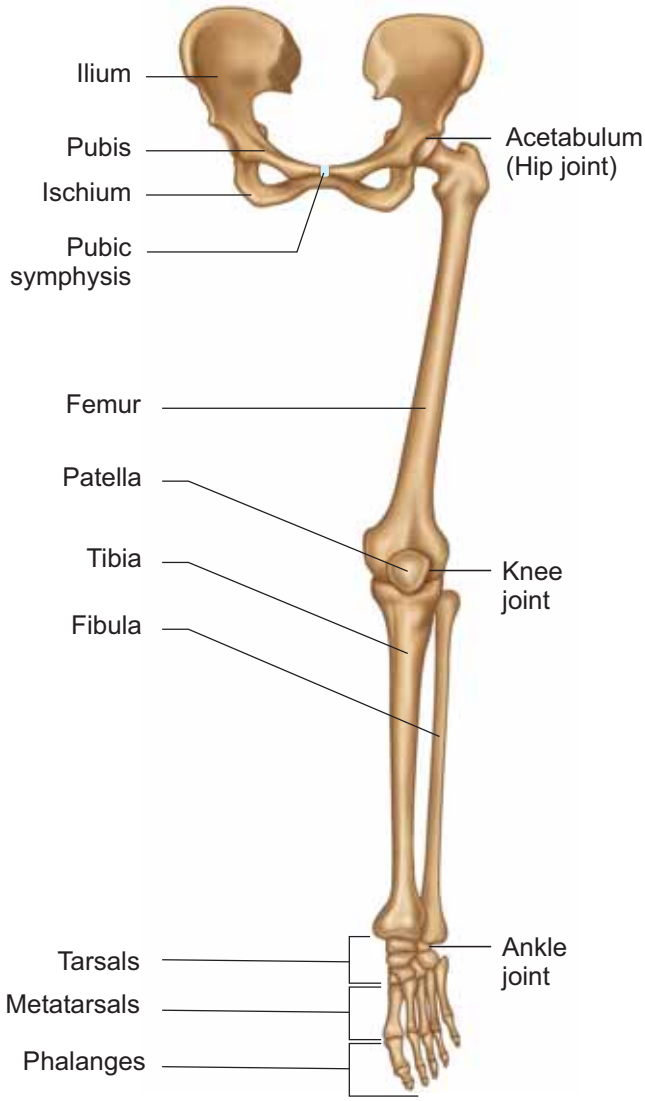


Figure 9.11 Pelvic girdle with lower limb

is made up of seven bones called tarsals. **The metatarsus** consists of five bones called metatarsals. The arrangement of the metatarsals is parallel to each other. There are 14 **phalanges** in the toes which are smaller than those of the fingers.

Structure of a typical long bone

A typical long bone has a **diaphysis**, **epiphyses** (singular-epiphysis) and **membranes** (Figure 9.12). A tubular diaphysis or shaft, forms the long axis of the bone. It is constructed of a thick collar of compact bone that surrounds a central **medullary cavity**

or **marrow cavity**. The epiphyses are the bone ends. Compact bone forms the exterior of epiphyses and their interior contains spongy bone with red marrow. The region where the diaphysis and epiphyses meet is called the **metaphysis**. The external surface of the entire bone except the joint surface is covered by a double-layered membrane called the **periosteum**. The outer fibrous layer is dense irregular connective tissue. The inner osteogenic layer consists of **osteoblasts** (bone- forming cells) which secrete bone matrix elements and **osteoclasts** (bone-destroying cells). In addition, there are primitive stem cells, osteogenic cells, that give rise to the osteoblasts. The periosteum is richly supplied with nerve fibres, lymphatic vessels and blood vessels. Internal bone surfaces are covered with a delicate connective tissue membrane called the **endosteum**. The endosteum covers the trabeculae of spongy bone and lines the canals that pass through the compact bone. It also contains both osteoblasts and osteoclasts. Between the epiphysis and diaphysis **epiphyseal plate** or **growth plate** is present.

9.10 Types of joints

Joints are essential for all types of movements performed by the bony parts of the body. The joints are points of contact (Figure 9.13) between bones.

The pelvic girdle is a heavy, strong girdle. How does its structure reflect its function?

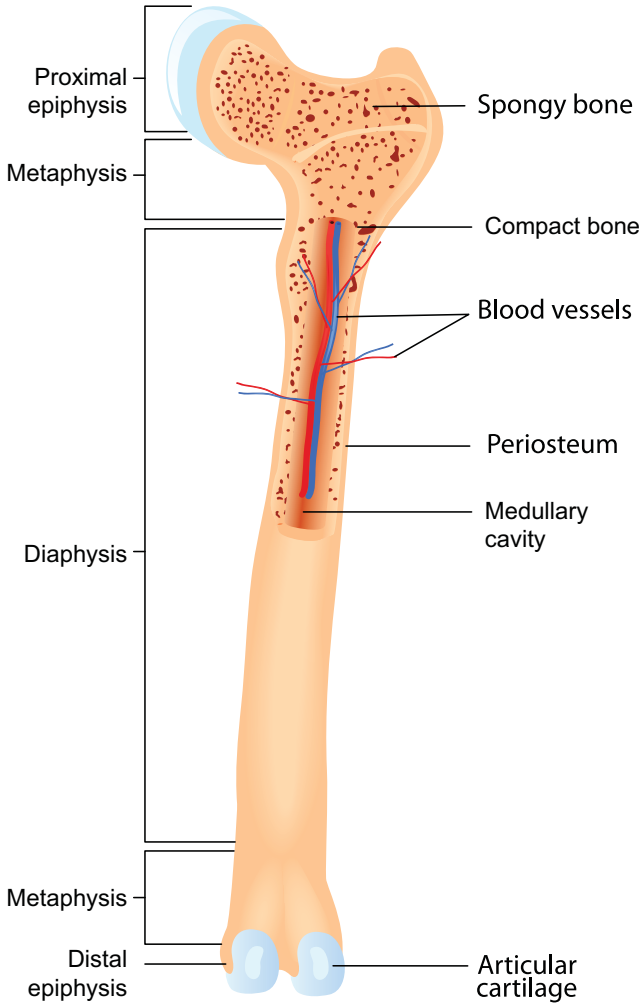


Figure 9.12 Structure of a long bone

Sometimes they are playing a protective role in the process. Force generated by the muscles are used to carry out the movement through joints which helps human functional activity of daily living and ambulation. The joint acts as a fulcrum of a lever.

(i) **Fibrous joints or Synarthroses:** They are immovable fixed joints in which no movement between the bones is possible. Sutures of the flat skull bones are fibrous joints.

(ii) **Cartilaginous joints or Amphiarthroses:** They are slightly movable joints in which the joint surfaces are separated by a cartilage and slight movement is only possible.

Table:1 Bones of the skeletal system

Skeleton	Name of Bone		Number of bones	Total number of bones
Axial skeleton (80 bones)	Skull	Cranium Facial bone Bones of middle ear Hyoid bone	8 14 6 (2 × 3) 1	29
	Vertebral column	Cervical Thoracic Lumbar Sacral Coccyx	7 12 5 5 bones fused to 1 bone 4 bones fused to 1 bone	26 (in adults)
	Sternum		1	1
	Ribs		12 × 2 = 24	24
Appendicular skeleton (126bones)	Fore limb	Humerus Radius Ulna Carpals Metacarpals Phalanges	1 1 1 8 5 14	60 (2 × 30)
	Hind limb	Femur Tibia Fibula Tarsal Metatarsals Phalanges Patella (Knee bone)	1 1 1 7 5 14 1	60 (2 × 30)
	Pectoral girdle	Scapula Clavicle	1 1	4 (2 × 2)
	Pelvic girdle	Innominate (Ilium, ischium and pubis fused into one bone)	1	2 (1 × 2)

Total number of bones in adults = 206

Human Muscular System

The skeletal muscles of our body work together or in opposition to achieve a wide variety of movements. Muscles can only pull; they never push. Activity of the muscles lead to increase in size or strength. Inactivity always leads to muscle weakness and wasting.

- **There are about 640 muscles in the body;**
- **It takes about 17 muscles to smile and 43 to frown;**
- **To take one step, we use about 200 muscles;**
- **The only muscle that never tires is our cardiac muscle.**

Cardiac Muscle

Smooth Muscle

Skeletal Muscle

The Masseter muscle is the strongest muscle present in the cheek.

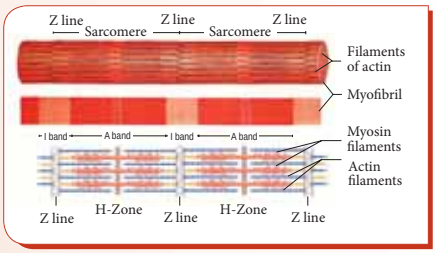
The Stapedius is the smallest muscle in the middle ear.

The tongue is the freely movable muscular organ.

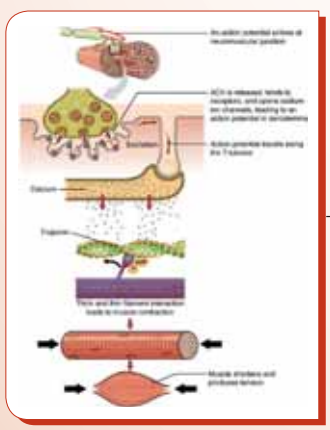
The Glutens maximus (buttock) is the largest muscle.

The Sartorius is the longest muscle runs from hip to knee.

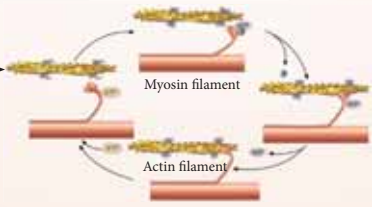
Ultra Structure of Skeletal Muscle

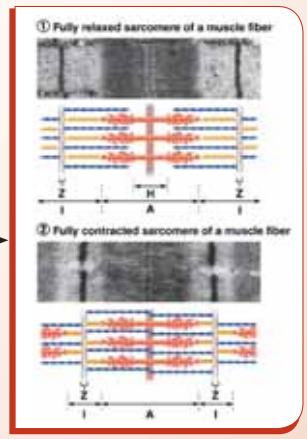


Events in Muscle Contraction



Cross bridge cycle





E.g., Joints of adjacent vertebrae of the vertebral column.

(iii) Synovial joints or Diarthroses joints: They are freely movable joints, the articulating bones are seperated by a cavity which is filled with synovial fluid.

E.g., Pivot joint – between atlas and axis
Plane/gliding joint – between the carpals
Saddle joint – between the carpal and metacarpal
Ball and socket joint – between humerus and pectoral girdle

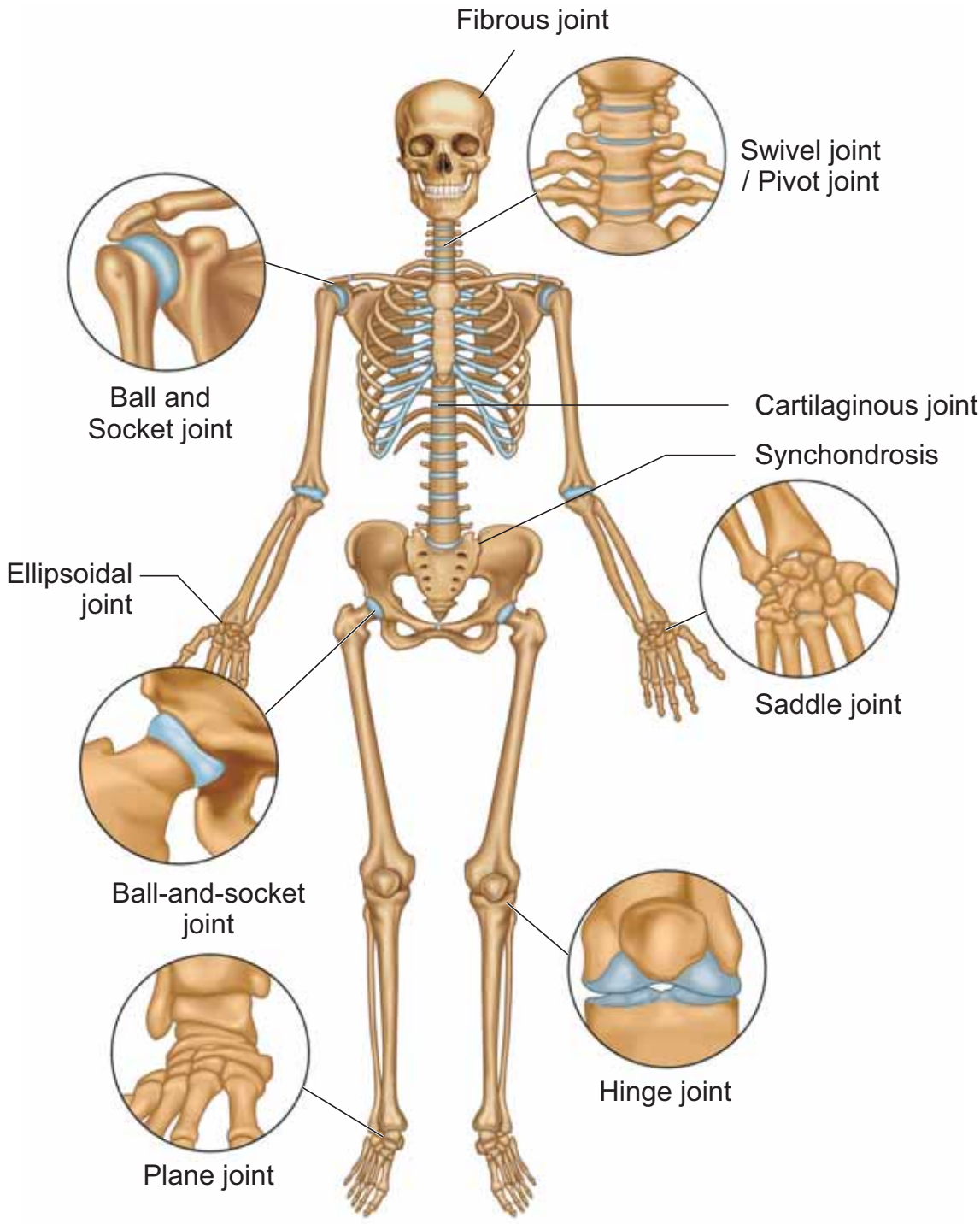


Figure 9. 13 Types of joints

Hinge joint – knee joint

Condyloid or Angular or Ellipsoid – joint between radius and carpal

9.11 Disorders of muscular and skeletal system

(a) Disorders of muscular system

Myasthenia gravis: An autoimmune disorder affecting the action of acetylcholine at neuromuscular junction leading to fatigue, weakening and paralysis of skeletal muscles. Acetylcholine receptors on the sarcolemma are blocked by antibodies leading to weakness of muscles. When the disease progresses, it can make chewing, swallowing, talking and even breathing difficult.

Tetany: Rapid muscle spasms occur in the muscles due to deficiency of parathyroid hormone resulting in reduced calcium levels in the body.

Muscle fatigue: Muscle fatigue is the inability of a muscle to contract after repeated muscle contractions. This is due to lack of ATP and accumulation of lactic acid by anaerobic breakdown of glucose

Atrophy: A decline or cessation of muscular activity results in the condition called atrophy which results in the reduction in the size of the muscle and makes the muscle to become weak, which occurs with lack of usage as in chronic bedridden patients.

Muscle pull: Muscle pull is actually a muscle tear. A traumatic pulling of the fibres produces a tear known as sprain. This can occur due to sudden stretching of muscle beyond the point of elasticity. Back pain is a common problem caused by muscle pull due to improper posture with static sitting for long hours.

Muscular dystrophy: The group of diseases collectively called the muscular dystrophy are associated with the progressive degeneration of skeletal muscle fibres, weakening the muscles and leading to death from lung or heart failure. The most common form of muscular dystrophy is called Duchene Muscular Dystrophy (DMD).

b) Disorders of skeletal system

Arthritis and osteoporosis are the major disorders of skeletal system.

1. **Arthritis:** Arthritis is an inflammatory (or) degenerative disease that damages the joints. There are several types of arthritis.
   - **(i) Osteoarthritis:** The bone ends of the knees and other freely movable joints wear away as a person ages. The joints of knees, hip, fingers and

CTS-(Carpal Tunnel Syndrome) – The narrow passage (tunnel) bounded by bones and ligaments in the wrist gets narrowed and pinches the median nerve. This syndrome is mostly seen among the clerks, software professionals and pregnant women and people who constantly play or text in mobile phones.

An exhausted student was attending a lecture. After 30 minutes or so, he lost interest and he let go with a tremendous yawn. To his great distress he couldn't close his mouth –his lower jaw was locked open. What do you think would have caused it?

vertebral column are affected.

(ii) **Rheumatoid arthritis:** The synovial membranes become inflamed and there is an accumulation of fluid in the joints. The joints swell and become extremely painful. It can begin at any age but symptoms usually emerge before the age of fifty.

(iii) **Gouty arthritis or gout:** Inflammation of joints due to accumulation of uric acid crystals or inability to excrete it. It gets deposited in synovial joints.

2. **Osteoporosis:** It occurs due to deficiency of vitamin D and hormonal imbalance. The bone becomes soft and fragile. It causes rickets in children and osteomalacia in adult females. It can be minimized with adequate calcium intake, vitamin D intake and regular physical activities.

9.12 Benefits of regular Exercise

Exercise and physical activity fall into four basic categories. Endurance, strength, balance and flexibility.

Endurance or aerobic activities increase the breathing and heart rate. They keep the circulatory system healthy and improve overall fitness.

DTI – Diffusion Tensor Imaging is applied to study skeletal muscle physiology, anatomy and pathology.

Strength exercises make the muscles stronger. They help to stay independent and carry out everyday activities such as climbing stairs and carrying bags.

Balance exercises help to prevent falls which is a common problem in older adults. Many strengthening exercises also improves balance.

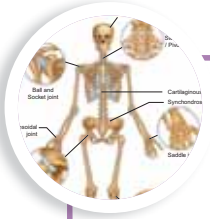
Flexibility exercises help to stretch body muscles for more freedom of joint movements.

Regular exercises can produce the following beneficial physiological changes:

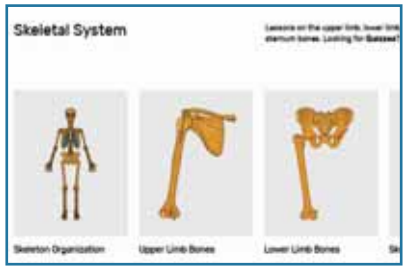
- The muscles used in exercise grow larger and stronger.
- The resting heart rate goes down.
- More enzymes are synthesized in the muscle fibre.
- Ligaments and tendons become stronger.
- Joints become more flexible.
- Protection from heart attack.
- Influences hormonal activity.
- Improves cognitive functions.
- Prevents Obesity.
- Promotes confidence, esteem.
- Aesthetically better with good physique.
- Over all well-being with good quality of life.
- Prevents depression, stress and anxiety.

During muscular exercise, there is an increase in metabolism. The O_2 need of the muscles is increased. This requirement is met with more oxygen rich RBCs available to the active sites. There is an increase in heart rate and cardiac output. Along with balanced diet, physical activity plays a significant role in strengthening the muscles and bones.

We like to move



Let's explore the skeletal system page to understand the **skeletal organization.**



Step – 1

Use the URL to reach the 'Skeletal System' page. From grid select 'Skeleton Organization' and explore the skeleton's general anatomical arrangement and functions.

Step – 2

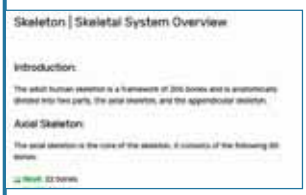
Then reach the 'Skeleton Organization page by clicking back button on the top of the window or use the 'Backspace' key. Select 'Upper Limb Bones' from the grid and explore the anatomy and functions of the clavicle, scapula, humerus, radius, ulna, carpal, and hand bones.

Step – 3

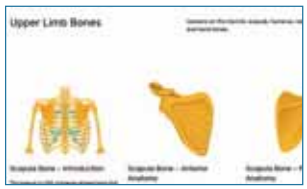
Follow the above steps and explore the interactives of each part and its functions.

Step – 4

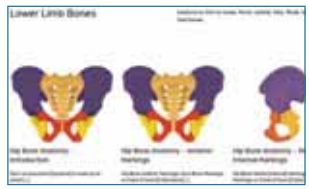
Use the reference given below the page to acquire additional details about 'Skeletal System'.



Step 1



Step 2



Step 3

Step 4

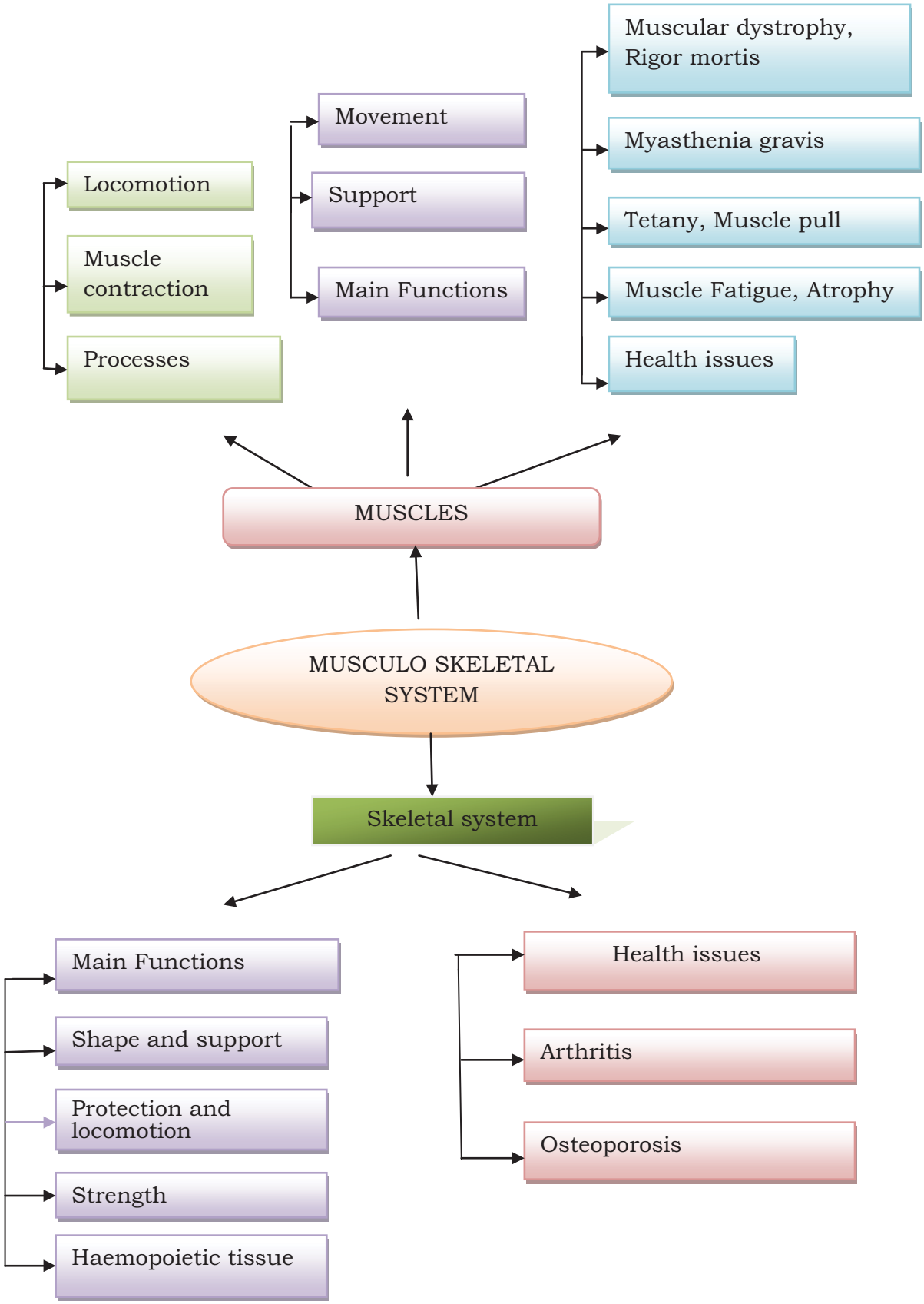
Skeletal System's URL:

https://www.getbodysmart.com/skeletal-system

B167_STD_11_ZOOLOGY_EM

* Pictures are indicative only

Concept Map


MUSCULO SKELETAL SYSTEM
MUSCLES
Locomotion
Muscle contraction
Processes
Movement
Support
Main Functions
Muscular dystrophy, Rigor mortis
Myasthenia gravis
Tetany, Muscle pull
Muscle Fatigue, Atrophy
Health issues
Skeletal system
Main Functions
Shape and support
Protection and locomotion
Strength
Haemopoietic tissue
Health issues
Arthritis
Osteoporosis

Summary

Movement is one of the significant features of living organisms. The different types of movements are amoeboid movement, ciliary movement, flagellar movement and muscular movement. Three types of muscles are present in human beings. They are the skeletal muscle, visceral muscle and cardiac muscle. The skeletal muscles are attached to the bones by tendons.

The most striking microscopic feature of skeletal muscle is a series of light and dark bands. There are two types of muscle contraction. They are isotonic and isometric contractions.

The skeletal system consists of a frame work of bones and cartilages. The skeletal system is grouped into two principal divisions: the axial skeleton and the appendicular skeleton. There are three types of joints present in the body: fibrous, cartilaginous and synovial joints.

The disorders related to muscular system are myasthenia gravis, muscular dystrophy, tetany, muscle fatigue, muscle pull, atrophy and rigor mortis. The disorders of the skeletal system are arthritis and osteoporosis. Regular body exercise keeps the body fit and healthy.

A typical long bone has a diaphysis (shaft), epiphyses (singular-epiphysis) and membranes. Even though the bones are strong, they are also susceptible to fractures or breaks.

Glossary

Acetylecholine – A neurotransmitter found throughout the nervous system.

Actin – A protein found in the cytoskeleton and muscle cells; it is the principal constituent of the thin filament.

Adenosine triphosphate(ATP) – A nucleotide molecule consisting of adenine, riboseand three phosphate molecules. It plays a central role in energy exchange in biological systems.

Cartilage – A firm, elastic connective tissue produced by the cells,called chondrocytes.

Exoskeleton – Skeletal elements are located upon body surface or in the skin (Example: Shells of snails in inverbrates, Hair claw and nails in vertibrates.

Endoskeleton – Skeletal elements are located inside the organisms with muscles outside. Found in skeletal system of vertibrates

Lever system – Movement takes place along the joints which act as fulcrum of the lever. One can observe functioning of all the three types of levers in the human skeleton.

Mesoderm – The middle embryonic germ layer. It gives rise to the muscular,skeletal,urogenital and circulatory system.

Motor neuron – A motor neuron that transmits nervous impulses from the spinal cord to effectors.

Myoglobin – Heme containing protein that binds molecular oxygen in muscle cells.

Myosin – A protein found in muscle cells that function in muscle contaction. It is present in thick filaments of muscles, known as myosin fibres

Sarcolemma – Muscle cell membrane capable of propagating action potentials

Sarcomere – The functional contractile unit of striated muscle.

Sarcoplasmic reticulum – The endoplasmic reticulum of a muscle cell. It envelopes myofibrils

Tendon – A fibrous connective tissue that connects a bone to a muscle

Evaluation

1. Muscles are derived from
   a. ectoderm b. mesoderm
   c. endoderm d. neuro ectoderm
2. Muscles are formed by
   a. myocytes b. leucocytes
   c. osteocytes d. lymphocytes
3. The muscles attached to the bones are called
   a. skeletal muscle
   b. cardiac muscle
   c. involuntary muscle
   d. smooth muscles
4. Skeletal muscles are attached to the bones by
   a. tendon b. ligament
   c. pectin d. fibrin
5. The bundle of muscle fibres is called
   a. Myofibrils b. fascicle
   c. sarcomere d. sarcoplasm
6. The pigment present in the muscle fibre to store oxygen is
   a. myoglobin b. troponin
   c. myosin d. actin
7. The functional unit of a muscle fibre is
   a. sarcomere b. sarcoplasm
   c. myosin d. actin
8. The protein present in the thick filament is
   a. myosin b. actin
   c. pectin d. leucin
9. The protein present in the thin filament is
   a. myosin b. actin
   c. pectin d. leucin
10. The region between two successive Z-discs is called a
    a. sarcomere b. microtubule
    c. myoglobin d. actin
11. Each skeletal muscle is covered by
    a. epimysium b. perimysium
    c. endomysium d. hypomysium
12. Knee joint is an example of
    a. saddle joint b. hinge joint
    c. pivot joint d. gliding joint
13. Name of the joint present between the atlas and axis is
    a. synovial joint b. pivot joint
    c. saddle joint d. hinge joint
14. ATPase enzyme needed for muscle contraction is located in
    a. actinin b. troponin
    c. myosin d. actin
15. Synovial fluid is found in
    a. Ventricles of the brain
    b. Spinal cord
    c. immovable joint
    d. freely movable joints.
16. Inflammation of joints due to accumulation of uric acid crystals is called as
    a. Gout b. myasthenia gravis
    c. osteoporosis d. osteomalacia
17. Acetabulum is located in
    a. collar bone b. hip bone
    c. shoulder bone d. thigh bone

18. Appendicular skeleton is
    a. girdles and their limbs
    b. vertebrae
    c. skull and vertebral column
    d. ribs and sternum
19. The type of movement exhibits by the macrophages are
    a. flagellar b. ciliary
    c. muscular d. amoeboid
20. The pointed portion of the elbow is
    a. acromion process
    b. glenoid cavity
    c. olecranon process
    d. symphysis
21. Name the different types of movement
22. Name the filaments present in the sarcomere
23. Name the contractile proteins present in the skeletal muscle
24. When describing a skeletal muscle, what does "striated" mean?
25. How does an isotonic contraction take place?
26. How does an isometric contraction take place?
27. Name the bones of the skull.
28. Which is the only jointless bone in human body?
29. List the three main parts of the axial skeleton
30. How is tetany caused?
31. How is rigor mortis happened?
32. What are the different types of rib bones that form the rib cage?
33. What are the bones that make the pelvic girdle?
34. List the disorders of the muscular system.
35. Explain the sliding- filament theory of muscle contraction.
36. What are the benefits of regular exercise?

Internet Resources

1. Understanding Mammalian Locomotion: Concepts and Applications https://books .google.co.in/books?isbn=0470454644
2. www.brookerbiology.com

Career link

1. A Physiotherapist rehabilitates patients by helping them improve their physical movement. They treat people who are injured or disabled in order to recover full function and movement.
2. Sports Medicine Physicians. Both medical doctors and doctors of osteopathy deal with sports-related injuries and illnesses.
3. Atheletic Trainers.
4. Exercise Physiologists.
5. Kinesiotherapists.

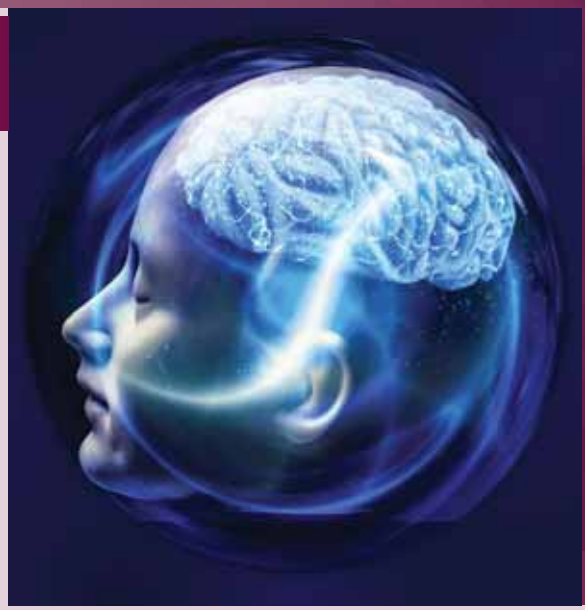
References

1. Elaine N. Mariep Katja Hoech, 2010, In human Anatomy and Physiology, Pearson Benjamin cummings Publishing Ltd.,
2. Sherwood. L, and Kell. R., 2010. Human Physiology, Nelson Education Ltd., Thomson Brooks/Cole.,
3. Guyton and Hall, 2003. In. Textbook of Medical Physiology; Harcourt Indian Private Limited. Inc.855 pp.

UNIT IV | Chapter 10

Neural Control And Coordination

Chapter Outline



Gamma-aminobutyric acid, or GABA, is the brain's major inhibitory neurotransmitter that reduces neuronal excitability.

Learning Objectives:

- *Understands the structure of neuron and neural system of human beings*
- *Learns to differentiate the functions of sensory and motor neuron*
- *Understands the conduction of nerve impulses and learns the importance of myelin sheath-saltatory conduction.*
- *Outlines the role of synapse and neuromuscular junction.*
- *Learns the structure and functions of central neural system*
- *Understands the structure, sensory reception and processing in Photo, Phono, Olfactory, Gustatory and Skin Receptors*

6PHTYB

Did you ever wonder how our body functions? The body maintains a stable condition even when the outside environment changes; Our eyes help to see things around us; Ears help us to hear various sounds; Heart beats continuously and rhythmically; Air goes in and out of lungs; Eyes shed tears when our limbs get hurt. Each cell of the body works in a coordinated manner. Do you know how it is coordinated and controlled?

The neural system of our body coordinates all the other systems to work together effectively and smoothly. Every second, diverse functions in our body are performed by the neural system. Day and night, millions of messages pass as stimuli through the cells of the neural system to stimulate the heart to beat; kidney to excrete waste; and mouth to relish the delicious food. An even more remarkable

feature of the neural system is its ability to respond simultaneously to several stimuli, for instance, we can play piano and sing; listen to music and do household chores. In all such coordinated movements, whether skilled performances or routine tasks like cycling or driving, the integrating power of the neural system is involved. In this chapter, you will understand how neural system is organized; how it integrates all organs and what kind of cellular events underlie its functioning.

10.1 Neural system

The neural system comprises of highly specialized cells called **neurons**, which can detect, receive, process and transmit different kinds of stimuli. Simple form of neural system as nerve net is seen in lower invertebrates. The neural system of higher animals are well developed and performs the following basic functions:

- **Sensory functions**- It receives sensory input from internal and external environment.
- **Motor functions**- It transmits motor commands from the brain to the skeletal and muscular system.
- **Autonomic functions**- Reflex actions.

10.2 Human Neural System

The human neural system is divided into two**, the central neural system (CNS)** and **the peripheral neural system** (**PNS**). The structural and functional units of the neural system are neurons that transmit nerve impulses. The non-nervous special cells called **neuroglia** form the supporting cells of the nervous tissue.

There are three functional classes of neurons. They are the **afferent neurons** that take sensory impulses to the Central Neural system (CNS) from the sensory organs; the **efferent neurons** that carry motor impulses from the CNS to the effector organs; and **interneurons** that lie entirely within the CNS between the afferent and efferent neurons.

The central neural system lacks connective tissue, so the interneuron space is filled by neuroglia. They perform several functions such as providing nourishment to the surrounding neurons; involving the memory process; repairing the injured tissues due to their dividing and regenerating capacity; and acting as phagocyte cells to engulf the foreign particles at the time of any injury to the brain.

Glial cells do not lose the ability to undergo cell division; so most brain tumours of neural origin consists of glial cells. Neurons themselves do not form tumours because they are unable to divide and multiply.

10.3 Neuron as a structural and functional unit of Neural system

A neuron is a microscopic structure composed of three major parts namely **cell body** (soma), **dendrites** and **axon.** The cell body is the spherical part of the neuron that contains all the cellular organelles as a typical cell (except centriole)**.** The plasma membrane covering the neuron is called **neurilemma** and the axon is **axolemma.** The repeatedly branched

short fibres coming out of the cell body are called **dendrites,** which transmit impulses towards the cell body. The cell body and the dendrites contain cytoplasm and granulated endoplasmic reticulum called **Nissl's granules.**

An axon is a long fibre that arises from a cone shaped area of the cell body called the **Axon hillock** and ends at the branched distal end. Axon hillock is the place where the nerve impulse is generated in the motor neurons. The axon of one-neuron branches and forms connections with many other neurons. An axon contains the same organelles found in the dendrites and cell body but lacks Nissl's granules and Golgi apparatus.

The axon, particularly of peripheral nerves is surrounded by **Schwann cells** (a type of glial cell) to form myelin sheath, which act as an insulator. **Myelin sheath** is associated only with the axon; dendrites are always non-myelinated. Schwann cells are not continuous along the axon; so there are gaps in the myelin sheath between adjacent Schwann

The longest cells in the human body are the **neurons**. The **longest** axons in the **human body**, for example, are those of the sciatic nerve, which run from the base of the spine to the big toe of each foot. These single-cell fibers may extend a meter or even longer. The axons of the inter neurons in the CNS are the shortest.

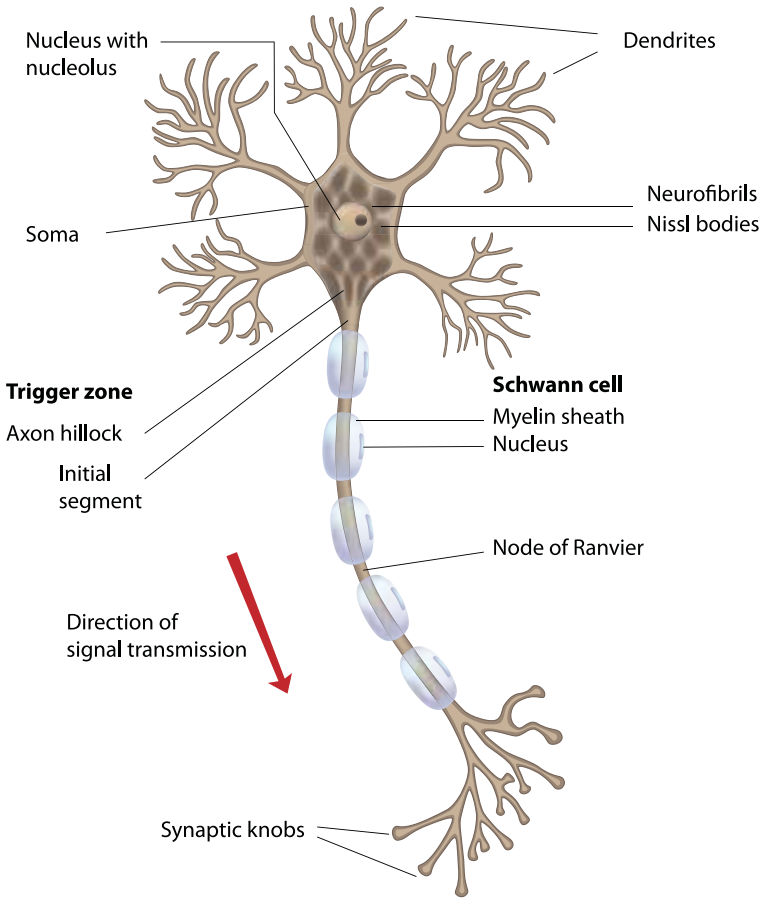


Figure 10.1 Neuron

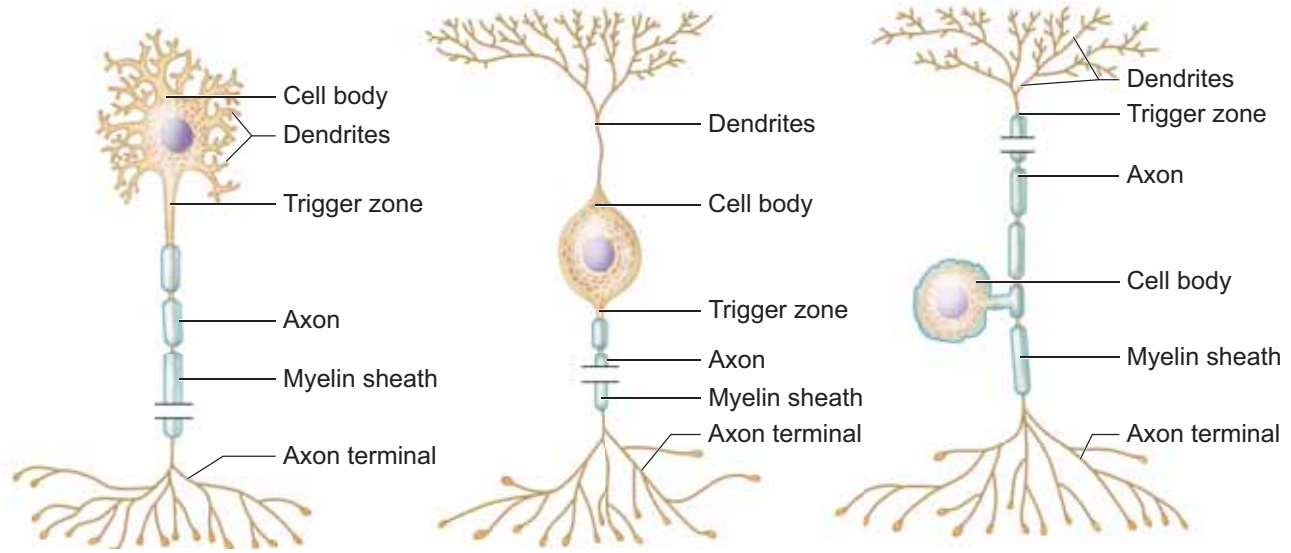


Figure 10.2. Types of Neurons

cells. These gaps are called **Nodes of Ranvier**. Large myelinated nerve fibres conduct impulses rapidly, whereas non-myelinated fibres conduct impulses quite slowly (Figure 10.1).

Each branch at the distal end of the axon terminates into a bulb like structure called **synaptic knob** which possesses **synaptic vesicles** filled with **neurotransmitters**. The axon transmits nerve impulses away from the cell body to an **inter neural space** or to a **neuro-muscular junction.**

The neurons are divided into three types based on number of axon and dendrites they possess (Figure.10.2).

1. Multipolar neurons have many processes with one axon and two or more dendrites. They are mostly interneurons.

2. Bipolar neurons have two processes with one axon and one dendrite. These are found in the retina of the eye, inner ear and the olfactory area of the brain.

3. Unipolar neurons have a single short process and one axon. Unipolar neurons are located in the ganglia of cranial and spinal nerves.

10.3.1 Generation and conduction of nerve impulses

This section deals with how the nerve impulses are produced and conducted in our body. Sensation felt in the sensory organs are carried by the nerve fibres in the form of electrical impulses. A nerve impulse is a series of electrical impulses, which travel along the nerve fibre. Inner to the axolemma, the cytoplasm contains the **intracellular fluid** (**ICF**) with large amounts of potassium and magnesium phosphate along with negatively charged proteins and other organic molecules.**The extra cellular fluid (ECF)** found outside the axolemma contains large amounts of sodium chloride, bicarbonates, nutrients and oxygen for the cell; and carbon dioxide and metabolic wastes released by the

Note: The charged particles have potential energy. The potential difference is the measure of potential energy between two points which is measured in volts or millivolts.

Table: 10.1 Ionic Channels in the Axolemma

Leakage Channels are ionic channels that remain open all the time	K^+ leakage channels are more in number than the Na^+ leakage channels. Sarcolemma has greater permeability to K^+ ions than Na^+ ions. These ions keep moving continuosly maintain the potential difference across the axolemma.
Ligand-gated Channels are chemically gated channels which open or close in response to a chemical stimuli.	They are located between the presynaptic membrane of the first axon and post synaptic membrane of the cell body of second neuron [i.e. dendrites and cell bodies]. The neurotransmitter acetylcholine opens ligand channels that allow Na^+ and Ca^{++} ions diffuse inward and K^+ ions diffuse outward.
Voltage-gated Channels are mechanically gated channels which open in response to a physical stimulus in the form of vibration such as touch and pressure.	These channels open in response to a change in membrane potential. There are two types of voltage-gated channels. **i. Sodium voltage-gated channel** **ii. Potassium voltage-gated channel**

neuronal cells. The ECF and ICF (cytosol) contains negatively charged particles (anions) and positively charged particles (cations). These charged particles are involved in the conduction of impulses.

The neurons maintain an uneven distribution of various inorganic ions across their axolemma for transmission of impulses. This unequal distribution of ions establishes the membrane potential across the axolemma. The axolemma contains a variety of membrane proteins that act as ionic channels and regulates the movement of ions across the axolemma. (Shown in Table 10.1).

10.3.2 Transmission of impulses

The transmission of impulse involves two main phases; **Resting membrane potential** and **Action membrane potential.**

Resting membrane Potential: The electrical potential difference across the plasma membrane of a resting neuron is called the **resting potential** during which the interior of the cell is negative due to greater efflux of K^+ outside the cell than Na^+ influx into the cell. When the axon is not conducting any impulses i.e. in resting condition, the axon membrane is more

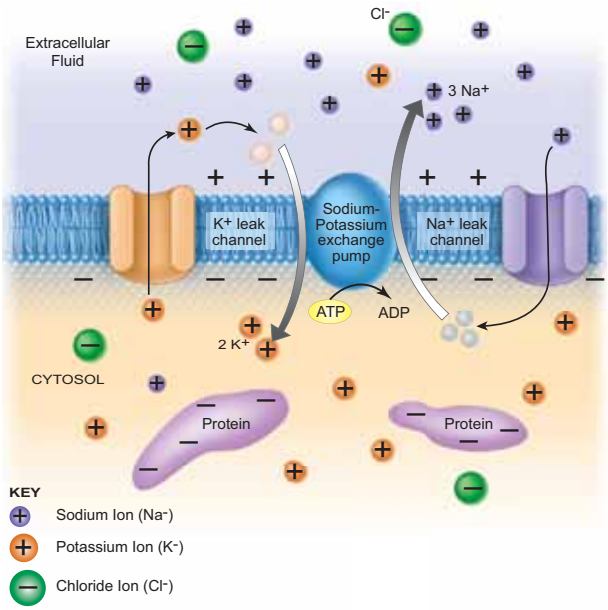


Figure 10.3 Ionic channels

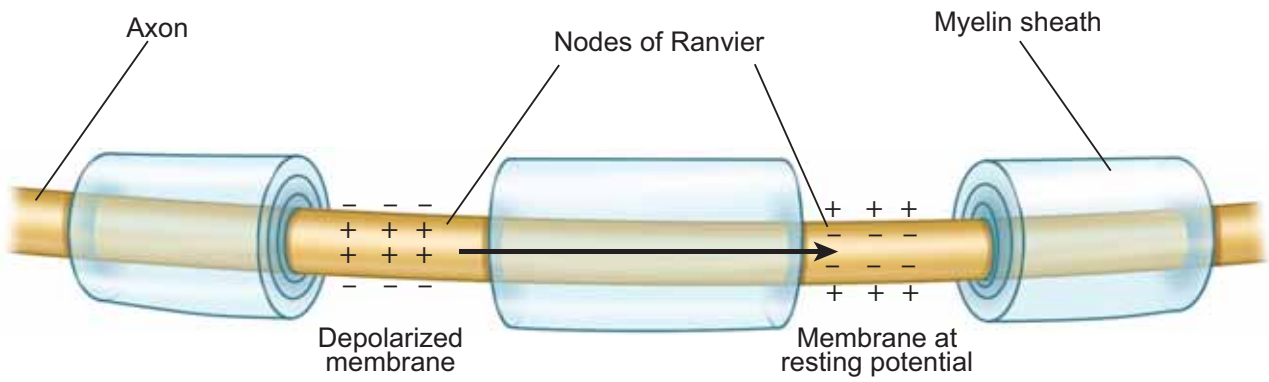


Figure 10.4 Conduction of nerve impulse

permeable to K^+ and less permeable to Na^+ ions, whereas it remains impermeable to negatively charged protein ions.

The axoplasm contains high concentration of K^+ and negatively charged proteins and low concentration of Na^+ ions. In contrast, fluid outside the axon (ECF) contains low concentration of K^+ and high concentration of Na^+, and this forms a concentration gradient. This ionic gradient across the resting membrane is maintained by ATP driven **Sodium-Potassium** pump,

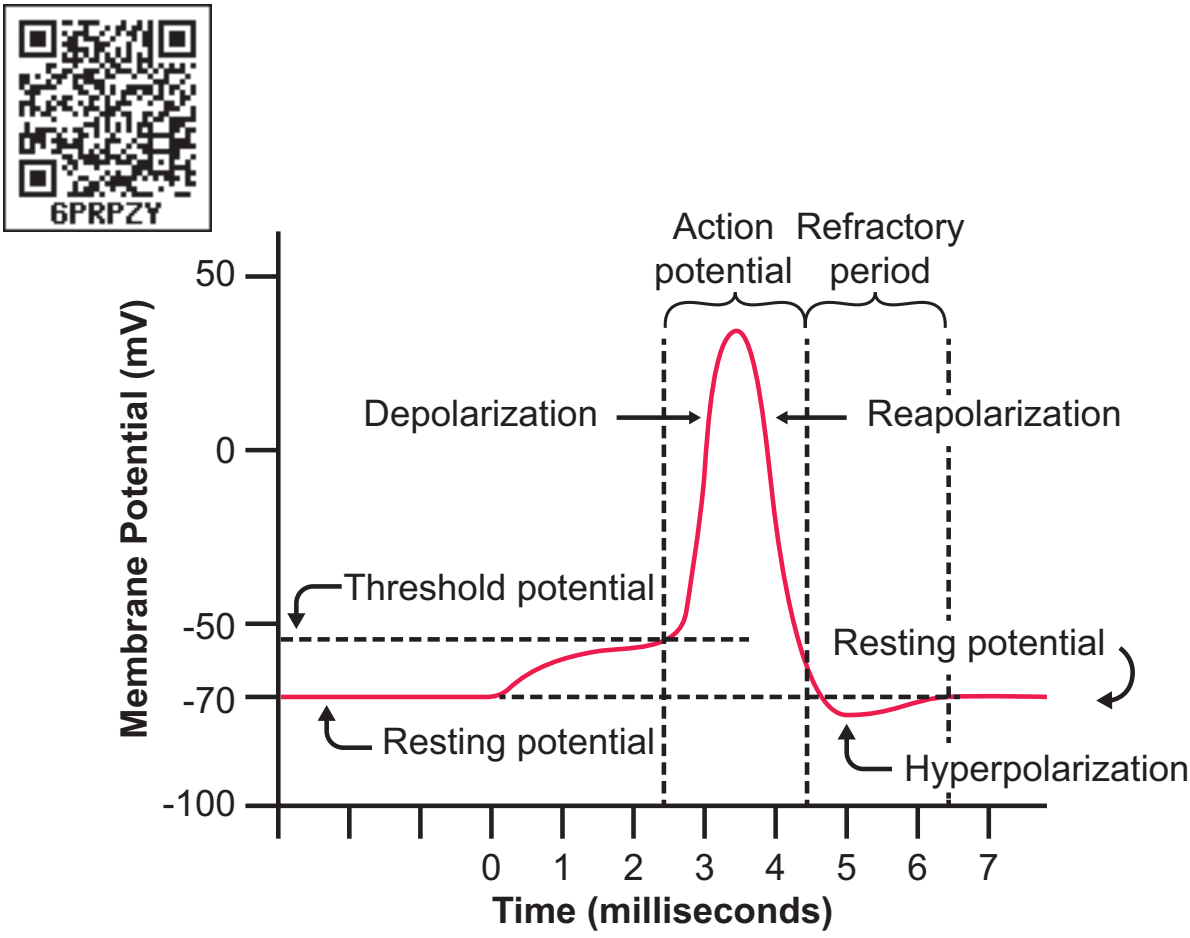


Figure 10.5 Graph showing Action potential in Neuron

which exchanges $3Na^+$outwards for $2K^+$ into the cells. In this state, the cell membrane is said to be **polarized**. In neuron, the **resting membrane potential** ranges from -**40mV** to -**90mV**, and its normal value is -**70mV**. The minus sign indicates that the inside of the cell is negative with respect to the outside (Figure 10.4).

Action membrane potential

An action potential occurs when a neuron sends information down an axon, away from the cell body. It includes following phases, depolarization, repolarisation and hypo polarization.

Depolarization – Reversal of polarity

When a nerve fibre is stimulated, **sodium voltage-gate opens** and makes the **axolemma** permeable to Na^+ ions; meanwhile **the potassium voltage gate** closes. As a result, the rate of flow of Na^+ ions into the **axoplasm** exceeds the rate of flow of K^+ ions to the outside fluid [ECF]. Therefore, the axolemma becomes positively charged inside and negatively charged outside. This reversal of electrical charge is called **Depolarization**.

During depolarization, when enough Na^+ ions enter the cell, the action potential reaches a certain level, called **threshold potential** [-55mV]. The particular stimulus which is able to bring the membrane potential to threshold is called **threshold stimulus**.

The action potential occurs in response to a **threshold stimulus** but does not occur at **subthreshold stimuli**. This is called **all or none principle.** Due to the rapid influx of Na^+ ions, the membrane potential shoots rapidly up to +45mV which is called the **Spike potential**.

Repolarisation [Falling Phase]

When the membrane reaches the spike potential, **the sodium voltage-gate closes** and **potassium voltage-gate opens**. It checks influx of Na^+ions and initiates the efflux of K^+ions which lowers the number of positive ions within the cell. Thus, the potential falls back towards the resting potential. The reversal of membrane potential inside the axolemma to negative occurs due to the efflux of K^+ ions. This is called **Repolarisation**.

Hyperpolarization

If repolarization becomes more negative than the resting potential -70 mV to about -90 mV, it is called **Hyperpolarization**. During this, K^+ ion gates are more permeable to K^+ even after reaching the threshold level as it closes slowly; hence called **Lazy gates**. The membrane potential returns to its original **resting state** when K^+ ion channels close completely. During hyperpolarization the Na^+ voltage gate remains closed (Figure 10.5).

Conduction Speed of a nerve impulse

The conduction speed of a nerve impulse depends on the diameter of axon. The greater the axon's diameter, the faster is the conduction. The **myelinated axon** conducts the impulse faster than the **non-myelinated axon**. The voltage-gated Na^+ and K^+ channels are concentrated at the **nodes of Ranvier**. As a result, the impulse jumps node to node, rather than travelling the entire length of the nerve fibre. This mechanism of conduction is called **Saltatory Conduction**. Nerve impulses travel at the speed of 1-300 m/s.

10.3.3 Synaptic transmission

The junction between two neurons is called a **Synapse** through which a nerve

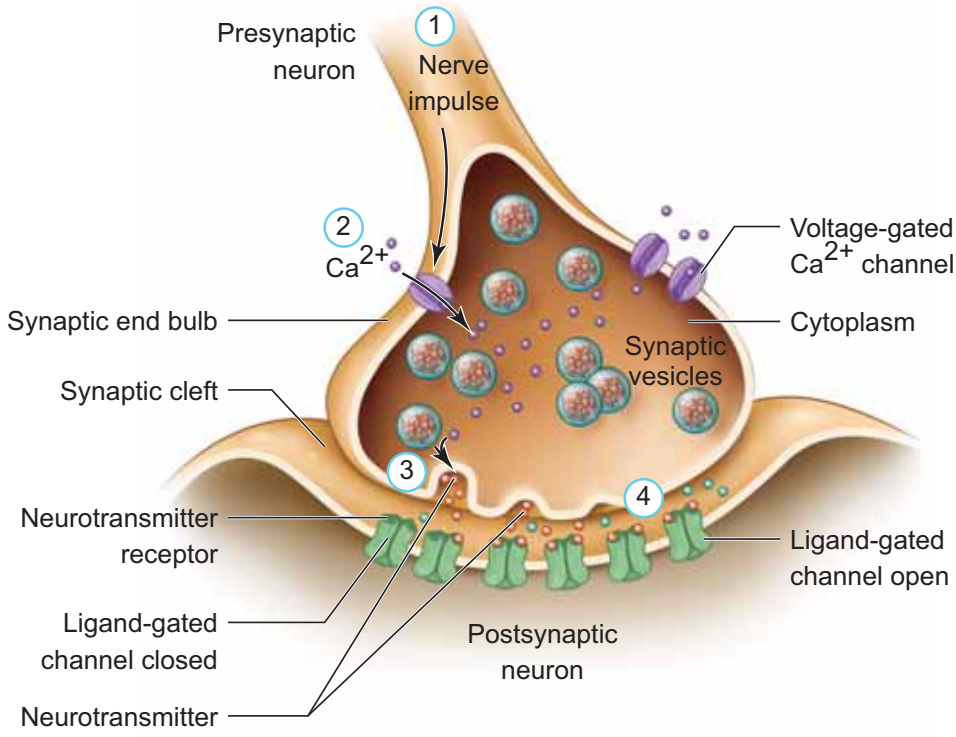


Figure 10.6 Synaptic Transmission

impulse is transmitted. The first neuron involved in the synapse forms the **pre-synaptic neuron** and the second neuron is **the post-synaptic neuron**. A small gap between the pre and postsynaptic membranes is called **Synaptic Cleft** that forms a structural gap and a functional bridge between neurons. The axon terminals contain synaptic vesicles filled with **neurotransmitters**. When an impulse [action potential] arrives at the axon terminals, it depolarizes the pre-synaptic membrane, opening the voltage gated calcium channels. Influx of calcium ions stimulates the synaptic vesicles towards the pre-synaptic membrane and fuses with it. In the neurilemma, the vesicles release their neurotransmitters into the synaptic cleft by **exocytosis.** The released neurotransmitters bind to their specific receptors on the post-synaptic membrane, responding to chemical signals. The entry of the ions can generate a new potential in the post-synaptic neuron, which may be either **excitatory** or **inhibitory**. Excitatory post-synaptic potential causes depolarization whereas inhibitory post-synaptic potential causes **hyperpolarization** of post-synaptic membrane (Figure 10.6).

Can you state why some areas of the brain and spinal cord are grey and some are white?

10.4 Central neural system (CNS)

The CNS includes the brain and the spinal cord, which are protected by the bones of the skull and vertebral column. During its embryonic development, CNS develops from the ectoderm.

10.4.1 Brain

The brain acts as the command and control system. It is the site of information processing. It is located in the cranial cavity

and is covered by three cranial meninges. The outer thick layer is **Duramater** which lines the inner surface of the cranial cavity; the median thin layer is **Arachnoid mater** which is separated from the duramater by a narrow **subdural space.** The innermost layer is **Piamater** which is closely adhered to the brain but separated from the arachnoid mater by the **subarachnoid space**. The brain is divided into three major regions: Forebrain, Midbrain and Hindbrain.

Human brain is formed of a large number of parts like cerebrum, thalamus, hypothalamus, pons, cerebellum and medulla oblongata. Each part performs some specialized function and all the parts are essential for the survival of a person. Discuss the following statements :

a) Thalami are called relay centres of the brain.

b) Damage to medulla may cause the death of organism.

Fore Brain

It comprises the following regions: **Cerebrum** and **Diencephalon**. Cerebrum is the 'seat of intelligence' and forms the major part of the brain. The cerebrum consists of an outer cortex, inner medulla and **basal nuclei.** The superficial region of the cerebrum is called **cerebral cortex**, which looks grey due to the presence of unmyelinated nerve cells. Cerebral cortex consists of neuronal cell body, dendrites, associated glial and blood vessels. The surface of the cerebrum shows many convolutions (folds) and grooves. The folds are called **gyri** (singular gyrus); the shallow grooves between the gyri are called **sulci** (singular sulcus) and deep grooves are called fissures. These sulci and gyri increase the surface area of the cerebral cortex. Several sulci divide the cerebrum into eight lobes: a pair of **frontals, parietals, temporals and occipital lobes** (Figure10.7 & Table 10.2).

A median longitudinal fissure divides the cerebrum longitudinally into two cerebral hemispheres (Figure 10.7). A transverse fissure separates the cerebral hemispheres from the cerebellum. The

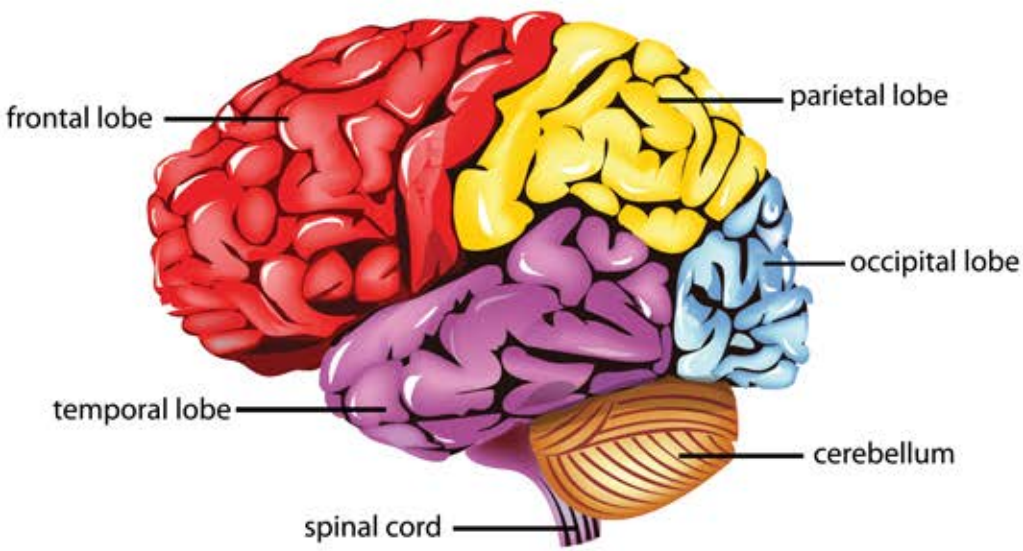


Figure 10.7 Lobes of Cerebral hemisphere

Nervous System

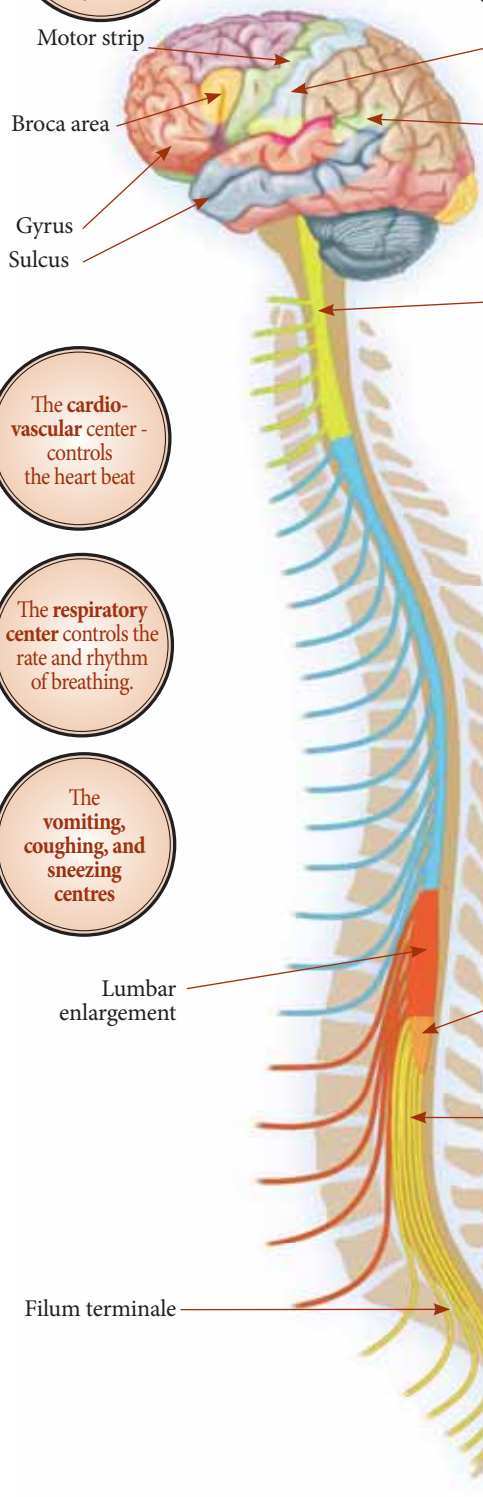
The Nervous system is a complex collection of specialized nerve cells known as neurons that transmit signals between different parts of the body.

The precentral gyrus is called as **Motor Strip** that controls the **voluntary movements** of the skeletal system.

The postcentral gyrus is called as Sensory Strip that controls the **five senses — sight, smell, taste, tounch and hearing.**

Broca area, region of the brain that contains neurons involved in **speech function.**

Wernicke area, region of the brain that contains motor neurons involved in the **comprehension of speech.**



The Medulla Oblongata

The Vital functional centres of medulla are:

The **cardio-vascular** center - controls the heart beat

The **respiratory center** controls the rate and rhythm of breathing.

The **vomiting, coughing, and sneezing centres**

Hippocampus plays an important role in emotion, learning and memory.

Amygdala plays role in aggression, eating, drinking and sexual behaviors.

Hypothalamus - monitors blood levels of glucose, salt, blood pressure and hormones.

Limbic Systems

A **blood brain barrier** protects the brain by preventing many foregin substances in our vascular system from reaching the brain.

Although sensations and feelings are processed in our brain, the **brain itself cannot feel pain,** as it lacks pain receptors.

The barriers does not work for some substances like **Nicotine** which rushes into the brain in mere 7 seconds and **Alcohol** on the other hand takes 6 minutes.

75% of the total brain mass is water. It is the **fattest organ** in the body, contains **100 billion nerve cells.**

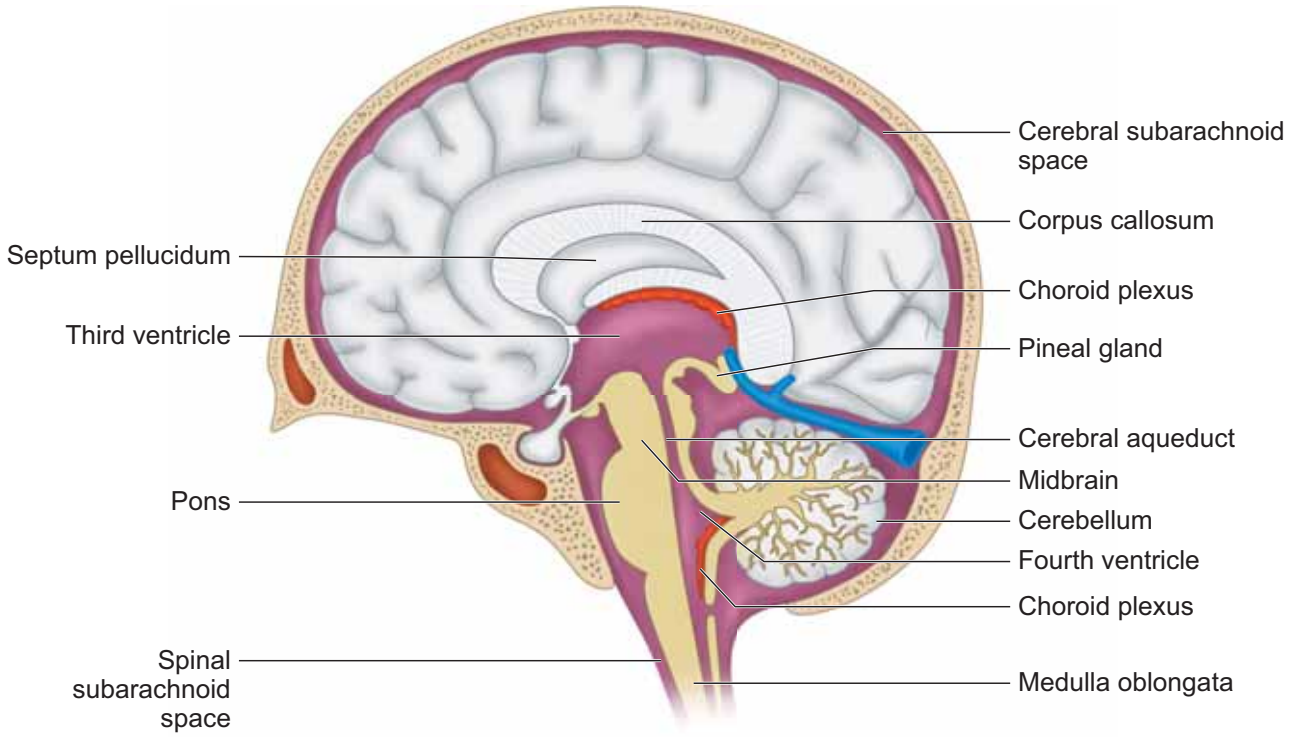


Figure 10.8 Mid sagittal section of brain

hemispheres are connected by a tract of nerve fibres called **corpus callosum**. Cerebral cortex has three functional areas namely **sensory areas** occur in the parietal, temporal and occipital lobes of the cortex. They receive and interpret the sensory impulses. **Motor area** of the cortex which controls voluntary muscular movements lies in the posterior part of the frontal lobes. The areas other than sensory and motor areas are called **Association areas** that deal with integrative functions such as memory, communications, learning and reasoning. Inner to the cortex is **medulla** which is white in colour and acts as a nerve tract between the cortex and the diencephalon.

Diencephalon consists largely of following three paired structures.

Epithalamus forms the roof of the diencephalon and it is a non-nervous tissue. The anterior part of epithalamus is vascular and folded to form the anterior **choroid plexus.** Just behind the choroid plexus, the epithalamus forms a short stalk which ends in a rounded body called **pineal body** which secretes the hormone, **melatonin** which regulates sleep and wake cycle.

Thalamus is composed of grey mater which serves as a relay centre for

Table 10.2 Functions of brain lobes

Structure	Functions
Frontal	Behaviour, Intelligence, Memory, Movement
Parietal	Language, Reading, Sensation
Temporal	Speech, Hearing, Memory
Occipital	Visual processing

Depression is a functional deficiency of **seratonin** or **norepinephrine** or both. This disorder is characterized by a pervasive negative mood, loss of interest, an inability to experience pleasure and suicidal tendencies. Antidepressant drugs increase the available concentration of these neurotransmitters in the CNS. Hence depression is treatable.

impulses between the spinal cord, brain stem and cerebrum. Within the thalamus, information is sorted and edited and plays a key role inlearning and memory. It is a major coordinating centre for sensory and motor signalling.

Hypothalamus forms the floor of the diencephalon. The downward extension of the hypothalamus, the **infundibulum** connects the hypothalamus with the pituitary gland. The hypothalamus contains a pair of small rounded body called **mammillary bodies** that are involved in olfactory reflexes and emotional responses to odour. Hypothalamus maintains homeostasis and has many centres which control the body temperature, urge for eating and drinking. It also contains a group of neurosecretory cells which secrete the hypothalamic hormones. Hypothalamus also acts as the **satiety centre.**

Limbic system

The inner part of the cerebral hemisphere constitutes the limbic system. The main components of limbic system are **olfactory bulbs, cingulate gyrus, mammillary body, amygdala, hippocampus and hypothalamus.** The limbic system is called 'emotional brain' because it plays a primary role in the regulation of pleasure, pain, anger, fear, sexual feeling and affection. The hippocampus and amygdala also play a role in memory (Figure 10.9).

Brain stem is the part of the brain between the spinal cord and the diencephalon. It consists of mid brain, pons varolii and medulla oblongata (Figure 10.10).

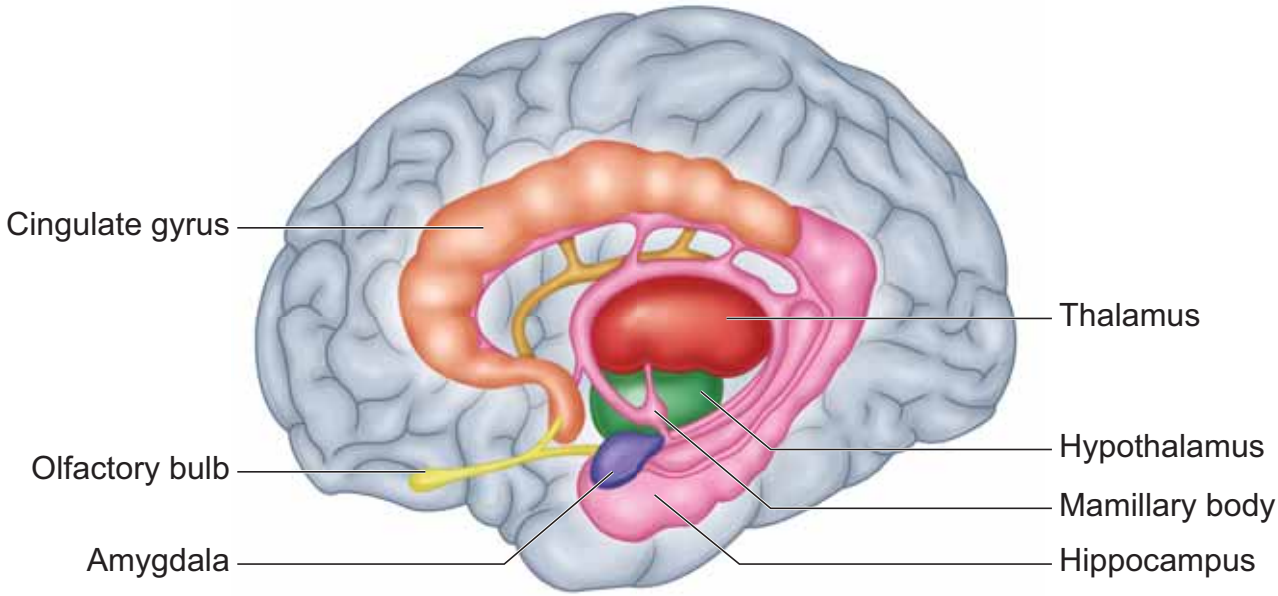


Figure 10.9 Limbic system

Mid brain

The mid brain is located between the diencephalon and the pons**.** The lower portion of the midbrain consists of a pair of longitudinal bands of nervous tissue called **cerebral peduncles** which relay impulses back and forth between cerebrum, cerebellum, pons and medulla. The dorsal portion of the midbrain consists of four rounded bodies called **corpora quadrigemina** which acts as a reflex centre for vision and hearing**.**

Hind brain

Rhombencephalon forms the hind brain. It comprises of cerebellum, pons varolii and medulla oblongata. **Cerebellum** is the second largest part of the brain. It consists of two **cerebellar hemispheres** and central worm shaped part, **the vermis.** The cerebellum controls and coordinates muscular movements and body equilibrium. Any damage to cerebellum often results in uncoordinated voluntary muscle movements.

Pons varoli lies infront of the cerebellum between the midbrain and the medulla oblongata. The nerve fibres in the pons varolii form a bridge between the two cerebellar hemispheres and connect the medulla oblongata with the other region of the brain. The respiratory nuclei found in the pons cooperate with the medulla to control respiration.

Medulla oblongata forms the posterior most part of the brain. It connects the spinal cord with various parts of the brain. It receives and integrates signals from spinal cord and sends it to the cerebellum and thalamus. Medulla contains vital centres that control cardio vascular reflexes, respiration and gastric secretions.

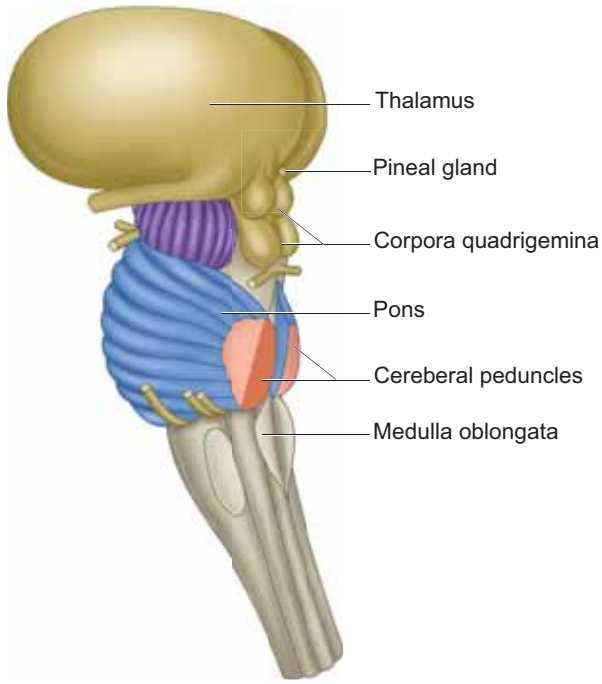


Figure 10.10 Brain stem

Ventricles of the brain

The brain has four hollow, fluid filled spaces. The C- shaped space found inside each cerebral hemisphere forms the lateral **ventricles I and II** which are separated from each other by a thin membrane called the **septum pellucidum.** Each lateral ventricle communicates with the narrow III ventricle in the diencephalon through an opening called **interventricular foramen (foramen of Monro).** The ventricle III is continuous with the ventricle IV in the hind brain through a canal called **aqueduct of Sylvius (cerebral aqueduct).** Choroid plexus is a network of blood capillaries found in the roof of the ventricles and forms **cerebro spinal fluid (CSF)** from the blood. CSF provides buoyancy to the CNS structures; CSF acts as a shock absorber for the brain and spinal cord; it nourishes the brain cells by transporting constant supply of food and oxygen; it carries harmful metabolic wastes from

the brain to the blood; and maintains a constant pressure inside the cranial vessels.

10.4.2 Spinal cord

The spinal cord is a long, slender, cylindrical nervous tissue. It is protected by the vertebral column and surrounded by the three membranes as in the brain. The spinal cord that extends from the brain stem into the vertebral canal of the vertebral column up to the level of 1st or 2nd lumbar vertebra. So the nerve roots of the remaining nerves are greatly elongated to exit the vertebral column at their appropriate space. The thick bundle of elongated nerve roots within the lower vertebral canal is called the **cauda equina** (horse's tail) because of its appearance.

In the cross section of spinal cord (Figure 10.11), there are two indentations: the posterior median sulcus and the anterior median fissure. Although there might be slight variations, the cross section of spinal cord is generally the same throughout its length. In contrast to the brain, the grey matter in the spinal cord forms an inner butterfly shaped region surrounded by the outer white matter. The grey matter consists of neuronal cell bodies and their dendrites, interneurons and glial cells. White matter consists of bundles of nerve fibres. In the center of the grey matter there is a central canal which is filled with CSF. Each half of the grey matter is divided into **a dorsal horn, a ventral horn** and **a lateral horn.**

The dorsal horn contains cell bodies of interneurons on which afferent neurons terminate. The ventral horn contains cell bodies of the efferent motor neurons supplying the skeletal muscle. Autonomic nerve fibres, supplying cardiac and smooth muscles and exocrine glands, originate from the cell bodies found in the lateral horn. In the white matter, the bundles of nerve fibres form two types of tracts namely **ascending tracts** which carry sensory impulses to the brain and descending **tracts** which carry motor impulses from the brain to the spinal nerves at various levels of the spinal cord. The spinal cord shows two enlargements, one in the cervical region and another one in the lumbosacral region. The **cervical**

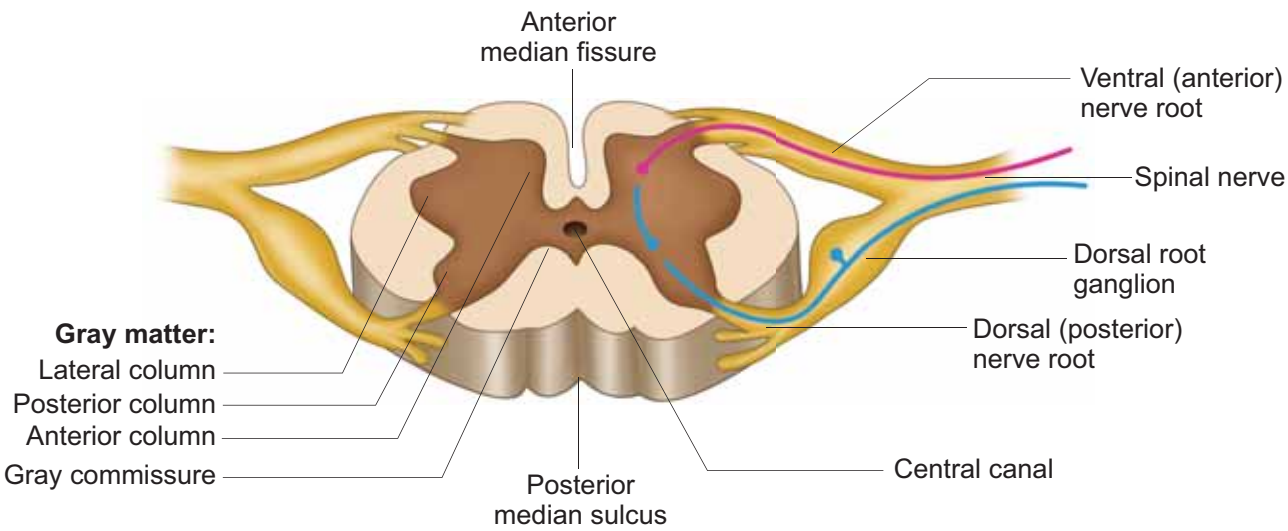


Figure 10.11 C.S. of Spinal cord

enlargement serves the upper limb and **lumbar enlargement** serves the lower limbs.

10.5 Reflex action and Reflex arc

When dust falls in our eyes, the eyelids close immediately not waiting for our willingness; on touching a hot pan, the hand is withdrawn rapidly. Do you know how this happens?

The spinal cord remains as a connecting functional nervous structure in between the brain and effector organs. But sometimes when a very quick response is needed, the spinal cord can effect motor initiation as the brain and brings about an effect. This rapid action by spinal cord is called reflex action. It is a fast, involuntary, unplanned sequence of actions that occurs in response to a particular stimulus. The nervous elements involved in carrying out the reflex action constitute a reflex arc or in other words the pathway followed by a nerve impulse to produce a reflex action is called a reflex arc (Figure 10.12).

Functional components of a reflex arc

Sensory Receptor - It is a sensory structure that responds to a specific stimulus.

Sensory Neuron - This neuron takes the sensory impulse to the grey (afferent) matter of the spinal cord through the dorsal root of the spinal cord.

Interneurons - One or two interneurons may serve to transmit the impulses from the sensory neuron to the motor neuron.

Motor Neuron - it transmits impulse from CNS to the effector organ.

Effector Organs -It may be a muscle or gland which responds to the impulse received.

There are two types of reflexes. They are

1) **Unconditional reflex** is an inborn reflex for an unconditioned stimulus. It does not need any past experience, knowledge or training to occur; Ex: blinking of an eye when a dust

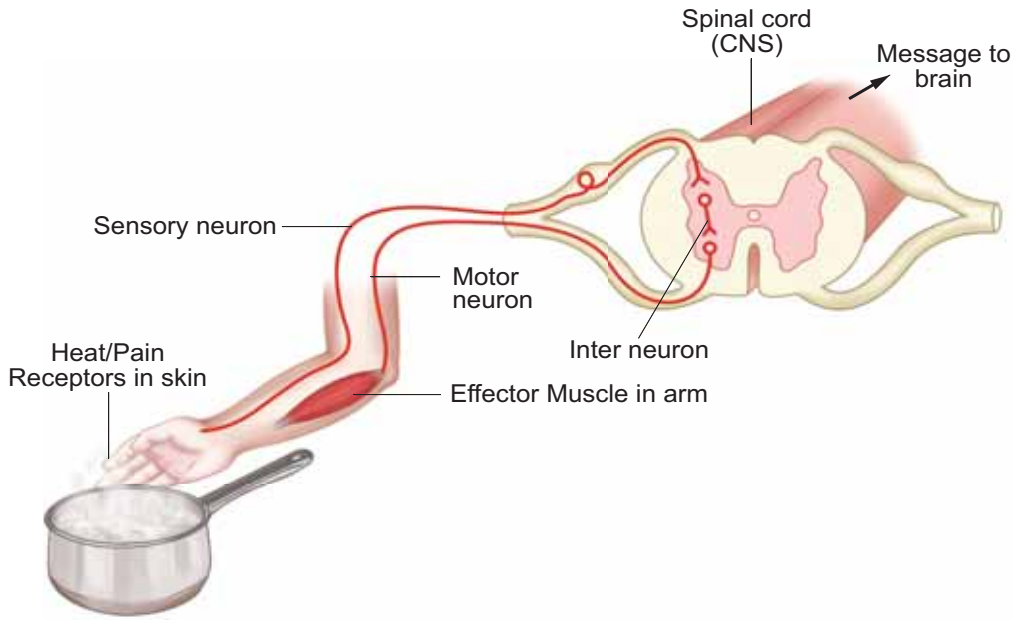


Figure 10.12 Reflex arc

Table 10.3 Cranial nerves and their functions

No.	Cranial nerves	Nature of nerve	Function
I	Olfactory nerve	Sensory	Sense of smell
II	Optic nerves	Sensory	Sense of sight
III	Oculomotor nerves	Motor	Movement of the eye
IV	Trochlear nerve	Motor	Rotation of the eye ball
V	Trigeminal nerve	Sensory and motor (mixed)	Functioning of facial parts
VI	Abducens nerve	Motor	Rotation of the eye ball
VII	Facial nerve	Mixed	Functioning of facial parts
VIII	Auditory/Vestibulo-cochlear nerve	Sensory	Maintains the equilibrium of the body /Auditory function
IX	Glossopharyngeal nerve	Mixed	Taste and touch
X	Vagus	Mixed	Regulation of the visceral organs
XI	Spinal accessory	Motor	Muscular movement of Pharynx, larynx, neck and shoulder
XII	Hypoglossal	Motor	Speech and swallowing

particle about to fall into it, sneezing and coughing due to foreign particle entering the nose or larynx.

2) **Conditioned reflex** is a respone to a stimulus that has been acquired by learning. This does not naturally exists in animals. Only an experience makes it a part of the behaviour. Example: excitement of salivary gland on seeing and smelling a food. The conditioned reflex was first demonstrated by the Russian physiologist **Pavlov** in his classical conditioning experiment in a dog. The cerebral cortex controls the conditioned reflex.

Peripheral Neural System (PNS)

PNS consists of all nervous tissue outside the CNS. Components of PNS include nerves, ganglia, enteric plexuses and sensory receptors. A nerve is a chord like structure that encloses several neurons inside. Ganglia (singular-ganglion) are small masses of nervous tissue, consisting primarily of neuron cell bodies and are located outside the brain and spinal cord. Enteric plexuses are extensive networks of neurons located in the walls of organs of the gastrointestinal tract. The neurons of these plexuses help in regulating the digestive system. The specialized structure

that helps to respond to changes in the environment i.e. stimuli are called **sensory receptor** which triggers nerve impulses along the afferent fibres to CNS. PNS comprises of cranial nerves arising from the brain and spinal nerves arising from the spinal cord.

(A) Cranial nerves: There are 12 pairs of cranial nerves, of which the first two pairs arise from the fore brain and the remaining 10 pairs from the mid brain. Other than the Vagus nerve, which extends into the abdomen, all cranial nerves serve the head and face (Table 10.3).

(B) Spinal nerves: 31 pairs of spinal nerves emerge out from the spinal cord through spaces called the **intervertebral foramina** found between the adjacent vertebrae. The spinal nerves are named according to the region of vertebral column from which they originate

i. Cervical nerves (8 pairs)
ii. Thoracic nerves (12 pairs)
iii. Lumbar nerves (5 pairs)
iv. Sacral nerves (5 pairs)
v. Coccygeal nerves (1 pair)

Each spinal nerve is a mixed nerve containing both afferent (sensory) and efferent (motor) fibres**.** It originates as two roots:1) a posterior dorsal root with a ganglion outside the spinal cord and 2) an anterior ventral root with no external ganglion.

Somatic neural system (SNS)

The **somatic neural system** (SNS or voluntary neural system) is the part of the peripheral neural system associated with the voluntary control of body movements via skeletal muscles. The sensory and motor nerves that innervate striated muscles form the somatic neural system. Major functions of the somatic neural system include voluntary movement of the muscles and organs, and reflex movements.

In adult, the total CSF volume is about 150 ml and is replaced every 8 hours. About 500 ml of CSF is formed daily. The choroid plexus helps cleanse the CSF by removing waste products.

Autonomic Neural System

The autonomic neural system is auto functioning and self governed. It is a part of peripheral neural system that innervates smooth muscles, glands and cardiac muscle. This system controls and coordinates the involuntary activities of various organs. ANS (Figure.10.13) controlling centre is in the hypothalamus.

Autonomic neural system comprises the following components:

Preganglionic neuron whose cell body is in the brain or spinal cord; its myelinated axon exits the CNS as part of cranial or spinal nerve and ends in an autonomic ganglion.

Autonomic ganglion consists of axon of preganglionic neuron and cell bodies of postganglionic neuron.

Postganglionic neuron conveys nerve impulses from autonomic ganglia to visceral effector organs.

The autonomic neural system consists of **Sympathetic neural system** and **Parasympathetic neural system** (Table 10.4)**.**

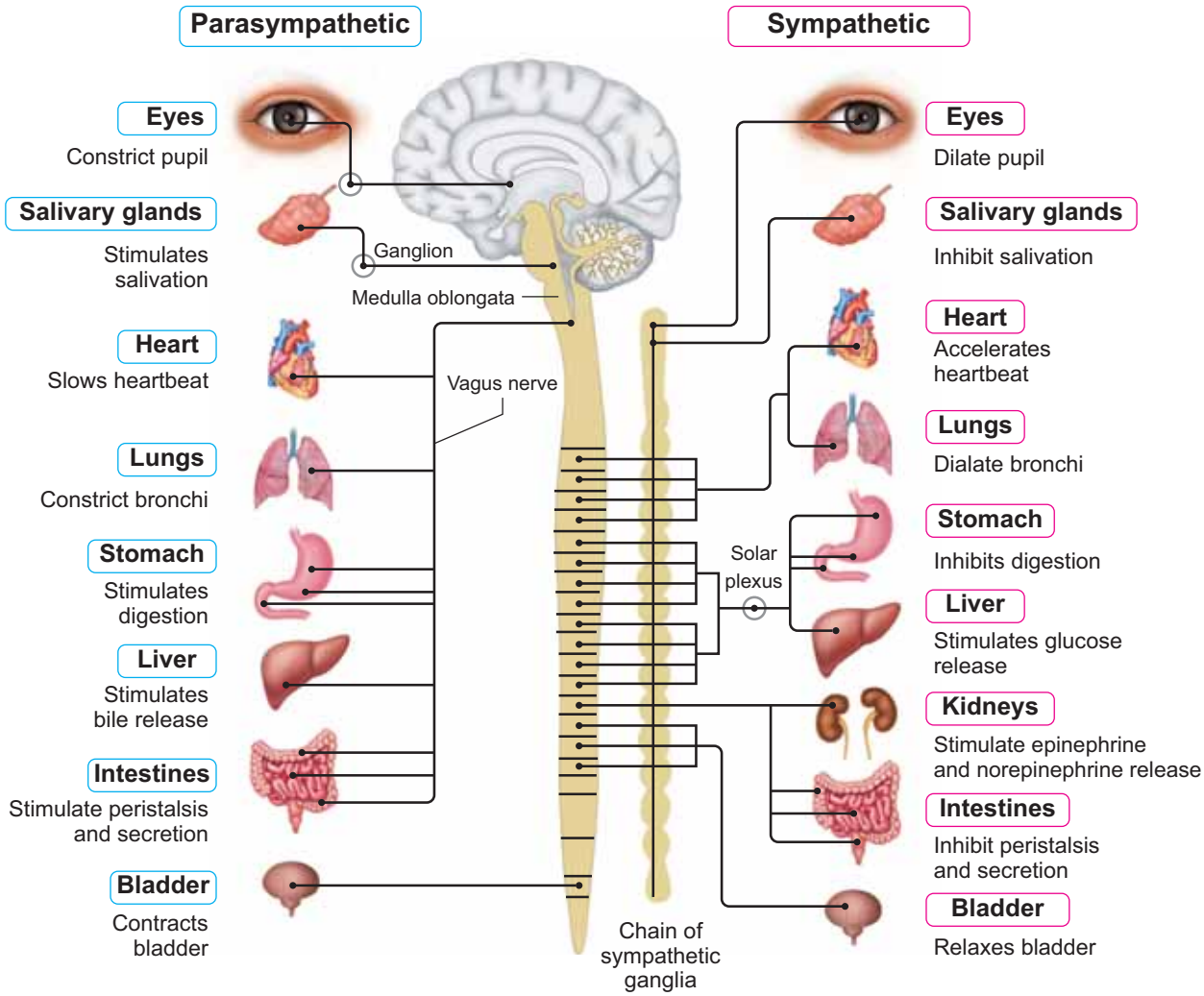


Figure 10.13 Autonomic nervous system

Table: 10.4 Differences between sympathetic and parasympathetic neural system

Sympathetic Neural system (SNS)	Parasympathetic Neural system (PNS)
SNS originates in the thoracic and lumbar region of the spinal cord.	PNS originates in the cranial region of the brain and the sacral region of the spinal cord.
Sympathetic ganglia are linked up to form a chain.	Its ganglia remain isolated.
Preganglionic fibres are short and the postganglionic fibres are long.	Preganglionic fibres are long and the postganglionic fibres are short.
Noradrenaline is produced at the terminal ends of the postganglionic fibres at the effector organs. Hence the system is adrenergic.	Acetylcholine is produced at the terminal ends of the postganglionic fibres at the effector organs. Hence the system is cholinergic.
Active during stressful conditions preparing the body to face them.	Active during relaxing times restoring normal activity after a stress.
The overall effect is excitatory and stimulating.	The overall effect is inhibitory.
It is considered as the flight or fight system.	It is considered as 'The Rest and Digest System' or 'The Feed and Breed System'.

Table: 10.5 Types of receptors

Receptors	Stimulus	Effector organs
Mechano receptors	Pressure and vibration	Mechano receptors are present in the cochlea of the inner ear and the semi circular canal and utriculus
Chemoreceptors	Chemicals	Taste buds in the tongue and nasal epithelium
Thermoreceptors	Temperature	Skin
Photoreceptors	Light	Rod and cone cells of the retina in the eye

10. 6 Sensory reception and processing

Our senses make us aware of changes that occur in our surroundings and also within our body. **Sensation** [awareness of the stimulus] and **perception** [interpretation of the meaning of the stimulus] occur in the brain.

Receptors are classified based on their location: **1. Exteroceptors** are located at or near the surface of the body. These are sensitive to external stimuli and receive sensory inputs for hearing, vision, touch, taste and smell. **2. Interoceptors** are located in the visceral organs and blood vessels. They are sensitive to internal stimuli. **Proprioceptors** are also a kind of interoceptors. They provide information about position and movements of the body. These are located in the skeletal muscles, tendons, joints, ligaments and in connective tissue coverings of bones and muscles. Receptors based on the type of stimulus are shown in Table 10.5.

10.6.1 Photoreceptor - Eye

Eye is the organ of vision; located in the orbit of the skull and held in its position with the help of six extrinsic muscles. They are **superior, inferior, lateral, median rectus muscles, superior oblique and inferior oblique** muscles. These muscles aid in the movement of the eyes and they receive their nerve innervation from III, IV and VI cranial nerves. Eyelids, eye lashes and eye brows are the accessory structures useful in protecting the eyes. The eye lids protect the eyes from excessive light and foreign objects and spread lubricating secretions over the eyeballs.

Eyelashes and the eyebrows help to protect the eyeballs from foreign objects, perspiration and also from the direct rays of sunlight. **Sebaceous glands** at the base of the eyelashes are called **ciliary glands** which secrete a lubricating fluid into the hair follicles. **Lacrymal glands,** located in the upper lateral region of each orbit, secrete tears. Tears are secreted at the rate of 1mL/day and it contains salts, mucus and **lysozyme** enzyme to destroy bacteria.

The conjunctiva is a thin, protective mucous membrane found lining the outer surface of the eyeball (Figure 10.14).

The eye has two compartments, the **anterior** and **posterior compartments**. The anterior compartment has two chambers,

Your friend is returning home after his visit to USA. All at home are waiting for his arrival. How would you feel? State the division of ANS that predominates and mention few changes that take place in your body.

first one lies between the cornea and iris and the second one lies between the iris and lens. These two chambers are filled with watery fluid called **aqueous humor**. The posterior compartment lies between the lens and retina and it is filled with a jelly like fluid called vitreous humor that helps to retain the spherical nature of the eye. **Eye lens** is transparent and biconvex, made up of long columnar epithelial cells called **lens fibres**. These cells are accumulated with the proteins called **crystalline**.

The eye ball

The eye ball is spherical in nature. The anterior one- sixth of the eyeball is exposed; the remaining region is fitted well into the orbit. The wall of the eye ball consists of three layers: fibrous **Sclera**, vascular **Choroid** and sensory **Retina** (Figure 10.15).

The outer coat is composed of dense non-vascular connective tissue. It has two regions: the anterior **cornea** and the posterior **sclera**. Cornea is a non-vascular transparent coat formed of stratified squamous epithelium which helps the cornea to renew continuously as it is very vulnerable to damage from dust. Sclera forms the white of the eye and protects the eyeball. Posteriorly the sclera is innervated by the optic nerve. At the junction of the sclera and the cornea, is a channel called **'canal of schlemm'** which continuously drains out the excess of aqueous humor.

Choroid is highly vascularized pigmented layer that nourishes all the eye layers and its pigments absorb light to prevent internal reflection. Anteriorly the choroid thickens to form the ciliary body and iris. Iris is the coloured portion of the eye lying between

DO YOU KNOW?

Dilation and congestion of the blood vessels of the conjunctiva due to local irritation or infection are the cause of bloodshot eye (conjunctivitis - commonly called Madras eye). Infection of ciliary glands by bacteria causes a painful, pus filled swelling called a Sty.

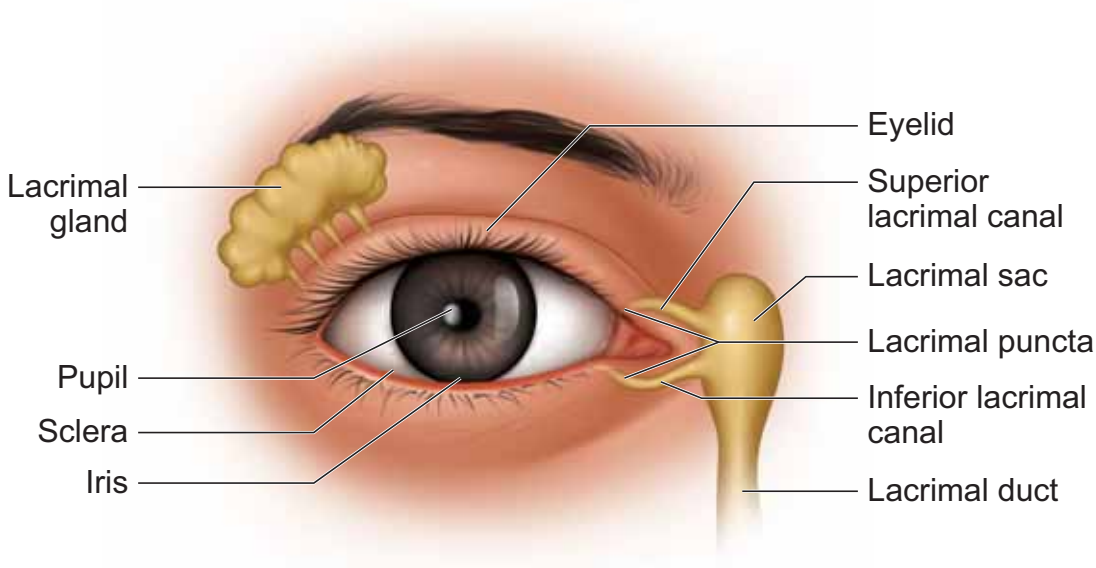


Figure.10.14 The human eye

Aqueous humour supplies nutrients and oxygen to the lens, cornea and some retinal cells. The aqueous humor is produced and drained at the same rate, maintaining a constant intra ocular pressure of about 16 mmHg. Any block in the canal of schlemm increases the infra ocular pressure of aqueous humor and leads to 'Glaucoma' where the optic nerve and the retina are compressed due to pressure.

the cornea and lens. The aperture at the centre of the iris is the **pupil** through which the light enters the inner chamber. Iris is made of two types of muscles the **dilator papillae** (the radial muscle) and the **sphincter papillae** (the circular muscle).In the bright light, the circular muscle in the iris contract; so that the size of pupil decreases and less light enters the eye. In dim light, the radial muscle in the iris contract; so that the pupil size increases and more light enters the eye. Smooth muscle present in the ciliary body is called the **ciliary muscle** which alters the convexity of the lens for near and far vision. The ability of the eyes to focus objects at varying distances is called **accommodation** which is achieved by **suspensory ligament, ciliary muscle** and **ciliary body**. The suspensory ligament extends from the ciliary body and helps to hold the lens in its upright position. The ciliary body is provided with blood capillaries that secrete a watery fluid called **aqueous humor** that fills the anterior chamber.

Retina forms the inner most layer of the eye and it contains two regions: A sheet of **pigmented epithelium** (non visual part) and **neural visual regions.** The neural retina layer contains three types of cells: photoreceptor cells – **cones and rods** (Figure 10.16 and Table 10.6), **bipolar**

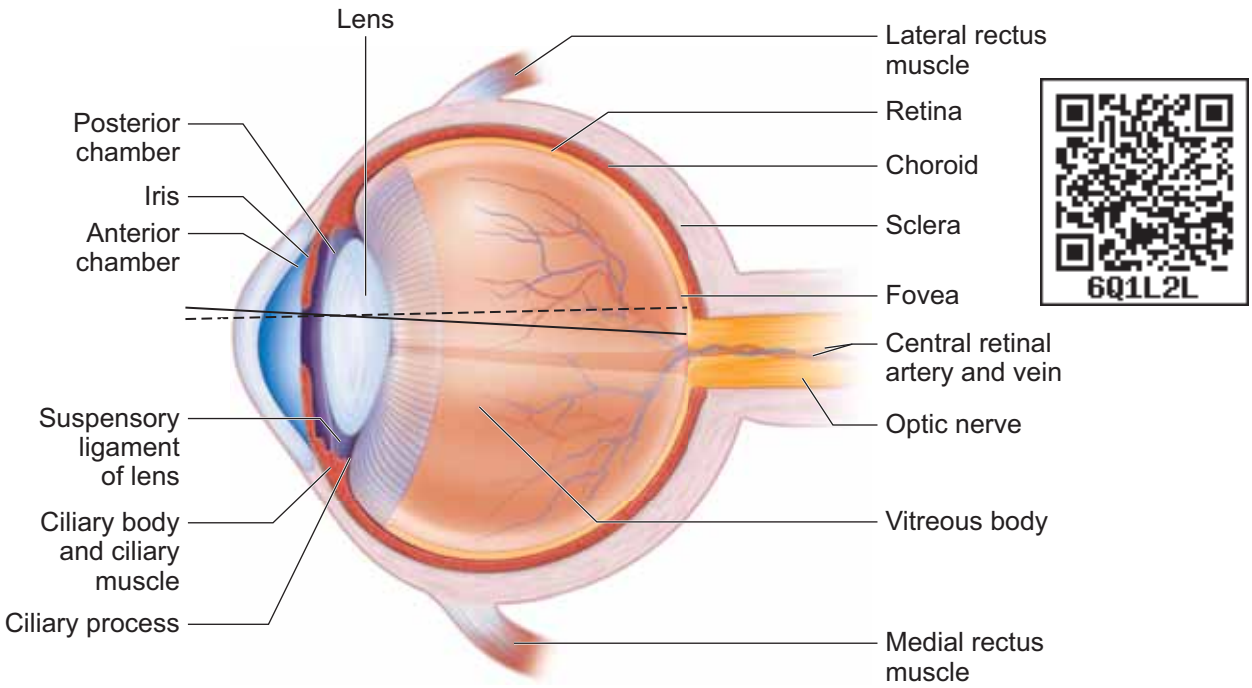


Figure 10.15 L.S. of the eye

The cornea is the only tissue in the body that can be transplanted from one person to another with little or no possibility of rejection. This is because cornea does not have blood vessels.

cells and ganglion cells. The yellow flat spot at the centre of the posterior region of the retina is called **macula lutea** which is responsible for sharp detailed vision. A small depression present in the centre of the yellow spot is called **fovea centralis** which contains only cones. The optic nerves and the retinal blood vessels enter the eye slightly below the posterior pole, which is devoid of photo receptors; hence this region is called **blind spot.**

Mechanism of vision

When light enters the eyes, it gets refracted by the **cornea, aqueous humor and lens and it is focused** on the retina and excites the rod and cone cells. The photo pigment consists of **Opsin**, the protein part and **Retinal**, a derivative of vitamin A. Light induces dissociation of retinal from opsin and causes the structural changes in opsin. This generates an action potential in the photoreceptor cells and is transmitted by the optic nerves to the visual cortex of the brain, via bipolar cells, ganglia and optic nerves, for the perception of vision.

Refractive errors of eye

Myopia (near sightedness): The affected person can see the nearby objects but not the distant objects. This condition may result due to an elongated eyeball or thickened lens; so that the image of distant

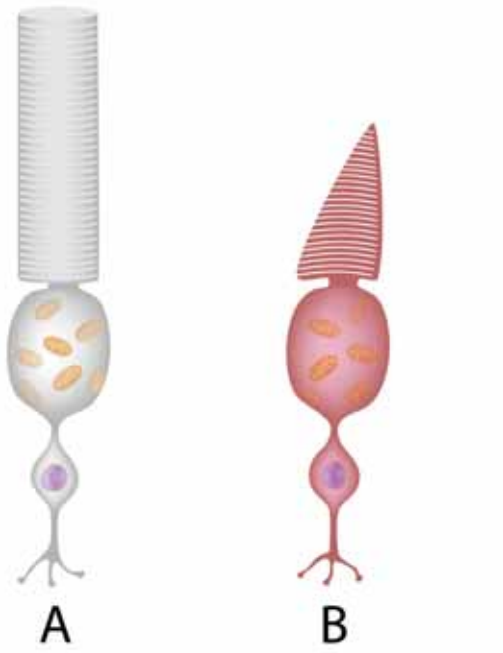


Figure 10.16 Rod and Cone cells

object is formed in front of the yellow spot. This error can be corrected using concave lens that diverge the entering light rays and focuses it on the retina.

Hypermetropia (long sightedness): the affected person can see only the distant objects clearly but not the objects nearby. This condition results due to a shortened eyeball and thin lens; so the image of closest object is converged behind the retina. This defect can be overcome

Visual pigments for colour vision are i) the red cones having the visual pigment, Erythropsin is sensitive to long wavelength close to 560 nm. ii) The green cones having the pigment, chloropsin is sensitive to medium wavelength of 530 nm iii) the blue cones having the pigment, cyanopsin is sensitive to short wavelength of 420 nm.

Table: 10.6 Differences between rod and cone cells

Rod cells	Cone cells
Rods are responsible for vision in dim light	The cones are responsible for colour vision and works best in the bright light.
The pigment present in the rods is rhodopsin, formed of a protein scotopsin and retinal (an aldehyde of vitamin A)	The pigment present in the cones is photopsin, formed of opsin protein and retinal.
There are about 120 millions rod cells	There may be 6-7 millions cone cells
Rods are predominant in the extra fovea region	Cones are concentrated in the fovea region

by using convex lens that converge the entering light rays on the retina.

Presbyopia: Due to aging, the lens loses elasticity and the power of accommodation. Convex lenses are used to correct this defect.

Astigmatism is due to the rough (irregular) curvature of cornea or lens. Cylindrical glasses are used to correct this error (Figure 10.17).

Cataract: Due to the changes in nature of protein, the lens becomes opaque. It can be corrected by surgical procedures.

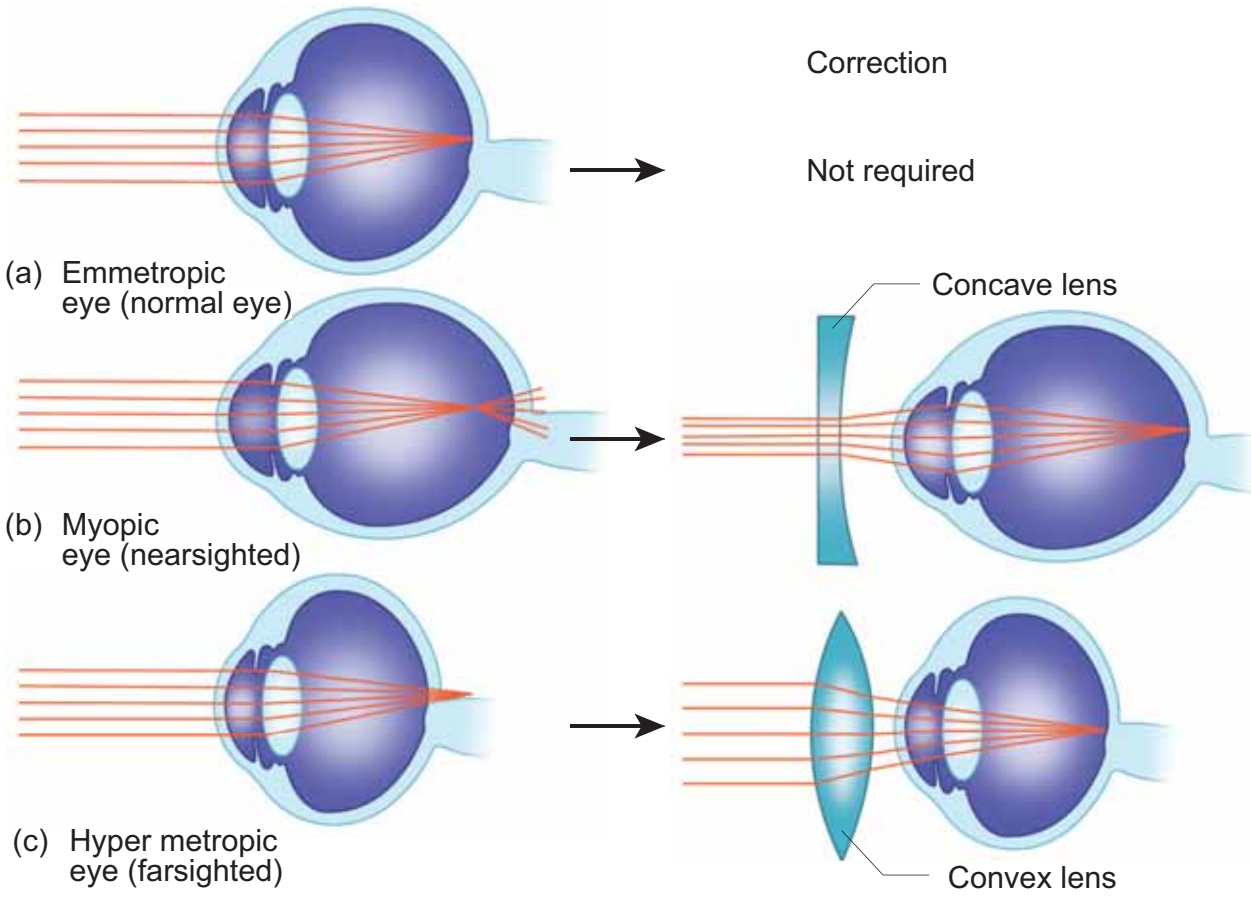


Figure 10.17 Refractive errors of the eye

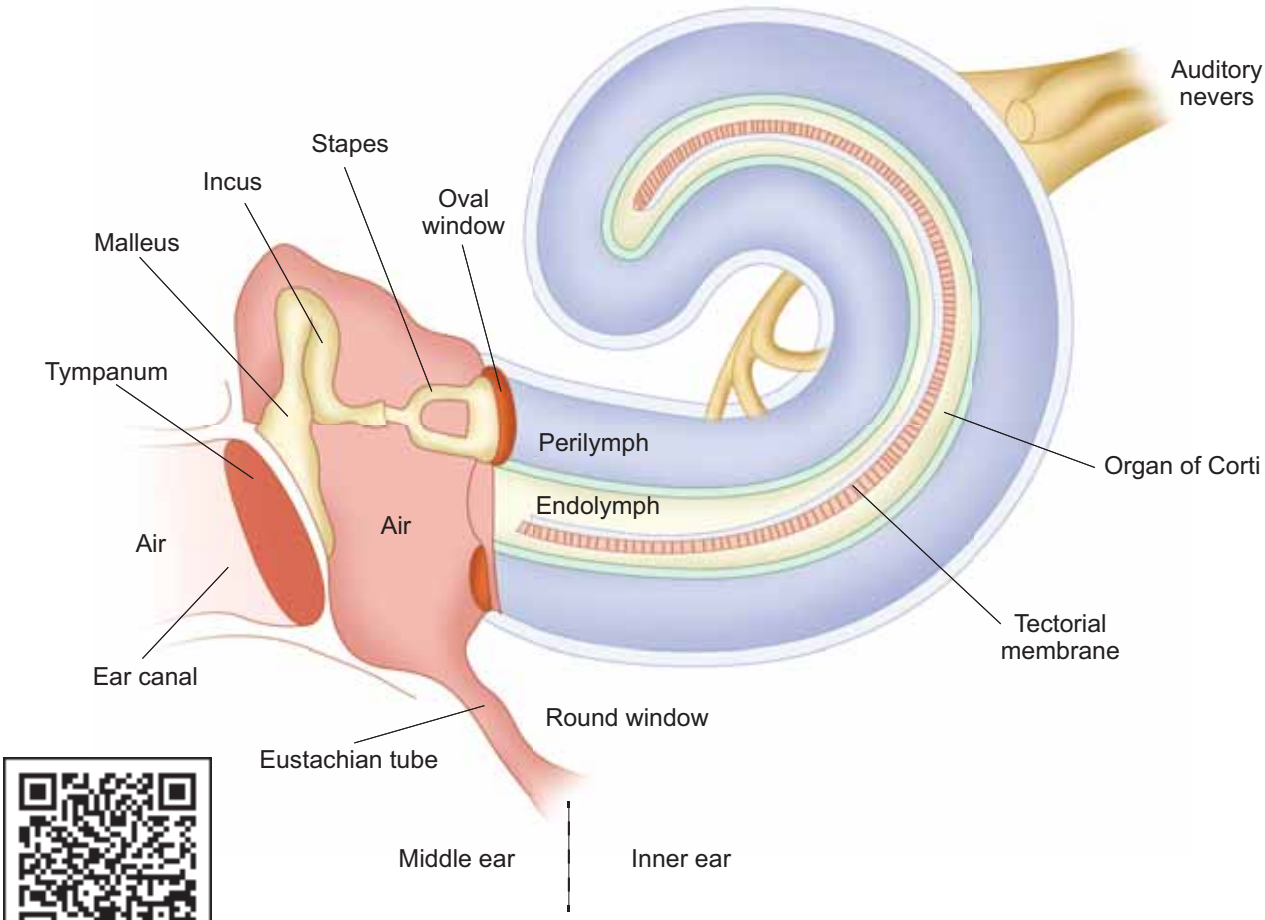


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Figure 10.18 Path of Sound wave

10.6.2 Phonoreceptor

The ear is the site of reception of two senses namely hearing and equilibrium. Anatomically, the ear is divided into three regions: the external ear, the middle ear and internal ear**.**

The external ear consists of **pinna, external auditory meatus** and **ear drum**. The pinna is flap of elastic cartilage covered by skin. It collects the sound waves. The external auditory meatus is a curved tube that extends up to the tympanic membrane [the ear drum]. The tympanic membrane is composed of connective tissues covered with skin outside and with mucus membrane inside.

There are very fine hairs and wax producing sebaceous glands called **ceruminous glands** in the external auditory meatus. The combination of hair and the **ear wax** [cerumen] helps in preventing dust and foreign particles from entering the ear.

The middle ear is a small air-filled cavity in the temporal bone. It is separated

Name the parts of the organ of equilibrium involved in the following functions.

a) Linear movement of the body

b) Changes in the body position

c) Rotational movement of the head.

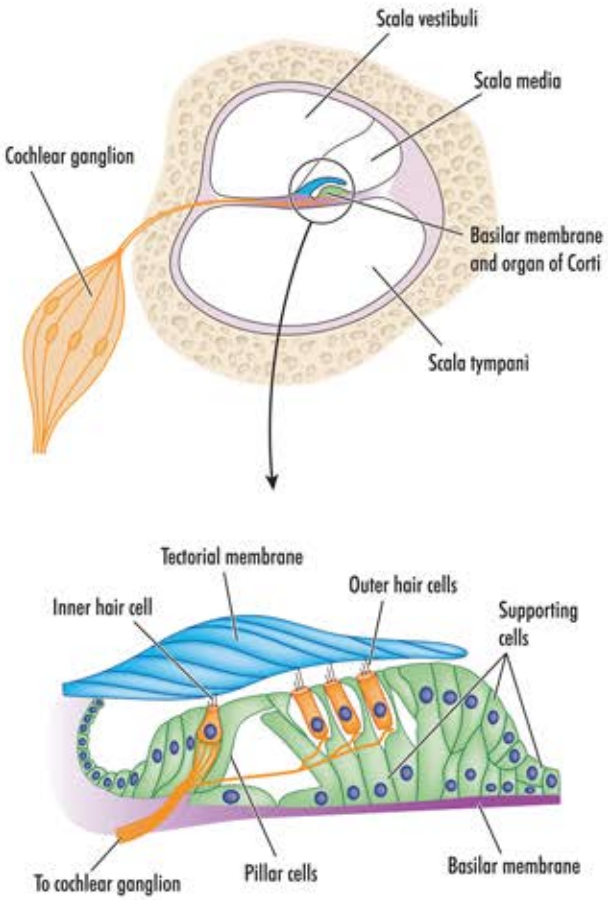


Figure 10.19 Organ of corti

from the external ear by the eardrum and from the internal ear by a thin bony partition; the bony partition contains two small membrane covered openings called the oval window and the round window.

The middle ear contains three ossicles: **malleus** [hammer bone], **incus** [anvil bone] and **stapes** [stirrup bone] which are attached to one another. The malleus is attached to the tympanic membrane and its head articulates with the incus which is the intermediate bone lying between the malleus and stapes. The stapes is attached to the oval window in the inner ear. The ear ossicles transmit sound waves to the inner ear. A tube called Eustachian tube connects the middle ear cavity with the pharynx. This tube helps in equalizing the pressure of air on either sides of the ear drum.

Inner ear is the fluid filled cavity consisting of two parts, the bony labyrinth and the membranous labyrinths. The bony labyrinth consists of three areas: **cochlea, vestibule** and **semicircular canals.** The **cochlea** is a coiled portion consisting of 3 chambers namely: **scala vestibuli** and **scala tympani**- these two are filled with **perilymph;** and the **scala media** is filled with **endolymph.** At the base of the cochlea, the scala vestibule ends at the 'oval window' whereas the scala tympani ends at the 'round window' of the middle ear. The chambers scala vestibuli and scala media are separated by a membrane called Reisner's membrane whereas the scala media and scala tympani are separated by a membrane called **Basilar membrane** (Figure 10.19).

Organ of corti

The **organ of corti** (figure.10.19) is a sensory ridge located on the top of **the Basilar membrane** and it contains numerous hair cells that are arranged in four rows along the length of the basilar membrane. Protruding from the apical part of each hair cell is hair like structures known as **stereocilia.** During the conduction of sound wave, stereocilia makes a contact with the stiff gel membrane called **tectorial membrane,** a roof like structure overhanging the organ of corti throughout its length.

Mechanism of hearing

Sound waves entering the external auditory meatus fall on the tympanic membrane. This causes the ear drum to vibrate, and these vibrations are transmitted to the oval window through the three auditory ossicles. Since the tympanic membrane is 17-20 times larger than the oval window,

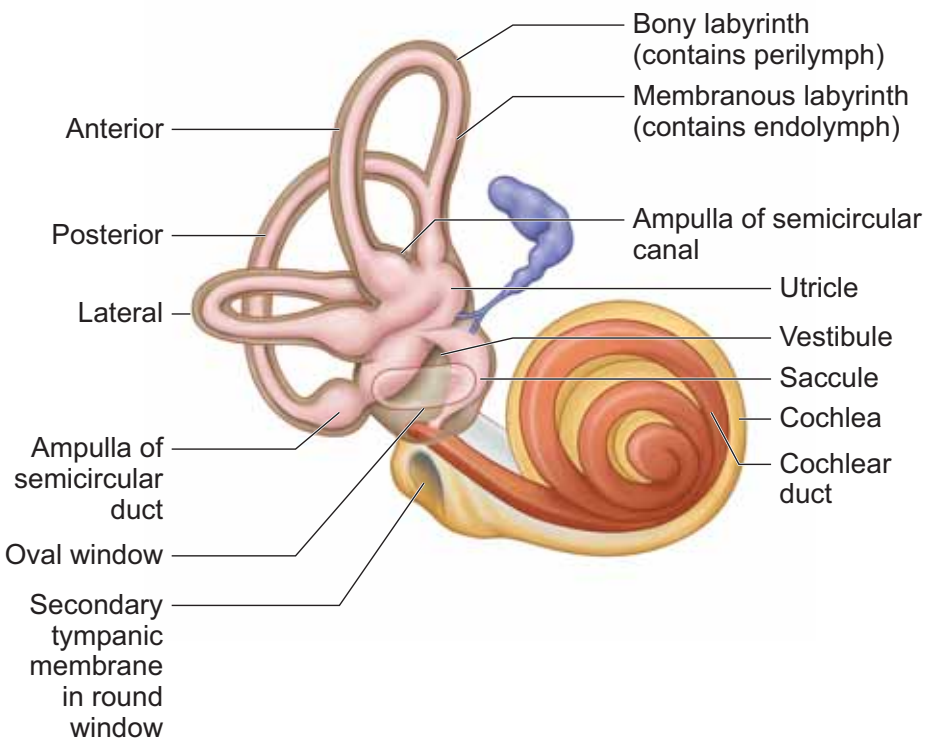


Figure 10.20 Organ of Equilibrium

the pressure exerted on the oval window is about 20 times more than that on the tympanic membrane. This increased pressure generates pressure waves in the fluid of perilymph. This pressure causes the round window to alternately bulge outward and inward meanwhile the basilar membrane along with the organ of Corti move up and down. These movements of the hair alternately open and close the mechanically gated ion channels in the base of hair cells and the action potential is propagated to the brain as sound sensation through cochlear nerve.

Defects of Ear

Deafness may be temporary or permanent. It can be further classified into **conductive deafness** and **sensory-neural deafness**. Possible causes for conductive deafness may be due to

i. the blockage of ear canal with earwax,
ii. Rupture of eardrum
iii. Middle ear infection with fluid accumulation
iv. Restriction of ossicular movement.

In **sensory-neural deafness**, the defect may be in the organ of Corti or the auditory nerve or in the ascending auditory pathways or auditory cortex.

Organ of Equilibrium

Balance is part of a sense called proprioception, which is the ability to sense

The intensity of sound is measured in decibels (dB). 0 dB is the threshold of hearing for normal ear. Severe hearing loss occurs with frequent or prolonged exposure to sound with intensities greater than 90dB. For meaningful conversations the intensity should be in the 50 dB range.

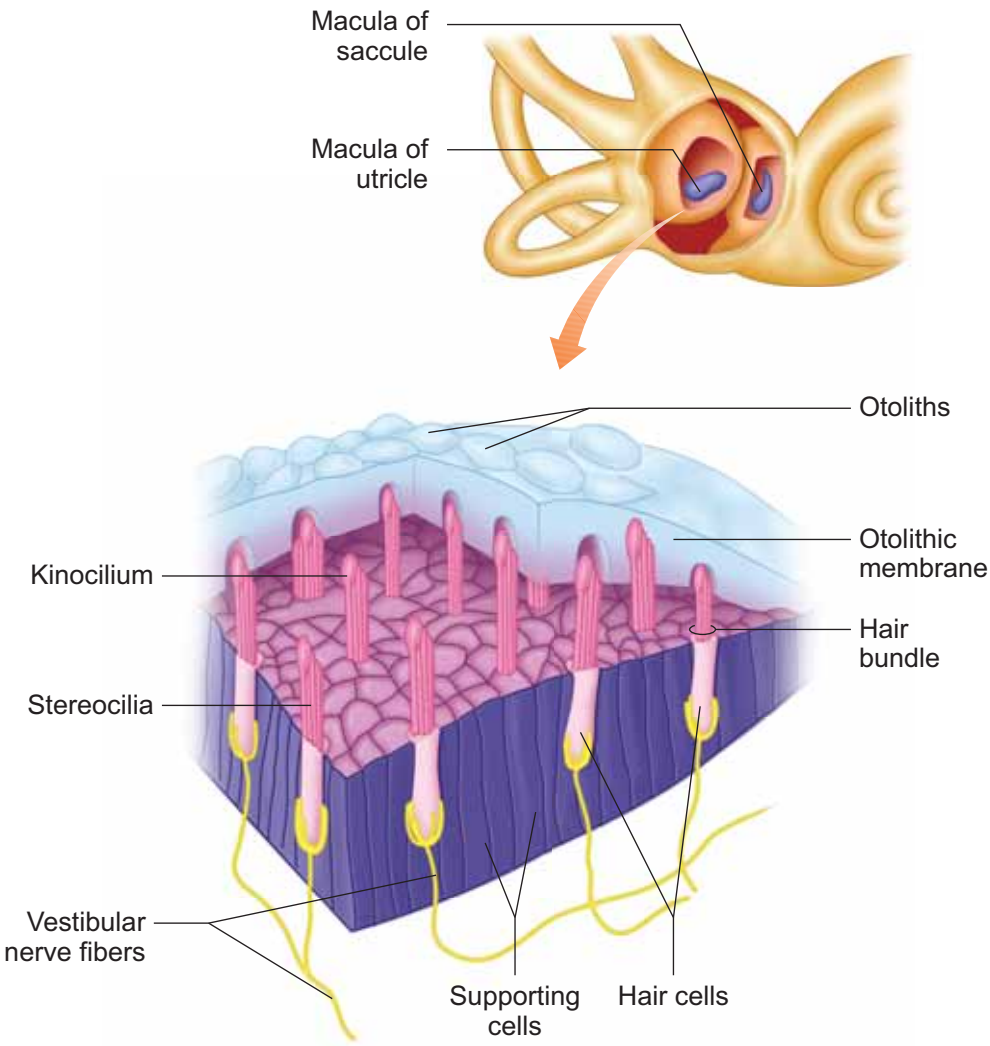


Figure 10.21 Structure of Macula

the position, orientation and movement of the body. The organ of balance is known as the **vestibular system** which is located in the inner ear next to the cochlea. The vestibular system is composed of a series of fluid filled sacs and tubules.These sacs and tubules contain endolymph and are kept in the surrounding perilymph (Figure 10.20). These two fluids, perilymph and endolymph, respond to the mechanical forces, during changes occurring in body position and acceleration (Figure 10.21).

The utricle and saccule are two membranous sacs, found nearest the cochlea and contain equilibrium receptor regions called **maculae** that are involved in detecting the linear movement of the head. The maculae contain the hair cells that act as mechanorecptors. These hair cells are embeded in a gelatinous otolithic membrane that contains small calcareous particles called **otoliths**. This membrane adds weight to the top of the hair cells and increase the inertia.

The canals that lie posterior and lateral to the vestibule are semicircular canals; they are **anterior, posterior and lateral canals** oriented at right angles to each other**.** At one end of each semicircular canal, at its lower end has a swollen area called **ampulla**. Each ampulla has a sensory area known as **crista ampullaris** which is

formed of sensory hair cells and supporting cells. The function of these canals is to detect rotational movement of the head.

10.6.3 Olfactory receptors

The receptors for taste and smell are the chemoreceptors. The smell receptors are excited by air borne chemicals that dissolve in fluids. The yellow coloured patches of olfactory epithelium form the olfactory organs (figure.10.22) that are located on the roof of the nasal cavity. The olfactory epithelium is covered by a thin coat of mucus layer below and olfactory glands bounded connective tissues, above. It contains three types of cells**: supporting cells, Basal cells** and millions of pin shaped **olfactory receptor cells** (which are unusual bipolar cells). The olfactory glands and the supporting cells secrete the mucus. The unmyelinated axons of the olfactory receptor cells are gathered to form the filaments of olfactory nerve [cranial nerve I] which synapse with cells of olfactory bulb. The impulse, through the olfactory nerves, is transmitted to the frontal lobe of the brain for identification of smell and the limbic system for the emotional responses to odour.

Gustatory receptor: The sense of taste is considered to be the most pleasurable of all senses. The tongue is provided with many small projections called **papillae** which give the tongue an abrasive feel. Taste buds are located mainly on the papillae which are scattered over the entire tongue surface.

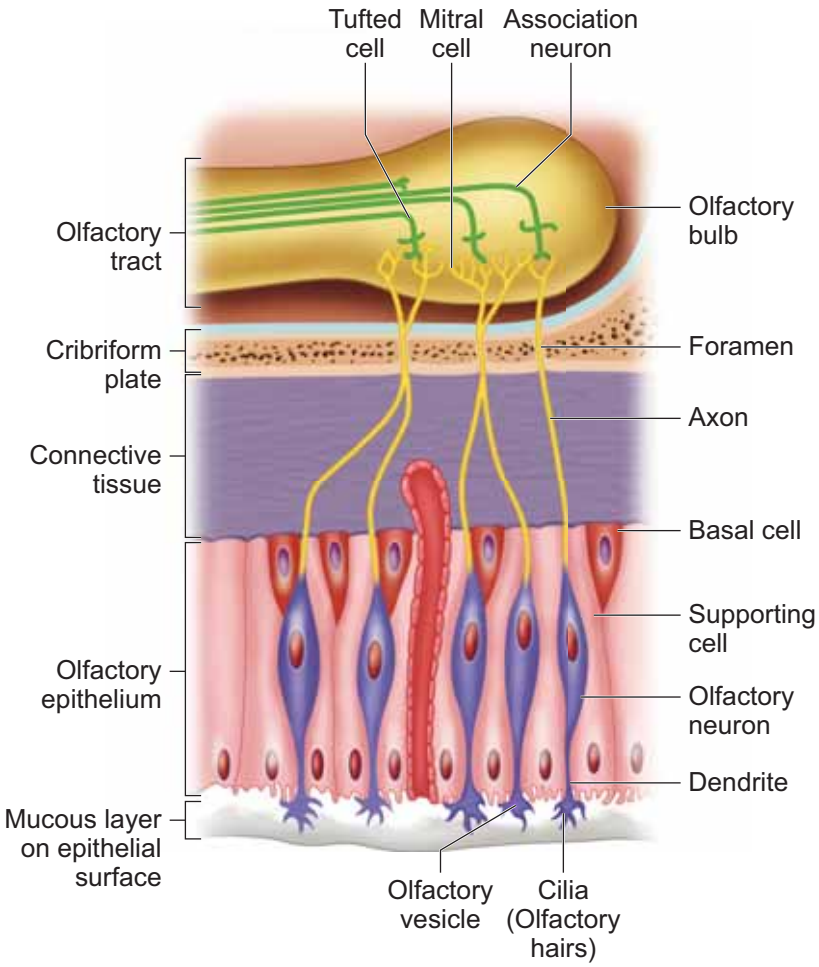


Figure 10.22 Olfactory organ

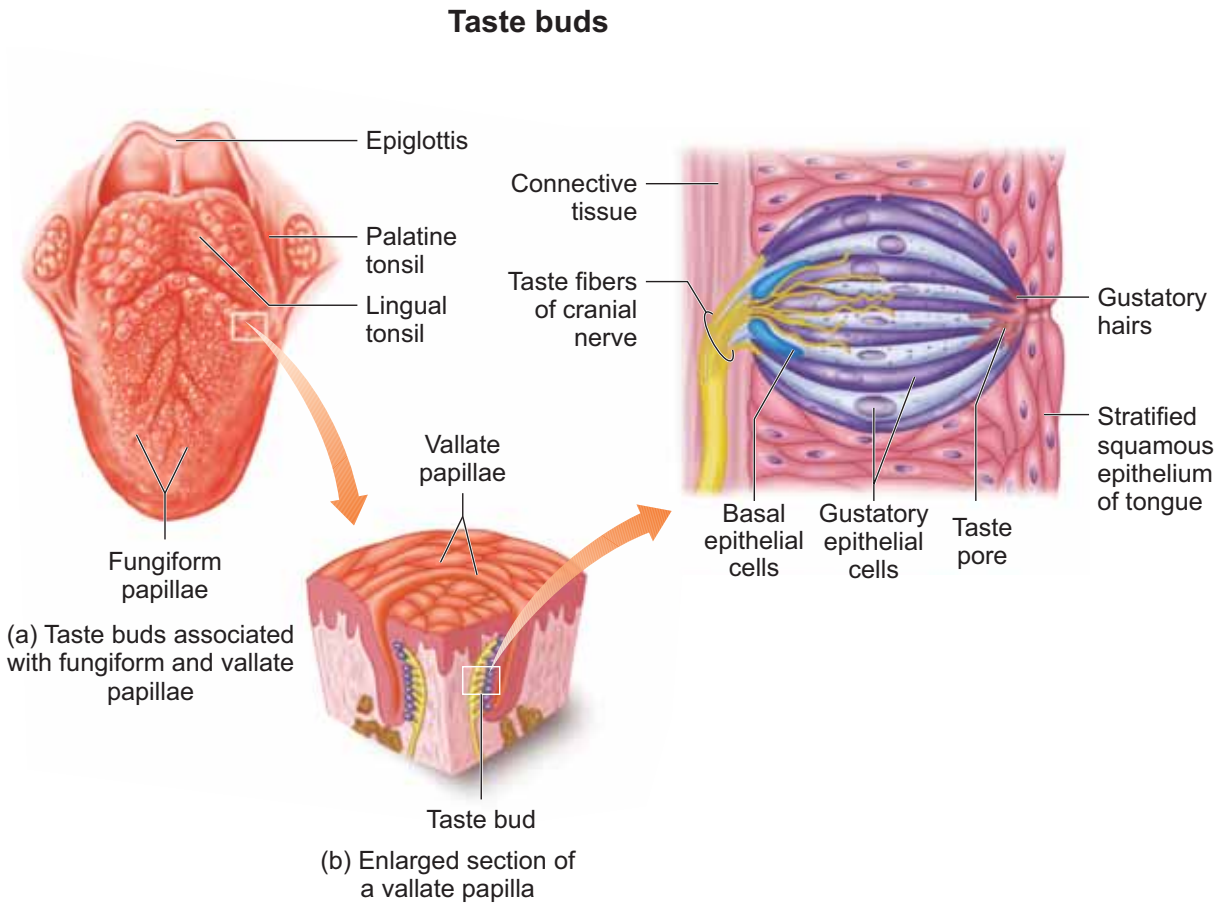


Figure 10.23 Gustatory receptor

Most taste buds are seen on the tongue (Figure 10.23) few are scattered on the soft palate, inner surface of the cheeks, pharynx and epiglottis of the larynx. Taste buds are flask-shaped and consist of 50 – 100 epithelial cells of two major types.

Gustatory epithelial cells (taste cells) and **Basal epithelial cells** (Repairing cells) Long microvilli called **gustatory hairs** project from the tip of the gustatory cells and extends through a taste pore to the surface of the epithelium where they are bathed by saliva. Gustatory hairs are the sensitive portion of the gustatory cells and they have sensory dendrites which send the signal to the brain. The basal cells that act as stem cells, divide and differentiate into new gustatory cells (Figure 10.23).

The taste bud cells are subjected to huge amounts of friction, because of their location and are routinely burned by hot foods. These are the most dynamic cells in the body and are replaced every seven to ten days.

Skin-Sense of touch

Skin is the sensory organ of touch and is also the largest sense organ. This sensation comes from millions of microscopic sensory receptors located all over the skin and associated with the general sensations of contact, pressure, heat, cold and pain. Some parts of the body, such as the finger tips have a large number of these receptors, making them more sensitive. Some of the sensory receptors present in the skin (Figure 10.24) are:

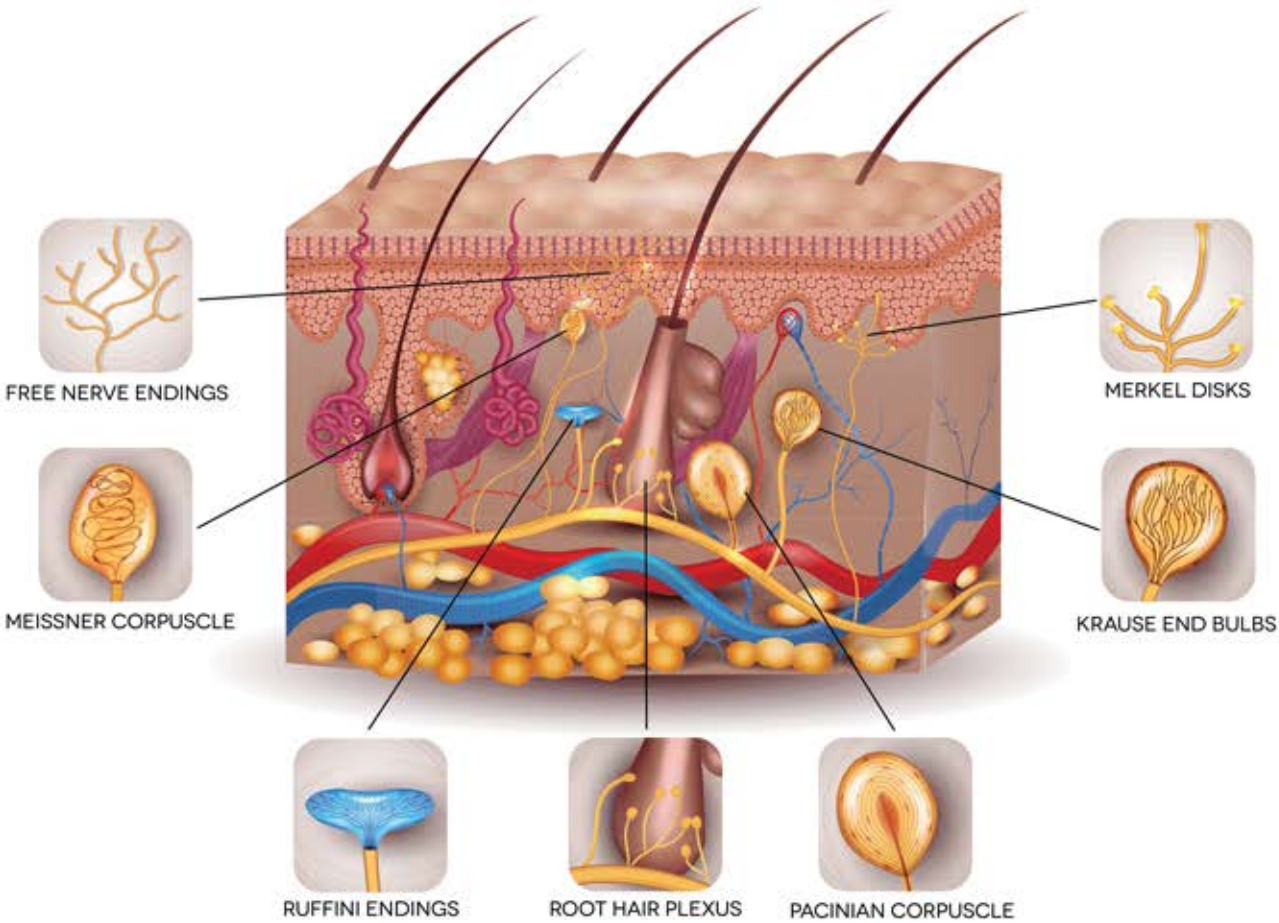


Figure 10.24 Skin receptors

- **Tactile merkel disc** is light touch receptor lying in the deeper layer of epidermis.
- **Hair follicle receptors** are light touch receptors lying around the hair follicles.
- **Meissner's corpuscles** are small light pressure receptors found just beneath the epidermis in the dermal papillae. They are numerous in hairless skin areas such as finger tips and soles of the feet.
- **Pacinian corpuscles** are the large egg shaped receptors found scattered deep in the dermis and monitoring vibration due to pressure. It allows to detect different textures, temperature, hardness and pain
- **Ruffini endings** which lie in the dermis responds to continuous pressure.
- **Krause end bulbs** are thermoreceptors that sense temperature.

Melanocytes are the cells responsible for producing the skin pigment, melanin, which gives skin its colour and protects it from the sun's UV rays. Vitiligo (Leucoderma) is a condition in which the melanin pigment is lost from areas of the skin, causing white patches, often with no clear cause. Vitiligo is not contagious. It can affect people of any age, gender, or ethnic group. The patches appear when melanocytes fails to synthesis melanin pigment.

Activity

- Create a model of the ear by using clay, recyclables etc.
- Use different colors to indicate different lobes of the brain.
- Draw the different areas of the cerebral cortex on the white swimming cap with different colour markers.

Summary

Neural system coordinates and integrates the functions of all organs and responds to changes in the internal and external environments.

Neural system includes two types of cells neurons and neuroglia. Neuron forms the structural and functional unit of the neural system.

CNS includes brain and spinal cord. The major parts of the brain are the cerebrum, diencephalon, cerebellum and the brain stem. The brain is protected by the cranium and meninges. CSF provides mechanical protection and nutrients to the CNS.

The spinal cord is the continuation of the medulla oblongata and ends at the second lumbar vertebra as conus medullaris. The components involved in reflex action are called reflex arc.

There are 12 pairs of cranial nerves which arise from the brain and 31 pairs of spinal nerves from the spinal cord make the PNS. The PNS is further divided into Somatic Neural system and Autonomic Neural system. The SNS operates under conscious control. The ANS usually operates unconsciously.

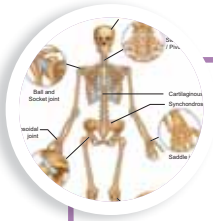
The motor portion of ANS has two major divisions: sympathetic and parasympathetic.

Sensation is the conscious or subconscious awareness of changes in the external or internal environment. Four events namely stimulation, transduction, generation of impulses and integration occurs typically for a sensation to take place.

Simple receptors are associated with the general senses such as somatic senses (skin); complex receptors are associated with the special senses such as smell, taste, vision, hearing and equilibrium.

A person on his way to a village in a car for weekend holidays after finishing the office work. As he is very tired, he begins to feel drowsy. He turns up the car stereo volume, opens the car window and has sips of ice-cold water. How do these actions keep him awake? The increase in the number of sensory stimuli he receives is relayed to the cerebral cortex which gets activated and prevents sleeping.

The Transmitters



Let's explore the structure and various functions of the **Nervous System**.

Step – 1

Use the URL to reach the 'Nervous system' page. Select 'Nervous System organization' from grid and explore the autonomic and somatic organizations of nervous system.

Step – 2

Then reach the 'Nervous system' page by clicking back button on the top of the window or use the 'Backspace' key. Select 'Nerve cells' from the grid and explore.

Step – 3

Follow the above steps and explore each and every parts and their functions of nervous system.

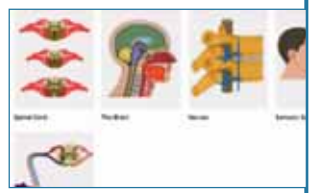
Step – 4

Use the reference given below to acquire additional details about nervous system.

Step 1

Step 2

Step 3



Step 4

Nervous System's URL:

https://www.getbodysmart.com/nervous-system

3D-Brain:
http://www.brainfacts.org/3d-brain#intro=false&focus=Brain&zoom=false

3D-Ear:
https://www.amplifon.com/web/uk/interactive-ear/index.html

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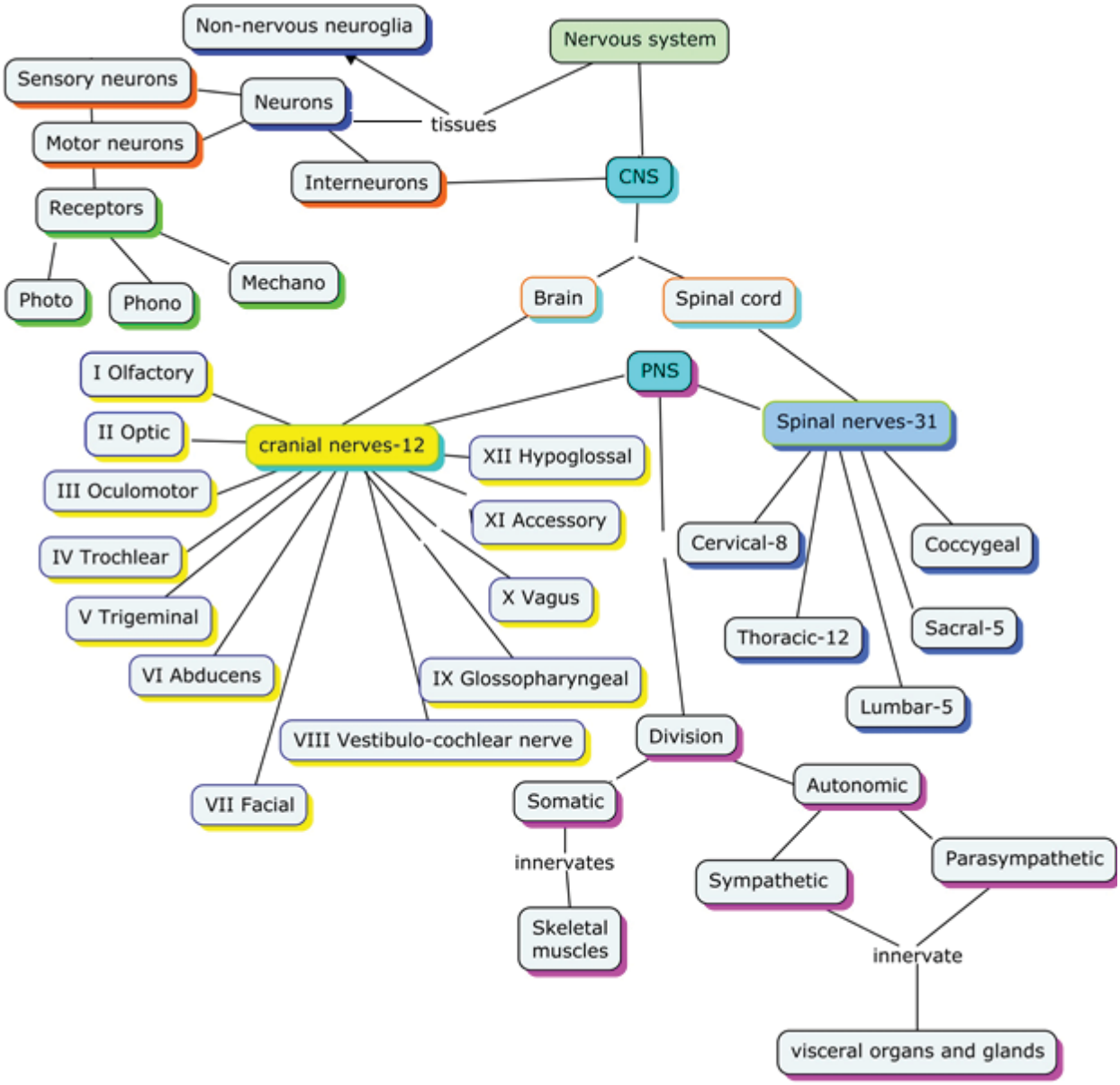
* Pictures are indicative only

Concept Map


Non-nervous neuroglia
Nervous system
Sensory neurons
Neurons
tissues
Motor neurons
Interneurons
CNS
Receptors
Photo
Phono
Mechano
Brain
Spinal cord
I Olfactory
PNS
II Optic
cranial nerves-12
XII Hypoglossal
Spinal nerves-31
III Oculomotor
XI Accessory
Cervical-8
Coccygeal
IV Trochlear
X Vagus
V Trigeminal
Thoracic-12
Sacral-5
VI Abducens
IX Glossopharyngeal
Lumbar-5
VIII Vestibulo-cochlear nerve
Division
VII Facial
Somatic
Autonomic
innervates
Parasympathetic
Sympathetic
Skeletal muscles
innervate
visceral organs and glands

Glossary

Ampulla – The widened opening for each of the semicircular canals, containing sensory innervations.

Depolarization – The loss of electric potential difference between the inside and outside the nerve cell due to a change in permeability and migration of sodium ions to the interior.

Neurotransmitters – Also known as chemical messengers, are chemicals that transmit signals across a neuromuscular junction, from one neuron to another "target" neuron, muscle cell, or gland cell.

Nissl's granules – Endoplasmic reticulum with free ribosomes, found in the cytoplasm of neuronal cell body, but absent in the axon. These are the site of protein synthesis.

Nodes of Ranvier – Periodic gap in the insulating sheath (myelin) on the axon of certain neurons that serves to facilitate the rapid conduction of nerve impulses.

Properioception – The ability to sense stimuli arising within the body regarding position, motion and equilibrium.

Schwann cells – It is also called neurilemma cell, produce the myelin sheath around neuronal axons in the peripheralneural system. Schwann cells are named after German physiologist Theodor Schwann, who discovered them in the 19th century.

Septum pellucidum – Located in the midline of the brain, between the two cerebral hemispheres. It separates the lateral ventricles I and II.

Threshold stimulus – The minimum stimulus needed to achieve an action potential.

Evaluation

Choose the followings:

1 Which structure in the ear converts pressure waves to action potentials?

a. Tympanic membrane
b. Organ of Corti
c. Oval window
d. Semicircular canal

2. Which of the following pairings is correct?

a. Sensory nerve – afferent
b. Motor nerve - afferent
c. Sensory nerve – ventral
d. Motor nerve – dorsal

3. During synaptic transmission of nerve impulse, neurotransmitter (P) is released from synaptic vesicles by the action of ions (Q). Choose the correct P and Q.

a. P = Acetylcholine, Q = Ca++
b. P = Acetylcholine, Q = Na+
c. P = GABA, Q=Na+
d. P = Cholinesterase, Q = Ca++

4. Examine the diagram of the two cell types A and B given below and select the correct option.

a. Cell-A is the rod cell found evenly all over retina
b. Cell-A is the cone cell more concentrated in the fovea centralis
c. Cell-B is concerned with colour vision in bright light

d. Cell-A is sensitive to bright light intensities

5. Assertion: The imbalance in concentration of Na^+, K^+ and proteins generates action potential. Reason: To maintain the unequal distribution of Na^+ and K^+, the neurons use electrical energy.
   a. Both Assertion and Reason are true and Reason is the correct explanation of the Assertion.
   b. Both Assertion and Reason are true but the Reason is not the correct explanations of Assertion.
   c. Assertion is true, but Reason is false.
   d. Both Assertion and Reason are false.
6. Which part of the human brain is concerned with the regulation of body temperature?
   a. Cerebellum
   b. Cerebrum
   c. Medulla oblongata
   d. Hypothalamus
7. The respiratory centre is present in the
   a. Medulla oblongata
   b. Hypothalamus
   c. Cerebellum
   d. Thalamus
8. Match the following human spinal nerves in column I with their respective number in column II and choose the correct option

column I	column II
P. Cervical nerves	i. 5 pairs
Q. Thoracic nerve	ii. 1 pair
R. Lumbar nerve	iii. 12 pair
S. Coccygeal nerve	iv. 8 pair

   a. (P-iv),(Q-iii),(R-i),(S-ii)
   b. (P-iii), (Q-i), (R-ii), (S-iv)
   c. (P-iv),(Q-i),(R-ii),(S-iii)
   d. (P-ii), (Q-iv), (R-i), (S-iii)
9. Which of the following cranial nerve controls the movement of eye ball ?
   a. trochlear nerve b. optic nerve
   c. Olfactory nerve d. vagus nerve.
10. The abundant intracellular cation is
   a. H^+ b. K^+ c. Na^+ d. Ca^{++}
11. Which of the following statements is wrong regarding conduction of nerve impulse?
   a. In a resting neuron, the axonal membrane is more permeable to K^+ ions and nearly impermeable to Na^+ ions.
   b. Fluid outside the axon has a high concentration of Na^+ ions and low concentration of K^+, in a resting neuron.
   c. Ionic gradient s are maintained by Na^+ K^+ pumps across the resting membrane, which transport 3Na ions outwards for $2K^+$ into the cell.
   d. A neuron is polarized only when the outer surface of the axonal membrane possess a negative a charge and its inner surface is positively charged.
12. All of the following are associated with the myeline sheath except
   a. Faster conduction of nerve impulses
   b. Nodes of Ranvier forming gaps along the axon
   c. Increased energy output for nerve impulse conduction
   d. Saltatory conduction of action potential

13. Several statements are given here in reference to cone cells which of the following option indicates all correct statements for cone cells ?

    Statements

    (i) Cone cells are less sensitive in bright light than Rod cells

    (ii) They are responsible for colour vision

    (iii) Erythropsin is a photo pigment which is sensitive to red colour light

    (iv) They are present in fovea of retina

    a. (iii), (ii) and (i)
    b. (ii) , (iii) and (iv)
    c. (i), (iii) and (iv)
    d. (i), (ii) and (iv)

14. Which of the following statement concerning the somatic division of the peripheral neural system is incorrect?

    a. Its pathways innervate skeletal muscles
    b. Its pathways are usually voluntary
    c. Some of its pathways are referred to as reflex arcs
    d. Its pathways always involve four neurons

15. When the potential across the axon membrane is more negative than the normal resting potential, the neuron is said to be in a state of

    a. Depolarization
    b. Hyperpolarization
    c. Repolarization
    d. Hypopolarization

16. Why is the blind spot called so?

17. Sam's optometrist tells him that his intraocular pressure is high. What is this condition called and which fluid does it involve?

18. Why are we getting running nose while crying?

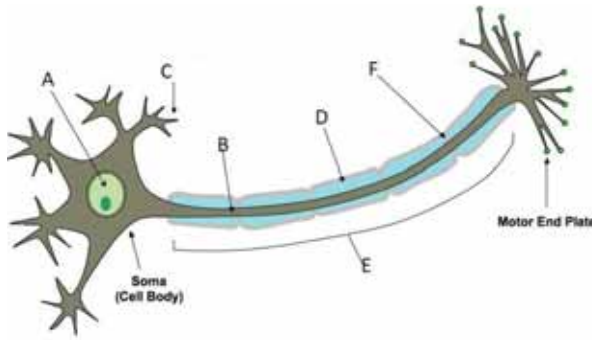
19. The action potential occurs in response to a threshold stimulus; but not at sub threshold stimuli. What is the name of the principle involved?

20. Pleasant smell of food urged Ravi to rush into the kitchen. Name the parts of the brain involved in the identification of food and emotional responses to odour.

21. Cornea transplant in humans is almost never rejected. State the reason.

22. At the end of repolarization, the nerve membrane gets hyperpolarized. Why?

23. Label the parts of the neuron.



24. The choroid plexus secretes cerebrospinal fluid. List the function of it.

25. What is the ANS controlling centre? Name the parts that are supplied by the ANS.

26. Why the limbic system is called the emotional brain? Name the parts of it.

27. Classify receptors based on type of stimuli.
28. Name the first five cranial nerves, their nature and their functions.
29. The sense of taste is considered to be the most pleasurable of all senses.

    Describe the structure of the receptor involved with a diagram.
30. Describe the structures of olfactory receptors?

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3. Sherwood.L., and Kell. R., 2010. In. Human Physiology. First Canadian Edition. Thomson Brooks/Cole, Inc.823.

Careers in Neural Science

Career	Details
Neurobiologist	Studies the biology of the nervous system.
https://en.wikipedia.org/wiki/Neuroscience	
Neuroanatomist	Studies the structure (anatomy) of the nervous system.
https://en.wikipedia.org/wiki/Neuroanatomy	
Electroneurodiagnostic Technician	Records electrical activity from the brain (electroencephalograms; evoked potentials) and spinal cord
https://en.wikipedia.org/wiki/Intraoperative_neurophysiological_monitoring.	
Neuroscience Nurse	Nurse who cares for patients with neurological disorders and assists other neuroscience-related health care professionals.
http://aann.org/	
Neuropharmacologist	Studies the action of drugs on the nervous system and/or behavior.
https://en.wikipedia.org/wiki/Neuropharmacology	
Neurophysiologist	Studies the physiology (electrical responses) of the nervous system.
https://en.wikipedia.org/wiki/Neurophysiology	
Neuropsychologist	Studies brain/behavior relationships especially cognitive function.
https://en.wikipedia.org/wiki/Neuropsychology	
Neuroradiologist	Uses imaging methods such as X-ray, MRI, CT and angiography to diagnose diseases of the nervous system.
https://en.wikipedia.org/wiki/Neuroradiology	
Optometry (B.Opto)	the occupation of measuring eyesight, prescribing corrective lenses, and detecting eye disease.
https://targetstudy.com/colleges/bsc-optometry-degree-colleges-in-tamil-nadu.html	

UNIT IV | Chapter 11

Chemical Coordination and Integration

Chapter Outline

6QT97J

Klotho an anti-aging hormone makes people smart enhances cognitive abilities and longevity.

Learning Objectives:

- *Understands the positions of the various endocrine glands and their secretions.*
- *Learns the mechanism of hormone action.*
- *Understands the disorders related to hypo and hyper activity of the endocrine glands.*
- *Learns the role of gastro intestinal hormones.*

While hearing your test marks, some may have anxiety and some may hesitate to hear and some may be worried. Do you know the reasons for such immediate changes? While seeing any unexpected happenings, we get goose bumps. Do you know the reason, why?

These are all due to the biochemical changes happening in our body, Which are created by the endocrine system. The above mentioned biochemical changes are due to the hormone adrenalin (flight, fright and fight hormone).

11.1 Endocrine glands and hormones

Physiological functions of our human body is regulated and coordinated by both neural and endocrine systems. The endocrine system influences the metabolic activities by means of **hormones** (hormone means *to excite*) which are chemical messengers released into the blood and circulated as chemical signals and acts specifically on certain organs or tissues called target organs or target tissues. Hormones may speed up or slow down or alter the activity of the target organs. The hormones secreted do not remain permanently in the blood but are converted by the liver into inactive compounds and excreted by the kidneys.

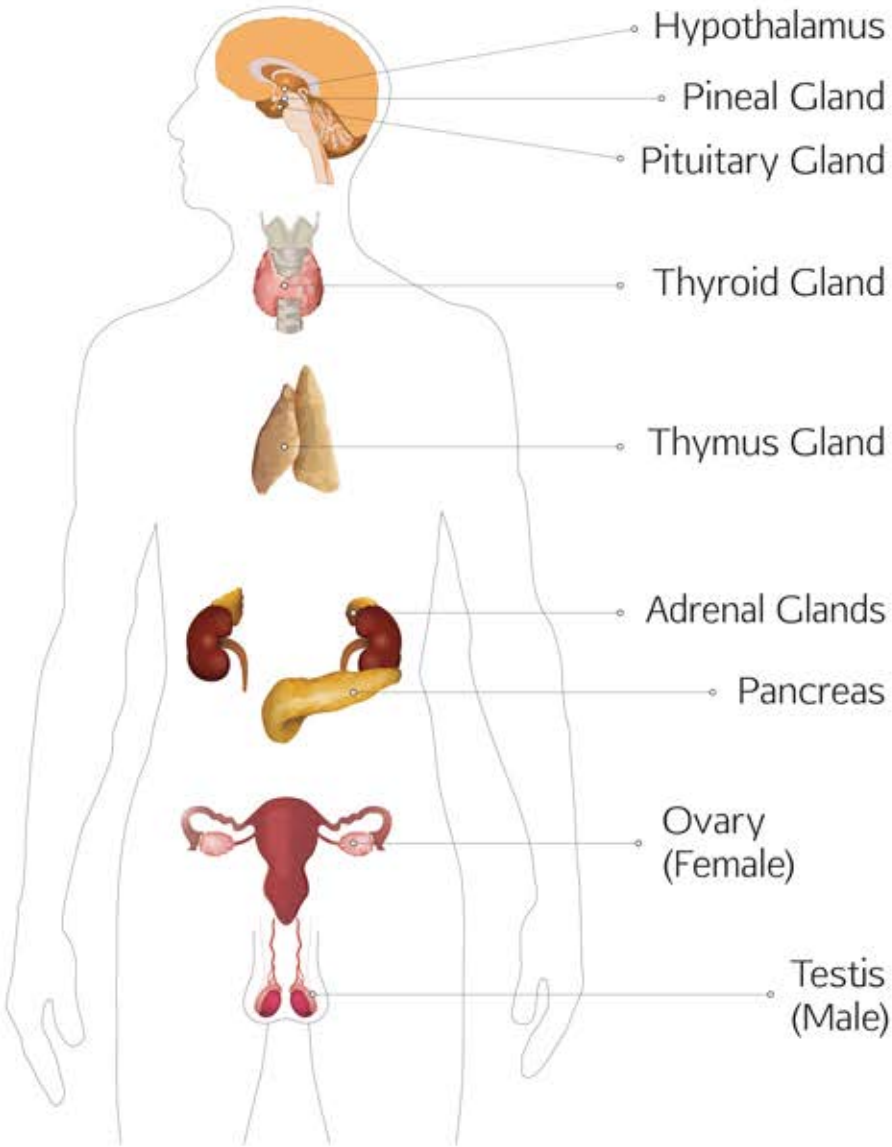


Figure :11. 1 Location of various endocrine glands

Hormones are chemical messengers because they act as organic catalysts and coenzymes to perform specific functions in the target organs. The target organs contain receptor molecules either on the surface or within the cell. Although different hormones come in contact with cells, only the cells that contain receptor molecules specific for the hormone are physiologically activated. A single hormone may have multiple effects on a single target tissue or on different target tissues.

Many hormones exhibit long term changes like growth, puberty and pregnancy. Hormones often influence many organs and organ systems at the same time. Serious deficiency or excess secretion of hormones leads to disorders. Hormones coordinate different physical, physiological, mental activities and

Homeostasis: Maintenance of constant internal environment of the body by the different coordinating system.

maintain **homeostasis.** Hormones are composed of water soluble proteins or peptides or amines or fat soluble steroids.

11.2 Human endocrine system

There are two glandular systems such as the exocrine glands and the endocrine glands. The exocrine glands secrete enzymes, saliva and sweat and have ducts that carry their substances to the membrane surfaces. Example: salivary gland and gastric gland. The endocrine glands, called ductless glands produce hormones and lack ducts; they release their hormone to the surrounding tissue fluid. The hormones circulate around the body and eventually reach the target organs. Endocrine glands (Figure: 11. 1) include the pituitary, thyroid, parathyroid, pineal, adrenal, thymus and are also known as **exclusive endocrine glands**. The hypothalamus along with its neural function also produces hormones and is considered as a **neuro endocrine gland.** In addition several organs such as pancreas, gastro intestinal tract epithelium, kidney, heart, gonads and placenta are also have endocrine tissues and are known as **partial endocrine glands.**

11.2.1 Hypothalamus

Hypothalamus is a small cone shaped structure that projects downward from the brain ending into the pituitary stalk. It interlinks both the nervous system and endocrine system. Though pituitary gland is known as master endocrine glands that controls the other endocrine glands, but it is, in turn controlled by the hypothalamus. Hypothalamus contains groups of neurosecretory cells. It produces neurotransmitters which regulate the secretions of the pituitary (Figure11. 2). The hormones produced by the hypothalamus act either as a releasing hormone or as an inhibitory hormone.

In the basal region of the brain, the **hypothalamic hypophyseal portal blood vessel** connects hypothalamus and anterior pituitary. It allows hypothalamic hormones to control anterior pituitary secretion. The posterior pituitary is connected with hypothalamus by a nerve bundle called **hypothalamic hypophyseal axis**. It produces nerve signal that control the posterior pituitary secretion. Hypothalamus maintains homeostasis, blood pressure, body temperature, cardio and fluid electrolyte balance of the body. As the part of limbic system it influences various emotional responses.

Table. 11.1. Chemical nature of hormones

Class	Chemical properties	Example
Amines	Small, water soluble derived from tyrosine or tryptophan	Adrenalin, nor adrenalin, melatonin and thyroid hormone
Protein/Peptides	Water soluble	Insulin, glucagon and pituitary hormones
Steroids	Derived from cholesterol mostly lipid soluble	Cortisol, aldosterone, testosterone, oestrogen, progesterone.

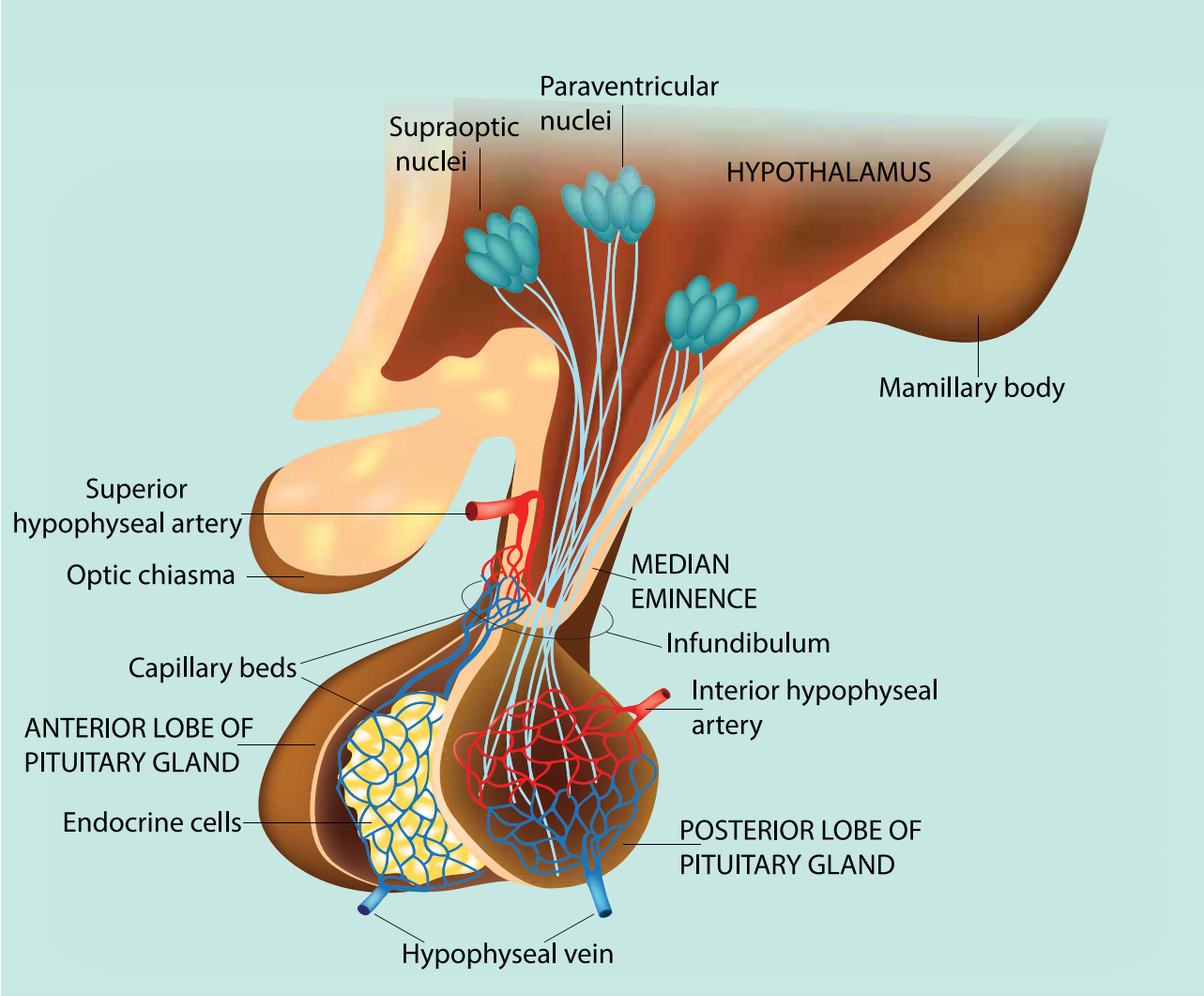


Figure.11. 2 Hypothalamus and pituitary gland

Table11.2 The major hypothalamic hormones and their functions

S.No.	Hormones	Functions
1.	Thyrotropin releasing hormone (TRH)	Stimulates the secretion of TSH
2.	Gonadotropin releasing hormone(GnRH)	Stimulates the secretion of FSH
3.	Corticotropin releasing hormone (CRH)	Stimulates the secretion of ACTH
4.	Growth hormone releasing hormone (GHRH)	Stimulates the secretion of GH
5.	Prolactin releasing hormone (PRH)	Stimulates the secretion of Prolactin
6.	Luteinizing hormone releasing hormone (LHRH)	Stimulates the secretion of LH
7.	MSH releasing hormone	Stimulates the secretion of MSH
8.	Growth hormone-inhibiting hormone (GHIH)	Inhibits the secretion of GH
9.	Prolactin inhibiting hormone (PIH)	Inhibits the secretion of Prolactin
10.	MSH inhibiting hormone	Inhibits the secretion of MSH

11.2.2 Pituitary gland or Hypophysis

The pituitary gland (means to grow under) is ovoid in shape and is located in the **sella turcica**, a bony cavity of the sphenoid bone at the base of brain and connected to the hypothalamic region of the brain by a stalk called **infundibulum**. It is about one centimetre in diameter and 0.5 gm in weight. The pituitary consists of two lobes, anterior glandular adenohypophysis and posterior neural neurohypophysis. The anterior lobe originates from the embryonic invagination of pharyngeal epithelium called **Rathke's pouch** and the posterior lobe is originates from the base of the brain as an outgrowth of hypothalamus. Anatomically the adenohypophysis has three lobes or zones namely pars intermedia, pars distalis and pars tuberalis. The neurohypophysis is otherwise known as pars nervosa.

The anterior lobe of pituitary secretes six tropic hormones such as growth hormone (GH), thyroid stimulating hormone (TSH), adreno corticotropic hormone (ACTH), follicle stimulating hormone (FSH), luteinizing hormone (LH), luteotropic hormone (LTH) and melanocyte stimulating hormone (MSH) (in lower animals only). The posterior lobe of pituitary secretes the hormones namely vasopressin and oxytocin.

- In mammals, the role of pars intermedia is insignificant, but in other vertebrates it secretes **melanocyte stimulating hormone** (MSH). MSH induces pigmentation in skin.

Hormones of Adenohypophysis

i) Growth hormone (GH): It is also known as somatotropic hormone (STH) or Somatotropin. It is a peptide hormone. Growth hormone promotes growth of all the tissues and metabolic process of the body. It influences the metabolism of carbohydrates, proteins and lipids and increases the rate of protein biosynthesis in the cells. It stimulates chondrogenesis (cartilage formation), osteogenesis (bone formation) and helps in the retention of minerals like nitrogen, potassium, phosphorus, sodium etc., in the body. GH increases the release of fatty acid from adipose tissue and decreases the rate of glucose utilization for energy by the cells. Thus it conserves glucose for glucose dependent tissues, such as the brain.

ii) Thyroid stimulating hormone (TSH) or thyrotropin: TSH is a glycoprotein hormone, which stimulates the thyroid gland to secrete Tri-iodothyronine (T_3) and thyroxine (T_4). TSH secretion is regulated by negative feedback mechanism. It's release from the anterior pituitary is induced by the thyrotropin releasing hormone (TRH). When thyroxine level in the blood increases, TRH acts on both the pituitary and hypothalamus to inhibit TSH secretion.

iii) Adrenocorticotropic hormone (ACTH): ACTH is a peptide hormone that stimulates the adrenal cortex to secrete glucocorticoids and mineralocorticoids. It stimulates melanin synthesis in melanocytes, induces the release of fatty acids from adipose tissues and stimulates insulin secretion. ACTH secretion is regulated by **negative feedback mechanism.**

iv) Follicle stimulating hormone (FSH): FSH is a glycoprotein hormone which regulates the functions of the gonads (ovary and testis). In males, FSH along with androgens acts on the germinal epithelium of seminiferous tubules and stimulates the production and release of sperms (spermatogenesis). In females, FSH acts on the ovaries and brings about the development and maturation of graffian follicles.

v) Luteinizing hormone (LH): LH is a glycoprotein hormone which is also known as interstitial cell stimulating hormone (ICSH). In males, ICSH acts on the interstitial cells of testis to produce the male sex hormone, testosterone. In females, LH along with FSH matures the ovarian follicles. LH independently induces ovulation, maintains the corpus luteum and promotes synthesis and release of ovarian hormones. FSH and LH are collectively referred as gonadotropins. FSH and LH are not produced during childhood. The secretion of FSH and LH starts only during pre pubertal period.

vi) Luteotropic hormone (LTH): LTH is also called luteotropin or lactogenic hormone or prolactin or mammotropin. It is a protein hormone which stimulates milk secretion after the child birth in females. High prolactin secretion during lactation suppresses LH secretion and ovulation since it induces the corpus luteum hence named as luteo tropic hormone.

Hormones of neurohypophysis

i) Vasopressin or antidiuretic hormone (ADH) : ADH is a peptide hormone which promotes reabsorption of water and electrolytes by distal tubules of nephron and thereby reduces loss of water through urine. Hence it is called as anti diuretic hormone. It also causes constriction of blood vessels when released in large amount and increases blood pressure. ADH deficiency causes ***Diabetes insipidus*** which induces the production of large amount of urine.

Vasopressin and oxytocin are composed of nine amino acids and are almost identical but they differ in only **two amino acids** and yet they have dramatically different physiological effects.

Amino acid sequence of **vasopressin**: cysteine-tyrosine-**phenyl alanine**-glutamine-aspargine-cysteine-proline-**arginine**-glycine.

Amino acid sequence of **oxytocin**:cysteine-tyrosine-**isoleu sine**-glutamine-aspargine-cysteine-proline-**leucine**-glycine.

ii) Oxytocin (means quick birth): It is a peptide hormone which stimulates vigorous contraction of the smooth muscles of uterus during child birth and ejection of milk from the mammary glands.

Pituitary gland is located in a depression in the sphenoid bone of skull below the brain, so is also called hypothalamus cerebri. Discuss the following :

a. Pituitary gland is commonly called "master gland" of the body.
b. Discuss the role of hypothalamus and pituitary as a coordinated unit in maintaining physiological processes.
c. How does the posterior lobe of pituitary help in osmoregulation?

11.2.3 Pineal gland

In human, the pineal gland or epiphysis cerebri or conarium is located behind the third ventricle of brain and is formed of parenchymal cells and interstitial cells. It secretes the hormone, **melatonin**, which plays a central role in the regulation of circadian rhythm of our body and maintains the normal sleep wake cycle. It also regulates the timing of sexual maturation of gonads. In addition melatonin also influences metabolism, pigmentation, menstrual cycle and defence mechanism of our body.

Melatonin is secreted at night, Light falling on the retina of eye decreases melatonin production.

Circadian rhythm is the 24 hour cycle of biological activities associated with natural periods of light and darkness. Example sleep wake cycle, body temperature, appetite etc.

11.2.4. Thyroid gland

The butterfly shaped thyroid gland is a bilobed gland located below the larynx on each side of upper trachea. It is the largest endocrine gland in the body. Its two lateral lobes are connected by a median tissue mass called **isthmus**. Each lobe is made up of many lobules .The lobules consist of follicles called **acini (acinus in singular)**. Each acinus is lined with glandular, cuboidal or squamous epithelial cells. The

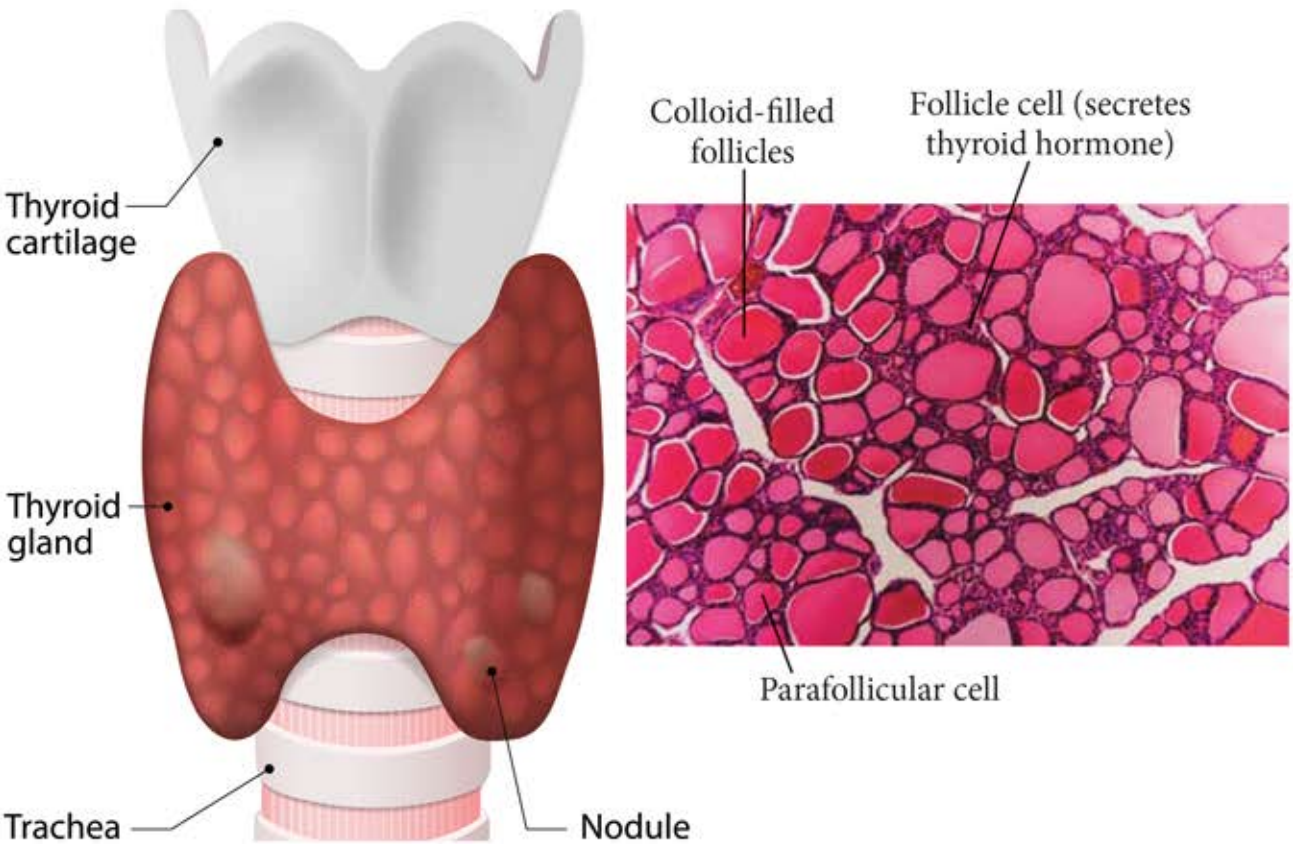


Figure.11. 3 Structures of thyroid gland

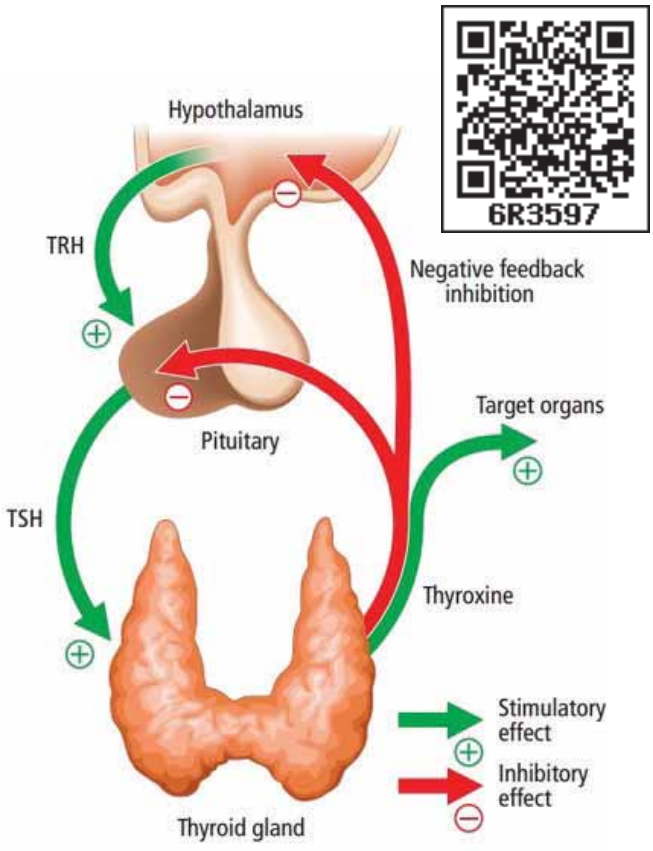


Figure: 11.4. Negative feedback mechanism

lumen of acinus is filled with colloid, a thick glycoprotein mixture consisting of thyroglobulin molecules.

Hormones of the thyroid gland are often called the major metabolic hormones. The follicular cells of thyroid gland secrete two hormones namely tri-iodothyronine (T_3) and thyroxine or tetra- iodothyronine (T_4). The parafollicular cells or 'C' cells of thyroid gland secrete a hormone called thyrocalcitonin. Iodine is essential for the normal synthesis of thyroid hormones. Thyroid releasing hormone from the hypothalamus stimulates the adenohypophysis to secrete TSH, which inturn stimulates the thyroid gland to secrete the thyroid hormones. Thyroid hormones show a negative feedback effect on the hypothalamus and pituitary (Figure11. 4).

Sporodic goitre is a genetic disease and is not caused by iodine or thyroxine deficiency.

Iodine is required for formation of thyroxine: To produce normal quantities of thyroxine, about 1mg/week of iodine is required. To prevent iodine deficiency common table salt is iodised with 1 part sodium iodide to every 1,00,000 parts of sodium chloride

Functions of thyroxine or tetra-iodothyronine (T4): Thyroxine regulates the basal metabolic rate (BMR) and body heat production. It stimulates protein synthesis and promotes growth. It is essential for the development of skeletal and nervous system. Thyroxine plays an important role in maintaining blood pressure. It reduces serum cholesterol levels, Optimum levels of thyroxine in blood is necessary for gonadial functions.

Functions of thyrocalcitonin (TCT): TCT is a polypeptide hormone, which regulates the blood calcium and phosphate levels. It reduces the blood calcium level and opposes the effects of parathyroid hormone.

11.2.5 Parathyroid gland

In human, four tiny parathyroid glands are found in the posterior wall of the thyroid glands. This gland is composed of two types of cells, the chief cells and oxyphil cells. The chief cells secrete parathyroid hormone (PTH) and the functions of oxyphil cells are not known.

Parathyroid hormone or Parathormone (PTH)

PTH is a **hypercalcemic hormone**. It is a peptide hormone involved in controlling the calcium and phosphate homeostasis. The secretion of PTH is controlled by calcium level in the blood. It increases the blood calcium level by stimulating osteoclasts to dissolve the bone matrix. As a result calcium and phosphate are released into the blood. PTH enhances the reabsorption of calcium and excretion of phosphates by the renal tubules and promotes activation of vitamin D to increase calcium absorption by intestinal mucosal cells.

11.2.6 Thymus gland

Thymus gland is partially an endocrine and partially a lymphoid organ. It is a bilobed structure located just above the heart and aorta, behind the sternum. It is covered by fibrous capsule and anatomically it is divisible into an outer cortex and an inner medulla. It secretes four hormones such **as thymulin, thymosin, thymopoietin and thymic humoral factor (THF).** The primary function of thymus is the production of immuno competent 'T' lymphocytes which provides cell mediated immunity.

Old age people are sick often, why?
Due to degeneration of thymus gland, thymosine level decreases, as a result the immunity of old age people becomes weak and causes sickness.

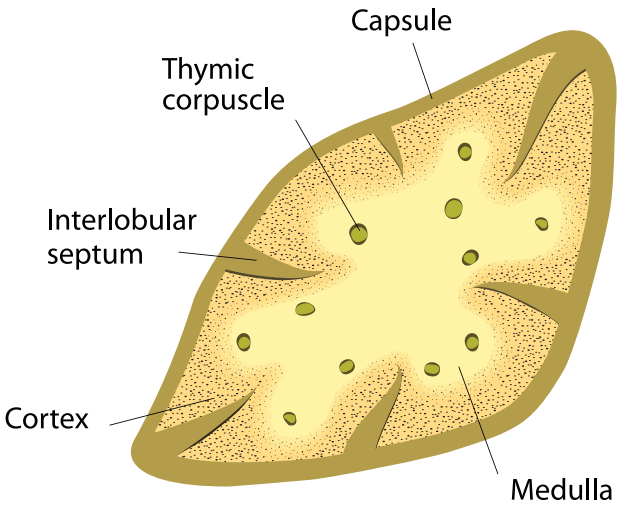


Figure 11. 5 : Structure of thymus gland

11.2.7 Adrenal gland

A pair of adrenal glands are located at the anterior end of the kidneys, hence also called suprarenal glands. Anatomically the outer region is the cortex and the inner region is the medulla. Histologically the adrenal cortex has three distinct zones, zona glomerulosa, zona fasciculata and zona reticularis. **Zona glomerulosa** an outer thin layer constitutes about 15% of adrenal cortex, and secretes mineralocorticoids. **Zona fasciculata**, the middle widest layer constitutes about 75% of adrenal cortex and secretes glucocorticoids such as cortisol, corticosterone and trace amounts of adrenal androgen and oestrogen. **Zona reticularis**, an inner zone of adrenal cortex constitute about 10% of adrenal cortex and secretes the adrenal androgen, trace amount of oestrogen and glucocorticoids.

Adrenal medulla: It is the central part of adrenal gland and is composed of ovoid and columnar cells, which are found around the network of blood capillaries. Adrenalin (epinephrine) and nor adrenalin (nor epinephrine) are the two hormones secreted by the adrenal medulla. Both adrenalin and nor adrenalin are **catecholamines.**

Laughing is good for health, because it reduces the stress hormone (adrenalin) secretion and makes us to relax.

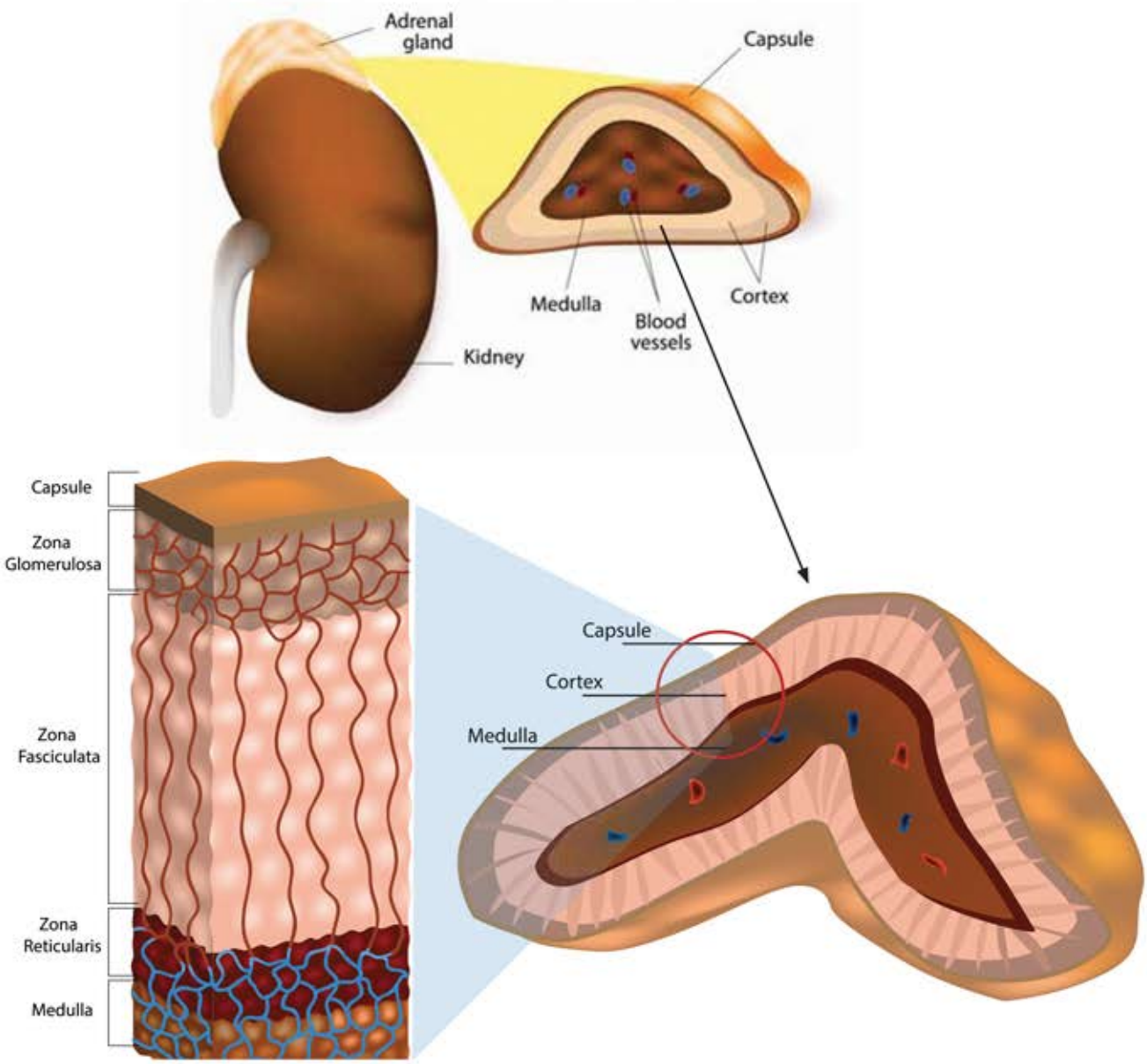


Figure 11.6: Structure of adrenal gland

Function of adrenal hormones: **Glucocorticoids** stimulate gluconeogensis, lipolysis and proteolysis (the life saving activity). **Cortisol** is a glucocorticoid involved in maintaining cardio vascular and kidney functions. It produces anti-inflammatory reactions and suppresses the immune response. It stimulates the RBC production. It is also known as stress combat hormone. **Mineralocorticoid**s regulates water and electrolyte balance of our body. **Aldosterone** stimulates the reabsorption of sodium and water and eliminates potassium and phosphate ions through excretion, thus it helps in

The general function of noradrenalin is to mobilize the brain and body for action. It's secretion is less during sleep, more during wakefulness and reaches much higher levels during stress situations. This response is known as **'fight or flight'** response.

maintaining electrolytes, osmotic pressure and blood pressure. Adrenal androgen plays a role in hair growth in the axial region, pubis and face during puberty.

The **adrenal medulla** secretes the hormones adrenalin and noradrenalin and are referred as "3F hormone" (fight, flight and fright hormone). Adrenalin increases liver glycogen breakdown into glucose and increases the release of fatty acids from fat cells. During emergency it increases heart beat rate and blood pressure. It stimulates the smooth muscles of cutaneous and visceral arteries to decrease blood flow. It increases blood flow to the skeletal muscles thereby increases the metabolic rate of skeletal muscles, cardiac muscles and nervous tissue.

11.2.8 Pancreas

Pancreas is a composite gland which performs both exocrine and endocrine functions. It is located just below the stomach as a leaf like structure. The pancreas is composed of two major tissues such the acini and islets of langerhans. Acini secretes digestive enzymes and the islets of langerhans secretes hormones like insulin and glucagon. Human pancreas has one to two million islets of langerhans. In each islet about 60% cells are beta cells, 25% cells are alpha cells and 10% cells are delta cells. The alpha cells secrete glucagon, the beta cells secrete insulin and delta cells secrete somatostatin.

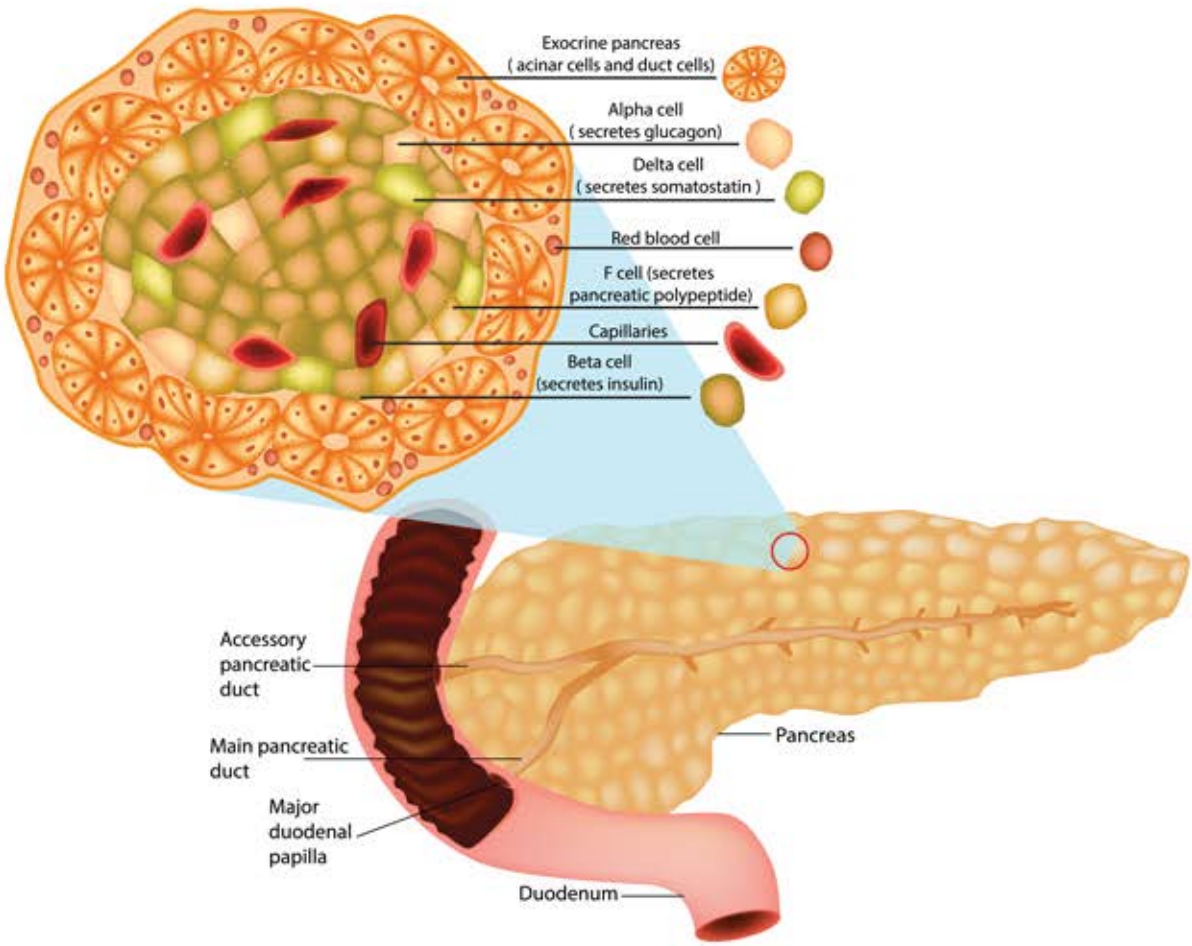


Figure 11.7: Structure of Islets of langerhans (pancreas)

Insulin: Insulin is a peptide hormone and plays an important role in glucose homeostasis. It's main effect is to lower blood glucose levels by increasing the uptake of glucose into the body cells, especially muscle and fat cells. Insulin also inhibits the breakdown of glycogen to glucose, the conversion of amino acids or fats to glucose, so insulin is rightly called a hypoglycemic hormone.

Humulin N: Human insulin is produced by recombinant DNA technology (genetic engineering) and administered to diabetic patients as injection and not by oral consumption. Reason: Digestive enzymes digest it.

Glucagon: Glucagon is a polypeptide hormone. It is a potent hyperglycaemic hormone that acts on the liver and promotes the breakdown of glycogen to glucose (Glygogenolysis), synthesis of glucose from lactic acid and from non-carbohydrate molecules (Gluconeogenesis). Glucagon releases glucose from the liver cells, increasing the blood glucose levels. Since glucagon reduces the cellular uptake and utilisation of glucose it is called a hyperglycemic hormone. Prolonged hyperglycemia leads to the disorder called diabetes mellitus.

Insulin: The half life period of insulin (in plasma) is 6 minutes

It is cleared from the circulation within 10-15 minutes

Endocrine glands control and coordinate the body functions through secreting certain chemical messengers called hormones. Due to certain physiological reasons, the blood glucose level of an otherwise normal person.

a. Give the possible cause for the increases in blood glucose level.

b. What is the chemical nature of this hormone? Discuss its role in the body.

c. How can this condition be reversed?

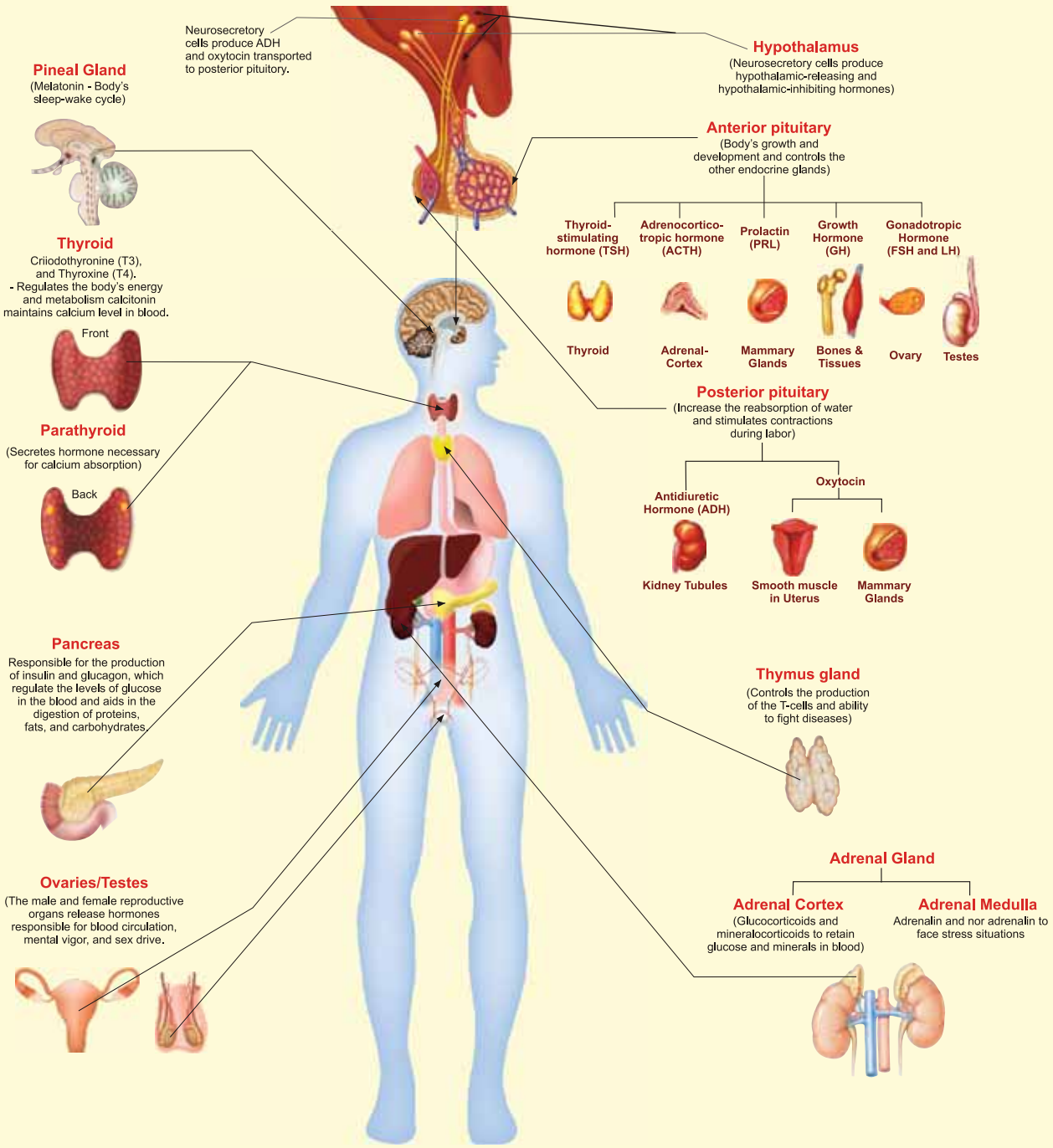
11.2.9 Gonads

Testis: A pair of testis is present in the scrotal sac of males. The testis functions as a sex organ and also as an endocrine gland. The testis is composed of seminiferous tubules and interstitial cells or Leydig cells. The Leydig cells secrete several male sex hormones, collectively called androgens, mainly testosterone.

Functions of testosterone: Under the influence of FSH and LH, testosterone initiates maturation of male reproductive organs, and the appearance of secondary sexual characters, muscular growth, growth of facial and axillary hair, masculine voice and male sexual behaviour. It enhances the total bone matrix and plays a stimulating role in the process of spermatogenesis.

Ovary: Females have a pair of ovaries located in the pelvic region of

Location of major endocrine glands - their secretions and storage,



Hypothalamus found deep inside the brain, its products are releasing and inhibiting hormones and controls the pituitary. Together, the hypothalamus and pituitary control the other endocrine glands in our body to make the hormones that control and co-ordinates various physical and physiological activities.

the abdomen. The ovary is composed of ovarian follicles and stromal tissues. It produces the eggs or ova. The ovaries secrete the steroid hormones oestrogen and progesterone. **Oestrogen** is responsible for the maturation of reproductive organs and the development of secondary sexual characters at puberty. Along with progesterone, oestrogens promotes breast development and initiate the cyclic changes during menstrual cycle. **Progesterone** prepares the uterus for implantation of the fertilized ovum. It decreases the uterine contraction during pregnancy and stimulates the development of mammary glands and milk secretion. It is responsible for premenstrual changes in the uterus and is essential for the formation of placenta.

Identify the peaks of FSH, LH, Oestrogen and Progesterone hormones through out the menstrual cycle.

Urine pregnancy test is done to test the presence of HCG in the urine. HCG can be deducted in the urine one or two weeks after conception.

11.2.10 Hormones of heart, kidney and gastro intestinal tract

Some tissues of the heart, kidney and gastro intestinal tract acts as partial endocrine glands. In the heart, cardiocytes on the atrial wall's secretes an important peptide hormone called atrial natriuretic factor (ANF). When blood pressure is increased, ANF is secreted and causes dilation of the blood vessels to reduce the blood pressure.

In kidneys, hormones such as renin, erythropoietin and calcitriol are secreted. **Renin** is secreted by juxta glomerular cells (JGA), which increases blood pressure when angiotensin is formed in blood. **Erythropoietin** is also secreted by the JGA cells of the kidney and stimulates erythropoiesis (formation of RBC) in bone marrow. **Calcitriol** is sercreted by proximal tubules of nephron. It is an active form of vitamin D_3 which promotes calcium and phosphorus absorption from intestine and accelerates bone formation.

Gastro intestinal tract hormones

Group of specialized endocrine cells present in gastro-intestinal tract secretes hormones such as gastrin, cholecystokinin (CCK), secretin and gastric inhibitory peptides (GIP). **Gastrin** acts on the gastric glands and stimulates the secretion of HCl and pepsinogen. **Cholecystokinin (CCK)** is secreted by duodenum in response to the presence of fat and acid in the diet. It acts on the gall bladder to release bile into duodenum and stimulates the secretion of pancreatic enzymes and its discharge. **Secretin** acts on acini cells of pancreas to secrete bicarbonate ions and water to neutralize the acidity. **Gastric inhibitory peptide (GIP)** inhibits gastric secretion and motility.

11.3 Hypo and Hyper activity of endocrine glands and related disorders

The hyper secretion and hypo secretion of hormones leads to several disorders

Dwarfism is due to hyposecretion of growth hormone (GH) in children, skeletal growth and sexual maturity is arrested. They attain a maximum height of 4 feet only (Figure 11.8).

Figure. 11.8: Dwarfism

Gigantism is due to hypersecretion of growth hormone (GH) in children. Overgrowth of skeletal structure occurs (up to 8 feet) and the visceral growth is not appropriate with that of limbs. Figure 11.9.

Figure. 11.9: Gigantism

Figure. 11.10: Acromegaly

Acromegaly is due to excessive secretion of growth hormone in adults. Over growth of hand bones, feet bones, jaw bones, malfunctioning of gonads, enlargement of viscera, tongue, lungs, heart, liver, spleen

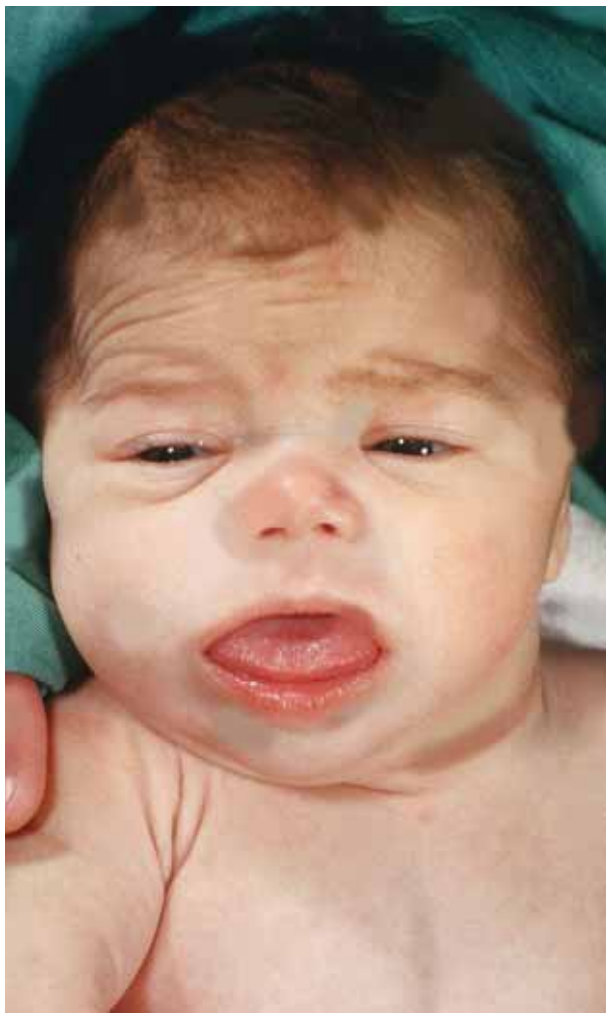


Figure. 11.11: Cretinism

and endocrine gland like thyroid, adrenal etc., are the symptoms of acromegaly. (Figure 11.10)

In infants, hypothyroidism causes **cretinism.** A cretin shows retarded skeletal growth, absence of sexual maturity, retarded mental ability, thick wrinkled skin, protruded enlarged tongue, bloated face, thick and short limbs occurs. The other symptoms are low BMR, slow pulse rate, subnormal body temperature and elevated blood cholesterol levels. (Figure 11.11)

Hyposecretion of thyroid in adults causes **myxodema**. It is otherwise called **Gull's disease**. This disease is characterised by decreased mental activity, memory loss, slowness of movement, speech, and general weakness of body, dry coarse skin, scarce hair, puffy appearance, disturbed sexual function, low BMR, poor appetite, and subnormal body temperature. (Figure 11.12)

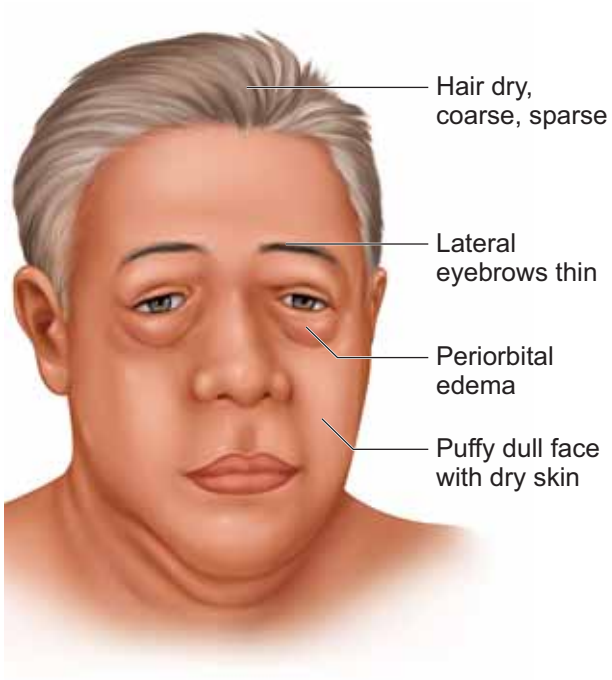


Figure. 11.12: myxodema

Figure. 11.13: Grave's disease

Grave's disease also called as **thyrotoxicosis** or **exophthalmic goitre**. This disease is caused due to hyper secretion of thyroid. It is characterised by enlargement of thyroid gland, increased BMR (50% - 100%), elevated respiratory and excretory rates, increased heart beat, high BP, increased body temperature, protrusion of eyeball and weakness of eye muscles and weight loss. (Figure 11.13)

Simple goitre is also known as **Endemic goitre**. It is caused due to hyposecretion of thyroxine. The symptoms includes enlargement of thyroid gland, fall in serum thyroxine level, increased TSH secretion. (Figure 11.14)

Tetany is caused due to the hyposecretion of parathyroid hormone (PTH). Due to hyposecretion of PTH serum calcium level decreases (Hypocalcemia), as a result serum phosphate level increases. Calcium and

Figure. 11.14: Simple goitre

Figure. 11.15: Addison's disease

phosphate excretion level decreases. Generalized convulsion, locking of jaws increased heart beat rate, increased body temperature, muscular spasm are the major symptoms of tetany.

Hyperparathyroidism is caused due to excess PTH in blood. Demineralisation of bone, cyst formation, softening of bone, loss of muscle tone, general weakness, renal disorders are the symptoms of hyperparathyroidism.

Addison's disease is caused due to hyposecretion of glucocorticoids and mineralocorticoids from the adrenal cortex. Muscular weakness, low BP., loss of appetite, vomiting, hyper pigmentation of skin, low metabolic rate, subnormal temperature, reduced blood volume, weight loss are the symptoms that occur in Addison's disease (Figure 11.15). Reduced aldosterone secretion increases urinary excretion of Na Cl. and water and decreases potassium excretion leading to dehydration.

Cushing's syndrome is caused due to excess secretion of cortisol. Obesity of the face and trunk, redness of face, hand, feet, thin skin, excessive hair growth, loss of minerals from bone (osteoporosis) systolic hypertension are features of Cushing's syndrome. Suppression of sexual function like atrophy of gonads are the other symptoms of Cushing's syndrome. (Figure 11.16)

Hypoglycaemia is due to increased secretion of insulin thereby blood glucose level decreases. In this disorder blood

Normal blood glucose level:

Preprandial : 70 – 110 mg/dl (Before food) – (Fasting)

Postprandial : 110 – 140 mg/dl (About two hours after food)

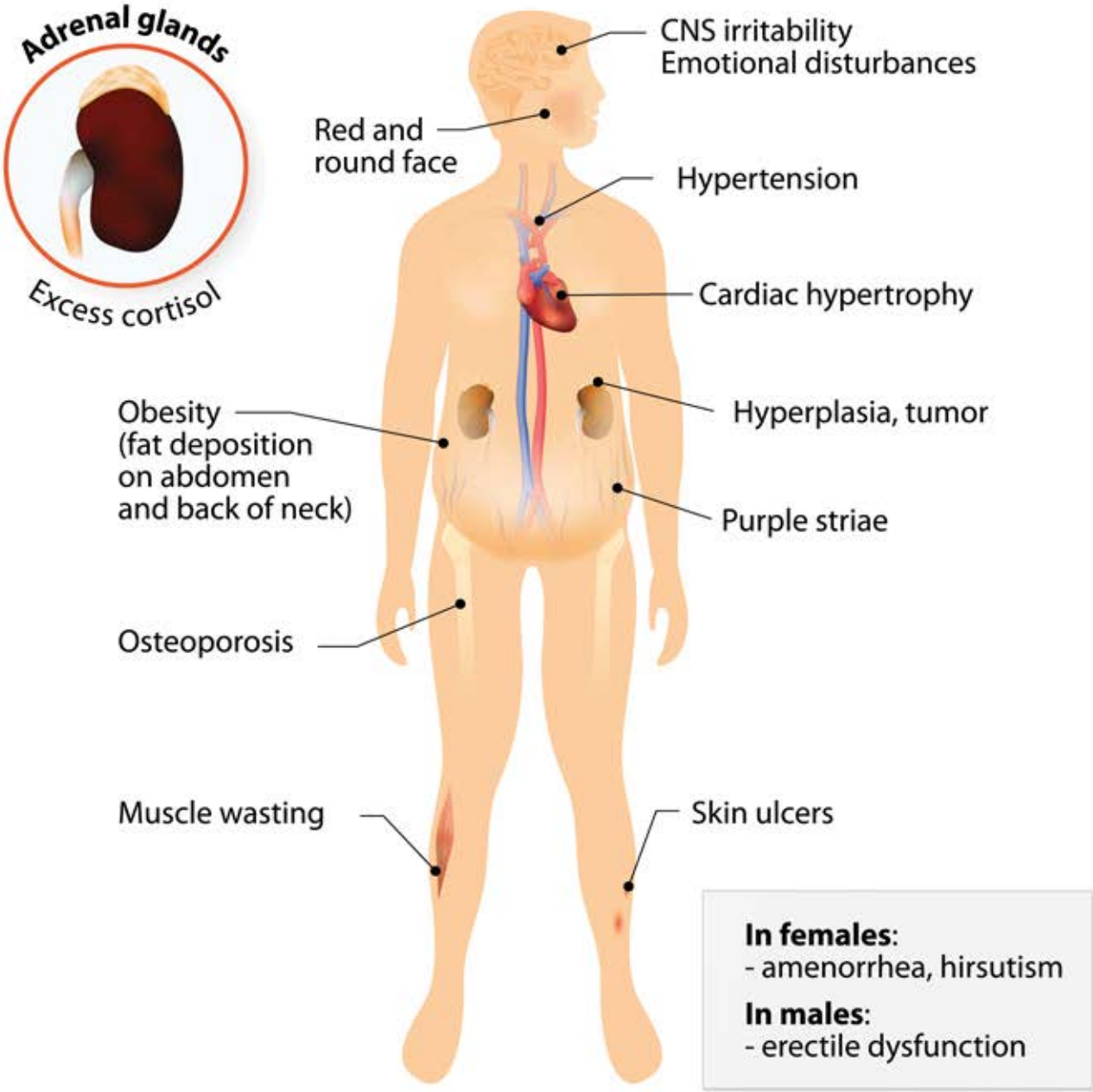


Figure. 11.16: Cushing's syndrome

Avoid use of synthetic soft drinks

The branded soft drinks damage our endocrine system. While consuming soft drinks, the sugar level increases in blood which leads to elevated insulin secretion to reduce the blood glucose level. The elevated insulin level diminishes immunity and causes obesity, cardio-vascular disorders etc.

glucose level lowers than normal fasting index. Increased heartbeat, weakness, nervousness, headache, confusion, lack of co-ordination, slurred speech, serious brain defects like epilepsy and coma occurs.

Hyperglycaemia is otherwise known as **Diabetes mellitus**. It is caused due to reduced secretion of insulin. As the result, blood glucose level is elevated. Diabetes mellitus is of two types, **Type I Diabetes** and **Type II Diabetes**. Type I diabetes is

also known Insulin dependent diabetes, caused by the lack of insulin secretion due to illness or viral infections. Type II diabetes is also known as Non- Insulin dependent diabetes, caused due to reduced sensitivity to insulin, often called as insulin resistance. Symptoms of diabetes includes, polyurea (excessive urination), polyphagia (excessive intake of food), polydipsia (excessive consumption liquids due to thirst), ketosis (breakdown of fat into glucose results in accumulation of ketone bodies) in blood. Gluconeogenesis (Conversion of non- carbohydrate form like amino acids and fat into glucose) also occur in diabetes.

Diabates insipidus is caused due to hyposecretion of vasopressin (ADH) from neurohypophysis. The symptom includes frequent urination (polyurea) and excessive consumption of liquids due to thirst (polydipsia).

Alcohol consumption has widespread effect on endocrine system. Alcohol impairs the regulation of blood glucose level, reduces testosterone level and increases the risk of osteoporosis.

11.4 Mechanism of hormone action

Hormones circulate in the blood but their concentration can increase or

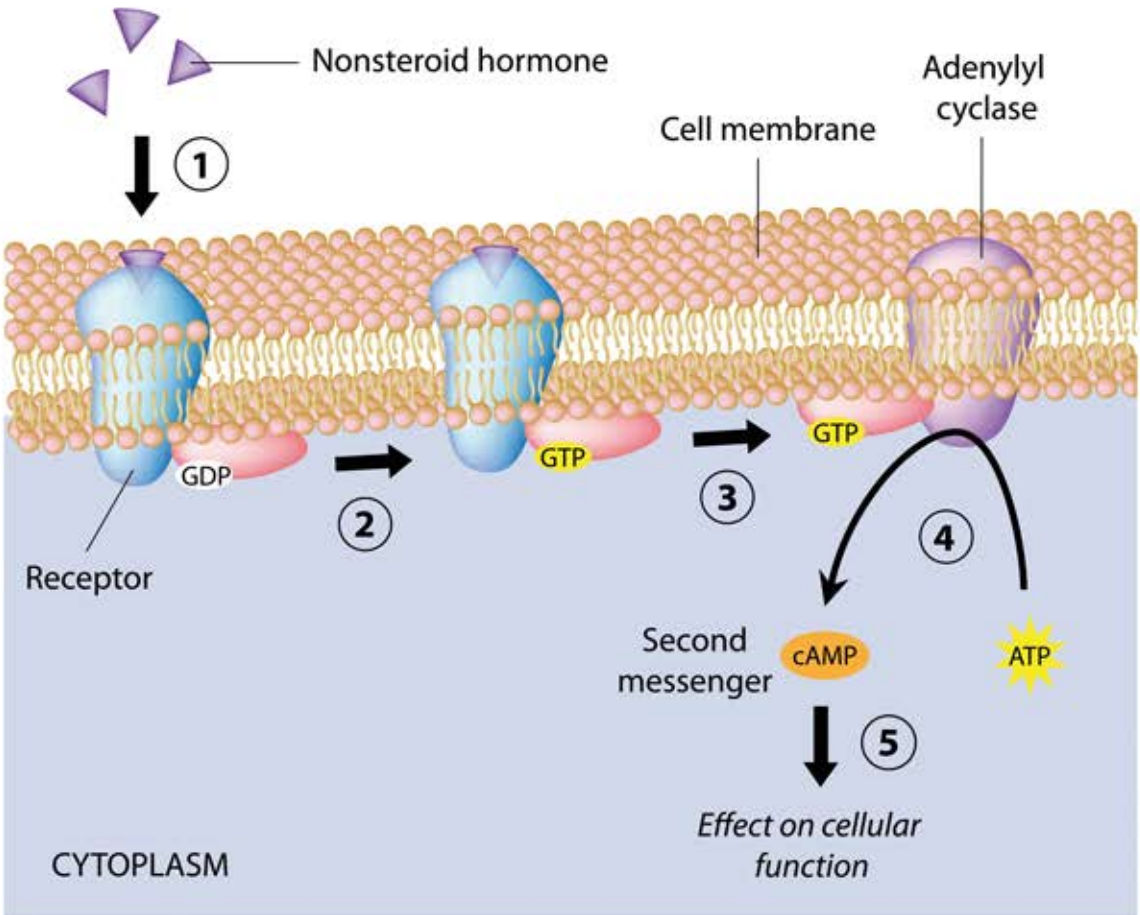


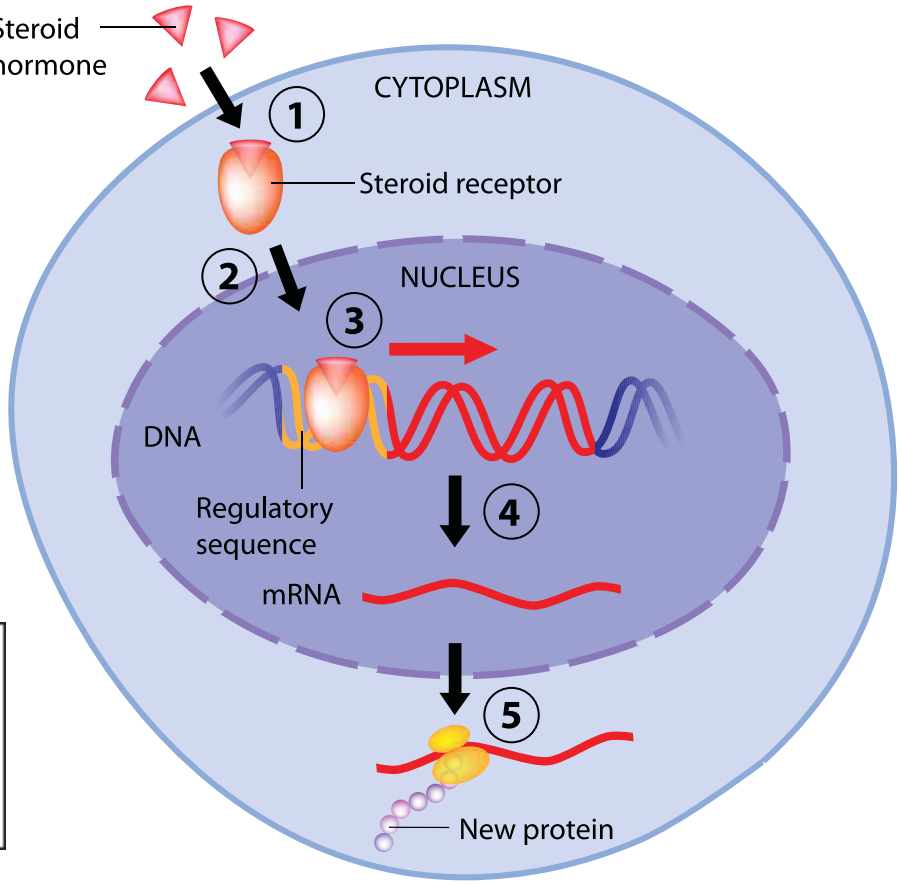
Figure 11.17: Mechanism of peptide hormone action

decrease based on the requirement of the body. This is controlled by feedback mechanisms. These mechanisms control the secretion of endocrine glands by stimulating the hypothalamus, pituitary or both, which inturn governs the secretion of a particular hormone. In positive feedback, the secretion of the hormone increases where as in negative feedback further secretion of hormone slows down. Feedback mechanisms are the key factors for maintaining homeostasis in our body.

Hormones are classified into three major groups as peptide hormones, steroid hormones and amino acid derived hormones based on their chemical structure.

- Peptide hormones cannot cross the phospolipid cell membrane and bind to the receptors on the exterior cell surface. They are are transported to the golgi, which is the site of modification. It acts as a **first messenger** in the cell. Hormones on binding to their receptors do not enter the target cell but generate the production of **second messengers** such as cyclic AMP (c AMP), which in turn regulates cellular metabolism. This is catalyzed by the enzyme **adenylate cyclase**. The interaction between the hormone at the surface and the effect brought out by cAMP within the cell is known as signaling cascade. At each step there is a possibility of amplification. (Figure 11.17)

1. One hormone molecule may bind to multiple receptor molecules before it is degraded.



6RC1AU

Figure 11.18: Mechanism of steroid hormone action

2. Each receptor may activate several adenylate cyclases each of which make much c AMP.
3. Thus there is more signal after each step.

The actions of cAMP are terminated by phosphodiesterases. The effect of peptide hormones like insulin, glucagon, somatotropin are usually short lived because they work through second messenger system.

- Steroid hormones can easily cross the cell membrane, and bind to their receptors, which are intracellular or intranuclear. Upon binding to the receptors, they pair up with another receptor – hormone complex (dimerize).This dimer can then bind to DNA and alter its transcription. (Figure 11.18)

Avoid use of steroid components

The abuse of anabolic steroids can cause serious health problems like high BP, heart diseases, liver damage, cancer, stroke and blood clots. Other side effects of steroid use includes nausea, vomiting, ligament and tendon injuries, head ache, joint pain, muscle cramps, diarrhoea, sleep problem etc.

Basal metabolic rate (BMR): The amount of energy needed to keep the body at rest.

- The effect of steroid hormones such as aldosterone, oestrogen, FSH are long lived, as they alter the amount of mRNA and protein in a cell.
- Amino acid derived hormones are derived from one or two aminoacid with a few additional modifications. Thyroid hormone is synthesised from tyrosine and includes the addition of several iodine atoms. Epinephrine an amino acid derivative may function through second messenger system like peptide hormones or they may actually enter the cell and function like steroid hormones.

Activity

1. Prepare a chart to show the location of various endocrine glands of human.
2. Visit a nearby medical college or hospital and gather data of endocrine disorder, diseases and treatment measures.

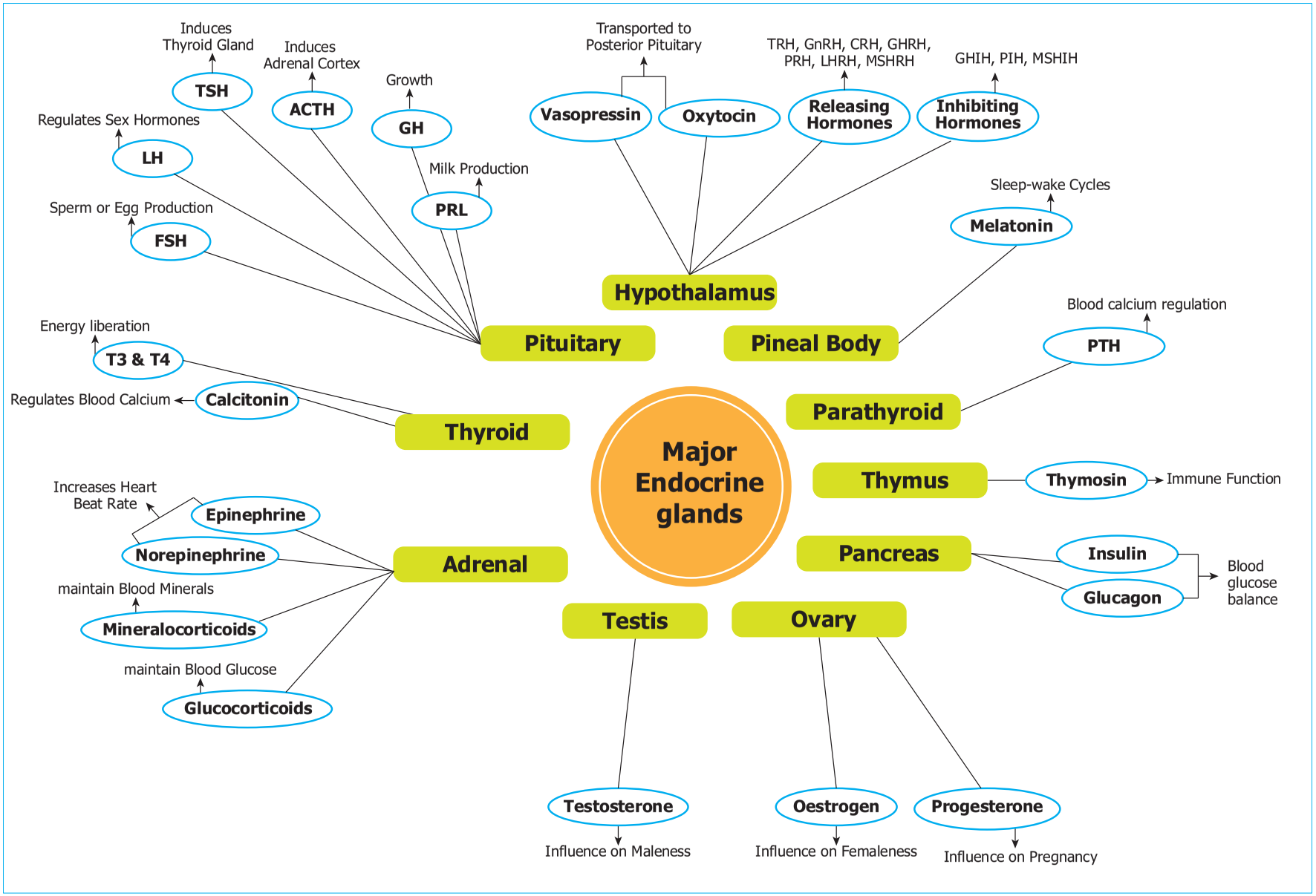
On an educational tour to Nilgiris, Nitish and his friends observed the local people. Few of them were with swollen neck.

1. Is it a disease? If so what is the cause? How is the disease treated?

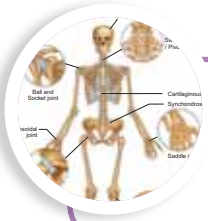
Visit a nearby medical college or hospital and gather data of endocrine disorder, diseases and treatment measures.

When my aunt comes to India from America through air after a long journey, she suffers with jetlag. Find out the reason.

Concept Map


Major Endocrine glands
Pituitary
Hypothalamus
Pineal Body
Thyroid
Parathyroid
Thymus
Adrenal
Pancreas
Testis
Ovary
TSH
Induces Thyroid Gland
ACTH
Induces Adrenal Cortex
GH
Growth
PRL
Milk Production
LH
Regulates Sex Hormones
FSH
Sperm or Egg Production
Vasopressin
Transported to Posterior Pituitary
Oxytocin
Releasing Hormones
TRH, GnRH, CRH, GHRH, PRH, LHRH, MSHRH
Inhibiting Hormones
GHIH, PIH, MSHIH
Melatonin
Sleep-wake Cycles
T3 & T4
Energy liberation
Calcitonin
Regulates Blood Calcium
PTH
Blood calcium regulation
Thymosin
Immune Function
Epinephrine
Increases Heart Beat Rate
Norepinephrine
Mineralocorticoids
maintain Blood Minerals
Glucocorticoids
maintain Blood Glucose
Insulin
Glucagon
Blood glucose balance
Testosterone
Influence on Maleness
Oestrogen
Influence on Femaleness
Progesterone
Influence on Pregnancy

Invisible switches



Let's explore the position and functions of **Endocrine system**.

Step – 1

Use the URL to land in the Endocrine system page.

Step – 2

Click on the gland to find out the position and functions of the gland.

Step – 3

Click on the Hormone name to get additional details about it.

Step – 4

Click the main menu on the top right corner to search back and go through the next gland.

Step 1

Step 2

Step 3

Step 4

Endocrine system's URL:

http://www.e-learningforkids.org/health/lesson/endocrine-system/

B167_STD_11_ZOOLOGY_EM

* Pictures are indicative only

Summary

Endocrine glands: secrete hormones which diffuse into blood and induce the target organs. They are chemical messengers or organic catalysts which interact with receptor in the target organs.

Hormones speed up or slow down or alter the activities of target organs. The hypo or hyper secretion of hormones leads to serious effects on human beings. Hormones coordinate different physical and mental activities to maintain homeostasis.

Hypothalamus interlinks nervous system and endocrine system. It is located in the diencephalon of cerebrum and controls the pituitary secretion. Pituitary gland secretes six tropic hormones which regulates various physiological functions of our body. Posterior pituitary gland secretes vasopressin that regulates water and electrolyte balance. Oxytocin helps during child birth. Melatonin secreted by pineal gland regulates circadian rhythm of our body. The thyroid gland secretes thyroxine which stimulates the nervous system, skeletal growth, and regulates basal metabolic rate.

Parathyroid gland regulates calcium level in our body. Thymus gland plays a vital role in cell mediated immunity by promoting T lymphocytes maturation. Pancreas regulates blood glucose homeostasis through its secretion of insulin and glucagon.

Adrenal cortex secretes mineralocorticoids which regulates mineral metabolism, glucocorticoids regulates carbohydrate metabolism. Adrenal medulla secretes the hormones adrenalin and noradrenalin. In male, reproductive functions are controlled by testosterone secreted by the testis. In female, ovary secretes three hormones oestrogen, progesterone and relaxin that regulates reproductive functions.

Hormonal deficiency causes serious harmful effects in human. It alters physiological and biochemical functions of the body. This leads into various disorders like acromegaly, dwarfism, tetany, diabetes etc.

Opportunities to Endocrinologists

An endocrinology career is a medical career that involves studying hormones and their effects on human body. They investigate and find new ways of treatment of hormonal imbalance. Just like doctors, endocrinologists speak with patients about their medical history and share current findings. They also study the test result of patients and advise them for treatment.

After completing basic degree in medicine (MBBS) doctors can study super specialty course in endocrinology such as endocrine surgery, general endocrinology, paediatric endocrinology etc.

Glossary

Alternation of generation – Alternation of haploid sexual and diploid asexual generation in the life cycle of an animal.

Autonomy - Breaking of a body part.

Dioecious - Animals in which male and female reproductive organs occur in separate individuals.

Acidosis – condition characterised by lower blood pH, due to the increase of keto acids (ketosis)

cAMP – Cyclic adenosine mono phosphate acts as a second messenger (intracellular messenger) in the case of peptide hormone.

Catecholamines – Naturally occurring amines that function as neurotransmitters. They are characterised by catechol group in which an amine group is attached. Example .Epinephrine

Limbic systems – It is a collection of special structures located in the middle of the brain. It is also known as paleomammalian brain. It control emotions, behaviour, motivation of long term memory and olfaction.

Melanocytes – Melanin (black pigment) containing cells.

Evaluation

1. The maintenance of constant internal environment is referred as
   a. Regulation b. homeostasis
   c. co-ordination d. hormonal control
2. Which of the following are exclusive endocrine glands?
   a. Thymus and testis
   b. adrenal and ovary
   c. parathyroid and adrenal
   d. pancreas and parathyroid
3. Which of the following hormone is not secreted under the influence of pituitary gland?
   a. thyroxine b. insulin
   c. oestrogen d. glucocorticoids
4. Spermatogenesis in mammalian testes is controlled by
   a. Luteinising hormone
   b. Follicle stimulating hormone
   c. FSH and prolactin
   d. GH and prolactin
5. Serum calcium level is regulated by
   a. Thyroxine b. FSH
   c. Pancreas d. Thyroid and parathyroid
6. Iodised salt is essential to prevent
   a. rickets b. scurvy
   c. goitre d. acromegaly
7. Which of the following gland is related with immunity?
   a. Pineal gland b. adrenal gland
   c. thymus d. parathyroid gland
8. Which of the following statement about sex hormones is correct?
   a. Testosterone is produced by Leydig cells under the influence of luteinizing hormone
   b. Progesterone is secreted by corpus luteum and softens pelvic ligaments during child birth
   c. Oestrogen is secreted by both sertoli cells and corpus luteum
   d. Progesterone produced by corpus luteum is biologically different from the one produced by placenta.
9. Hypersecretion of GH in children leads to
   a. Cretinism b. Gigantism
   c. Graves disease d. Tetany
10. A pregnant female delivers a baby who suffers from stunted growth, mental retardation, low intelligence quotient and abnormal skin. This is the result of
    a. Low secretion of growth hormone
    b. Cancer of the thyroid gland
    c. Over secretion of pars distalis
    d. Deficiency of iodine in diet.
11. The structure which connects the hypothalamus with anterior lobe of pituitary gland is the
    a. Dendrites of neuro hypophysis

b. Axons of neurohypophysis
c. Bands of white fibers from cerebellar region
d. Hypophysial portal system

12. Comment on homeostasis.
13. Which one of the following statement is correct
    a. Calcitonin and thymosin are thyroid hormones
    b. Pepsin and prolactin are secreted in stomach
    c. Secretin and rhodopsin are polypeptide hormones
    d. Cortisol and aldosterone are steroid hormones
14. which of the given option shows all wrong statements for thyroid gland

    Statements

    (i) It inhibits process of RBC formation
    (ii) It helps in maintenance of water and electrolytes
    (iii) Its more secretion can reduce blood pressure
    (iv) It stimulates osteoblast

    (a) (i) and (ii) (b) (iii) and (iv)
    (c) (i) and (iv) (d) (i) and (iii)
15. Hormones are known as chemical messenger. Justify.
16. Write the role of oestrogen in ovulation.
17. Comment on Acini of thyroid gland.
18. Write the causes for diabetes mellitus and diabetes insipidus.
19. Specify the symptoms of acromegaly
20. Write the symptoms of cretinism.
21. Briefly explain the structure of thyroid gland.
22. Name the layers of adrenal cortex and mention their secretions.
23. Differentiate hyperglycemia from hypoglycemia.
24 Write the functions of (CCK) cholecystokinin.
25. Growth hormone is important for normal growth. Justify the statement.
26. Pineal gland is an endocrine gland, write its role.
27. Comment on the functions of adrenalin.
28. Predict the effects of removal of pancreas from the human body.
29. Enumerate the role of kidney as an endocrine gland.
30. Write a detailed account of gastro intestinal tract hormones.

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UNIT V

Chapter 12

Trends in Economic Zoology

Chapter Outline

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Give a man a fish and you feed him for a day;
teach a man to fish and you feed him for a lifetime.

Learning Objectives:

- *Creating awareness on self employment opportunities in various fields*
- *Understands the economic importance of earthworm, honeybee, lac insect, silk worm, fish, cattle and birds*
- *Knows the techniques and tools required for various culture methods*
- *Learns to manage the culture practices*

Zoology is a branch of science which deals with the study of animals. For someone who is interested in pursuing a career in Zoology, there are several specializations that the students can venture into. There are physiologists, who study the metabolic processes of animals; there are taxonomists who deal with the naming and the classification of animal species; embryologist whose job is to study and focus on the early developmental stages of animal life. **Zoology as a career** as a number of specializations and students are presented with a plethora of career options once they chose to be associated with this field. This field is concerned with the preservation and management of animal kingdom and a career in it would mean that you are a part of that responsibility. A zoologist shall get avenues across the world. Channels like National Geographic, Animal Planet, and Discovery Channel are in constant need of Zoologists for research and documentaries. Zoologists are also hired for zoos, wildlife services, botanical gardens, conservation organizations, national parks, nature reserves, universities, laboratories, aquariums, animal clinics, fisheries and aquaculture, museums, research, pharmaceutical companies, veterinary hospitals, etc.

If you want to be an entrepreneur you have to learn the methods of culturing

farm animals and their importance, since farm animals possess great economic value. Since prehistoric time human beings taken maximum advantage from animals by keeping them under their control through domestication. The economic success of the industries, based on animals and their products, depends on the proper production, management and development of the next generation of farm animals.

12.1 Scope of Zoology

Studying Zoology can provide self employment opportunities and you can become an entrepreneur. Economic Zoology is a branch of science that deals with economically useful animals. It involves the study of application of animals for human welfare. The need of Zoology is not just to improve our economic condition but also to provide food security and provide employment opportunities. Based on the economic importance, animals can be categorized as:

1. Animals for food and food products
2. Economically beneficial animals
3. Animals of aesthetic importance
4. Animals for scientific research.

12.2 Vermiculture

Vermiculture is the process of using earthworms to decompose organic food waste, into a nutrient-rich material capable of supplying necessary nutrients which helps to sustain plant growth. The aim is to continually increase the number of worms to have a sustainable harvest. The excess worms can either be used to expand a vermicomposting operation or sold to customers. Vermicompost is the primary goal of vermiculture. Technically, the worm castings are pure worm waste and are fine and nutrient rich organic soil amendment. Vermicompost on the other hand, is comprised of the castings, bits of bedding and other organic matter. Essentially, though the terms are used interchangeably, they are both worm manure and are valuable for improving soil health. Applications of earthworm in technology of composting and bioremediation of soils and other activities is called Vermitech (Sultan Ismail, 1992).

The disposal of solid wastes (bio-degradable and non- biodegradable) remains a serious challenge in most of the countries. Earthworms play a vital role in maintaining soil fertility; hence these worms are called as **"farmer's friends"**. These are also called as **"biological indicators of soil fertility"**. The reason is that they support bacteria, fungi, protozoans and a host of other organisms which are essential for sustaining a healthy soil. The breakdown of organic matter by the activity of the earthworms and its elimination from its body is called vermicast. It is a finely divided granular material and is noted for its porosity, aeration, drainage and moisture holding capacity and serves as rich organic manure.

Earthworms are divided into two major groups. The first group, the humus formers, dwell on the surface and feed on organic matter. They are generally darker in colour. These worms are used for vermicomposting. The second group, the humus feeders, are burrowing worms that are useful in making the soil porous, and

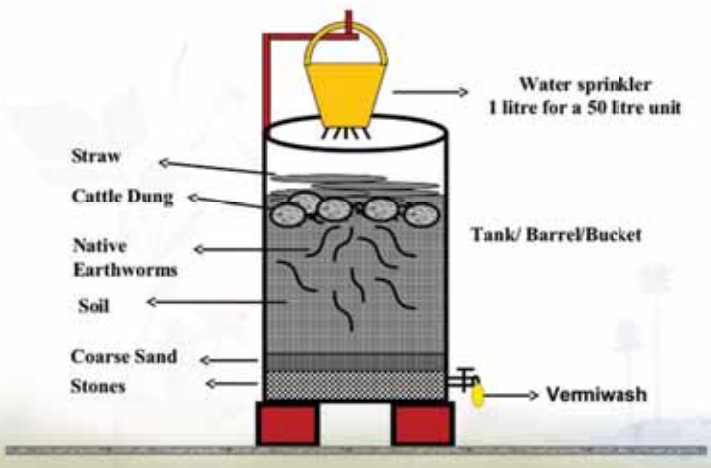
Without the work of this humble creature, who knows nothing of the benefits he confers upon mankind, agriculture, as we know it, would be very difficult, if not wholly impossible.

Charles Darwin

Worms are the intestines of the earth.

Aristotle

Earthworm is farmer's best friend
Earthworms are capable of moving 6 tonnes of soil up and down in a year. This is equivalent to 100 litres of fossil fuel.



mixing and distributing humus through out the soil. There are different **endemic** (native) species of earthworms cultured in India for vermicomposting such as *Periyonyx excavatus, Lampito mauritii, Octochaetona serrata.* Some earthworm species have been introduced from other countries and called as **exotic species** Eg. *Eisenia fetida, Eudrilus eugeniae.*

Vermicomposting

Vermicompost is the compost produced by the action of earthworms in association with all other organisms in the compost unit. Vermicompost bed may be selected on upland or an elevated level as it prevents the stagnation of water. You may construct a cement pit of 3x2x1m size (LxWxD) over ground surface using bricks. The size of pit may vary as per availability of raw materials. Cement pot or well rings are practically good. Provision should be made for excess water to drain. The vermibed should not be exposed to direct sunlight and hence shade may be provided (Figure. 12.1). The first layer of vermibed contains gravel at about 5 cm in height, followed by coarse sand to a thickness of 3.5 cm, which will facilitate the drainage of excess water.

Earthworms collected from native soil prefer a layer of local soil in their compost beds. If local soil earthworms are used, add a layer of native loamy soil for about 15 cm on top of the gravel sand layer and introduce earthworms into it. For exotic species such as *Eisenia fetida* and *Eudrilus eugeniae,* the layer of soil is not needed. The unit can now be loaded with digested biomass or animal dung such as cow dung that has lost its heat. The number of earthworms to be introduced in an unit depends on the size of the vermibed prepared. Earthworms such as *Periyonyx. excavatus, Eisenia fetida* or *Eudrilus eugeniae* are introduced on the top. Jute bags or cardboards or broad leaves are used to cover the unit. As worms require moisture, water management is most important for the survival of the earthworms. Too little or too much of water is not good for the worms.

Earthworms release their castings on the surface. One can start harvesting this from the surface on noticing the castings on the surface. It may take several days for the entire biomass to be composted depending on the amount of biomass.

Figure 12.1 Vermiculture unit and Earthworms

When all the compost is harvested, earthworms can be handpicked by creating small conical heaps of harvested compost and leaving in sunlight for a few hours. The earthworms then move down and settle at the bottom of the heap as a cluster. Earthworms from the lower layers of the compost can be recovered and the worms can be transferred to new composting units.

Vermiwash is a liquid collected after the passage of water through a column of vermibed. It is useful as a foliar spray to enhance plant growth and yield. It is obtained from the burrows or **drilospheres** formed by earthworms. Nutrients, plant growth promoter substances and some useful microorganisms are present in vermiwash.

Earthworm Pests and Diseases

Earthworms are subjected to attack by a variety of pests. Most outbreaks are the result of poor bed management. Earthworm enemies include ants, springtails, centipedes, slugs, mites, certain beetle larvae, birds, rats, snakes, mice, toads, and other insects or animals which feed on worms. The earthworm has a number of internal parasites including numerous protozoa, some nematodes, and the larvae of certain flies. Larger predators can be excluded from worm beds by proper construction of the bins, and by use of screens or gratings at the bottom and top of the beds.

My vermicompost manufacturing unit is plagued by a number of red ants. Are there any bio-friendly measures to tackle the menace as I do not want to use any chemicals?

Advantages of Using Vermicompost

People are aware about benefits of organic inputs in farming. Vermicompost is excellent organic manure for sustainable agro-practices. So, marketing vermicompost is now a potential and flourishing industry. Retail marketing of vermicompost in urban areas is most promising. Vermicompost is neatly packed in designed and printed packets for sale. People of different age groups are involved in the production and selling of vermicompost. Marketing of vermicompost can provide a supplementary income.

i. Vermicompost is rich in essential plant nutrients.
ii. It improves soil structure texture, aeration, and water holding capacity and prevents soil erosion
iii. Vermicompost is a rich in nutrients and an eco-friendly amendment to soil for farming and terrace gardening.
iv. It enhances seed germination and ensures good plant growth

12. 3 Sericulture

Silk is Nature's gift to mankind and a commercial fiber of animal origin other than wool. Being eco-friendly, biodegradable and self-sustaining material; silk has assumed special relevance in present age. Sericulture is an agro –based industry, the term which denotes commercial production of silk through silkworm rearing. Historical evidence reveals that sericulture was

practiced in China long back and they preserved the secret for more than 3000 years and maintained monopoly in silk trade with the rest of the world. According to Western historians, mulberry cultivation spread to India about 140BC from China through Tibet. The fabulous silk from China and India were carried to European countries. The 7000 mile lengthy road, historically called the "**Silk road**" passing through Baghdad, Tashkent, Damascus and Istanbul was used for silk transport. Today more than 29 countries in the world are practicing sericulture and producing different kinds of silk. India stands second in silk production next to China.

Production of silk from the silk worm, by rearing practices on a commercial scale is called sericulture. It is an agro-based industry comprising three main components: i) cultivation of food plants for the silkworms, ii) rearing of silkworms, and iii) reeling and spinning of silk. The first two are agricultural and the last one is an industrial component. Only few species of silkworms are used in the sericulture industry (Table 12. 1 and Figure 12. 2).

Life cycle of *Bombyx mori*

The adult of *Bombyx mori* is about 2.5 cm in length and pale creamy white in colour. Due to heavy body and feeble wings, flight is not possible by the female moth. This moth is unisexual in nature and does not

Mulberry

Eri

Muga

Tassar

Figure 12.2 Different types of silkworms

Table 12.1 Different types of Silkworm

Species of silkmoth	Silk Producing States	Preferred Food (Leaves)	Type Of Silk
Bombyx mori	Karnataka, Andhra Pradesh and Tamil Nadu	Mulberry	Mulberry Silk
Antheraea assamensis	Assam, Meghalaya. Nagaland, Arunachala Pradesh and Manipur	Champa	Muga Silk
Antheraea mylitta	West Bengal, Bihar and Jharkand	Arjun	Tassar Silk
Attacus ricini	Assam, Meghalaya. Nagaland, Arunachala Pradesh and Manipur	Castor	Eri Silk

feed during its very short life period of 2-3 days. Just after emergence, male moth copulates with female for about 2-3 hours and if not separated, they may die after few hours of copulating with female. Just after copulation, female starts egg laying which is completed in1-24 hours. A single female moth lays 400 to 500 eggs depending upon the climatic conditions. Two types of eggs are generally found namely diapause type and non-diapause type. The diapause type is laid by silkworms inhabiting the temperate regions, whereas silkworms belonging to subtropical regions like India lay non-diapause type of eggs. The eggs after ten days of incubation hatch into larva called as caterpillar. The newly hatched caterpillar is about 3 mm in length and is pale, yellowish-white in colour. The caterpillars are provided with well developed mandibulate type of mouth-parts adapted to feed easily on the mulberry leaves.

After 1st, 2nd, 3rd and 4th moultings caterpillars get transformed into 2nd, 3rd, 4th and 5th instars respectively (Figure12.3). It takes about 21 to 25 days after hatching. The fully grown caterpillar is 7.5 cm in length. It develops salivary glands, stops feeding and undergoes pupation. The caterpillars stop feeding and move towards the corner among the leaves and secretes a sticky fluid through their silk gland. The secreted fluid comes out through spinneret (a narrow pore situated on the hypopharynx) and takes the form of long fine thread of silk which hardens on exposure to air and is wrapped around the body of caterpillar in the forms of a covering called as cocoon. It is the white coloured bed of the pupa whose outer threads are irregular while the inner threads are regular. The length of continuous thread secreted by a caterpillar for the formation of cocoon is about 1000-1200 metres which requires 3 days to complete. The pupal period lasts for 10 to 12 days and the pupae cut through the cocoon and emerge into adult moth.

On the basis of the moults which they undergo during their larval life, *B. mori*

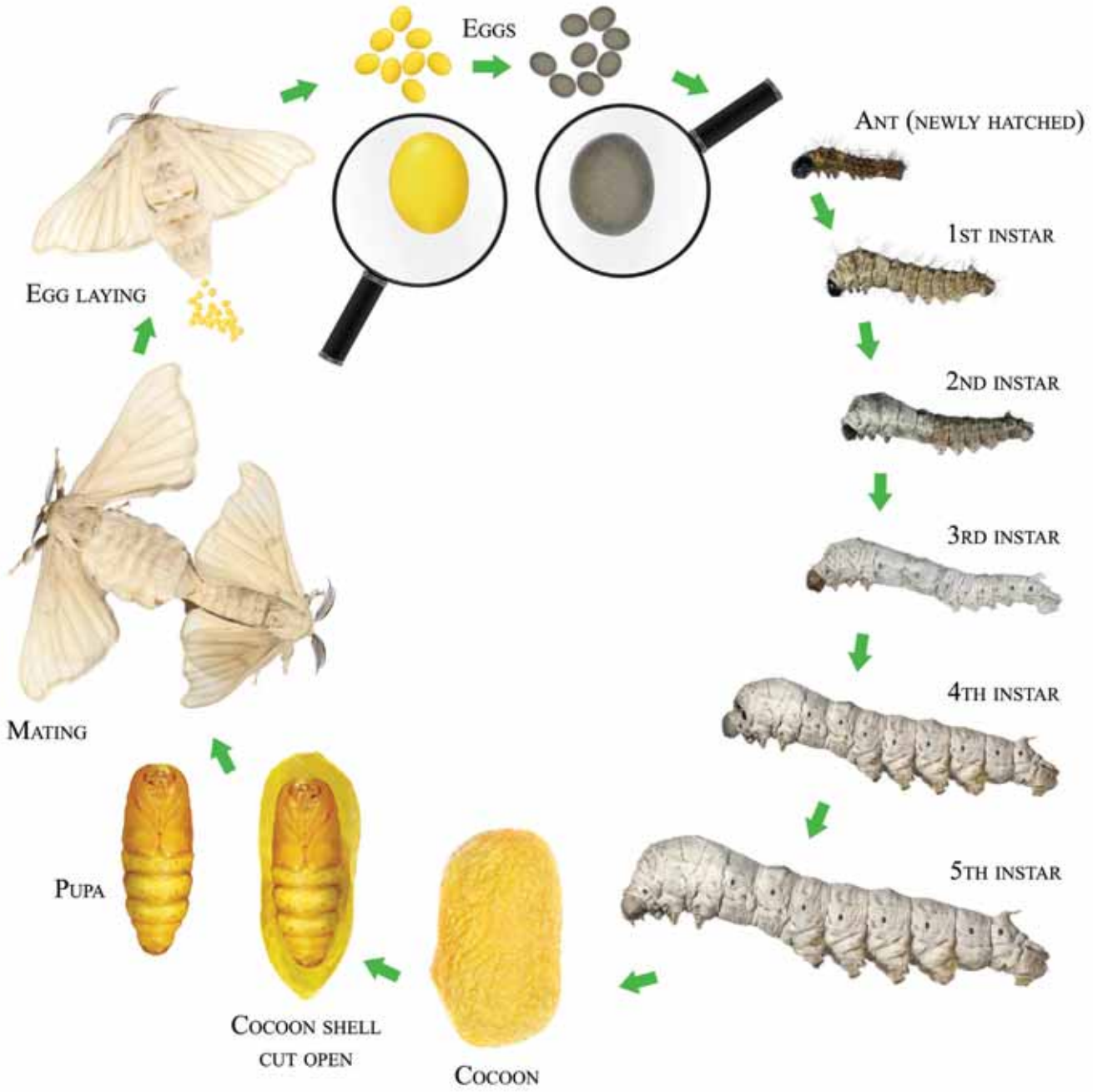


Figure 12. 3 Life cycle of *Bombyx mori*

is divided into three races – tri-moulters, tetra-moulters and penta-moulters. Based on voltinism (the number of broods raised per year), three kinds of races are recognized in mulberry silkworm – univoltines (one brood only), bivoltines (two broods only) and multivoltines (more than two broods).

India has the distinction of producing all the four types of silk i.e. (a) Mulberry silk (91.7%); (b) Tasar silk (1.4%); (c) Eri silk (6.4%); and (d) Muga silk (0.5%) which are produced by different species of silkworms. Name the species that produces large amount and least amount of silk in India.

Cultivation of food plants for the silkworms

The first component, is to grow the food plants for the silkworms. Mulberry leaves are widely used as food for silkworm *Bombyx mori* and the cultivation of mulberry is called as **Moriculture**. Presently improved mulberry varieties like Victory1, S36, G2 and G4 which can withstand various agro - climatic and soil conditions are used for planting. The favourable season for cultivating of the mulberry plants is June, July, November and December. The mulberry crop production technology includes land preparation, preparation of cutting, planting techniques, maintenance of mulberry nursery, disease and pest management and uprooting for raising new mulberry gardens. Mulberry is also being grown as tree plant at an height of 123-152 cm with 20 x 20 cm or 25 x 25 cm spacing to harvest better silkworm cocoon crops.

Rearing of silkworms

The second component is the rearing of silkworm. A typical rearing house (6m x 4m x 3.5m) is constructed on an elevated place under shade to accommodate 100 dfls (disease free layings). Space of 1m should be provided surrounding the rearing house. Sufficient windows and ventilators should be provided for free circulation of air inside the rearing house. The windows and ventilators should be covered with nylon net to restrict the entry of uzi flies and other insects. Apart from the specified area of the rearing house; the following appliances such as hygrometer, power sprayers, rearing stands, foam pads, wax coated paraffin papers, nylon nets, baskets for keeping leaves, gunny bags, rotary or bamboo mountages and drier are needed for effective rearing of silkworms. The steps involved in rearing process of silkworm are disinfection of rearing house, incubation of eggs, brushing, young larval rearing and late age larval rearing.

The selected healthy silk moths are allowed to mate for 4 hours. Female moth is then kept in a dark plastic bed, it lays about 400 eggs in 24 hours; the female is taken out, crushed and examined for any disease, only certified disease-free eggs are reared for industrial purpose. The eggs are incubated in an incubator. The small larvae (caterpillars) hatch between 7-10 days. These larvae are kept in trays inside a rearing house at a temperature of about 20°C - 25°C. These are first fed on chopped mulberry leaves. After 4-5 days fresh leaves are provided. As the larvae grow, they are transferred to fresh leaves on clean trays, when fully grown they spin cocoons. Their maturity is achieved in about 45 days. At this stage the salivary glands (silk glands) starts secreting silk to spin cocoons.

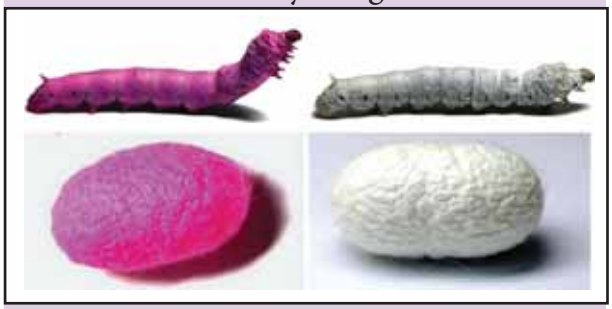
Post cocoon processing

The method of obtaining silk thread from the cocoon is known as post cocoon processing. This includes **stifling** and **reeling.**

The process of killing the cocoons is called stifling. The process of removing the threads from the killed cocoon is called reeling. For reeling silk the cocoons are gathered about 8 -10 days after spinning had begun. The cocoons are first treated by steam or dry heat to kill the insect inside. This is necessary to prevent the destruction of the continuous fibre by the emergence of the moth. The cocoons are

then soaked in hot water (95° -97°C) for 10-15 minutes to soften the gum that binds the silk threads together. This process is called cooking. The "cooked" cocoons are kept in hot water and the loose ends of the thread are caught by hand. Threads from several cocoons are wound together on spinning wheels (Charakhas) to form the reels of raw silk. Only about one-half of the silk of each cocoon is reelable, the remainder is used as a silk waste and formed into spun silk. Raw silk thus obtained is processed through several treatments to bring about the luster on the thread.

New silkworm diet produces coloured silk. The Institute of Materials Research and Engineering (IMRE) in Singapore has developed a way to replace the traditional dying process necessary to make coloured silk. A simple dietary change (feeding a diet of mulberries treated with fluorescent dye) for the silkworm larva and they are able to produce silk in a variety of colors. The colour directly integrated into the



Uses of Silk

1. Silk fibers are utilized in preparing silk clothes. Silk fibers are now combined with other natural or synthetic fibers to manufacture clothes like **Teri-Silk, Cot-Silk** etc. Silk is dyed and printed to prepare ornamented fabrics. They are generally made from Eri-silk or spun silk.
2. Silk is used in industries and for military purposes.
3. It is used in the manufacture of fishing fibers, parachutes, cartridge bags, insulation coils for telephone, wireless receivers, tyres of racing cars, filter fibres, in medical dressings and as suture materials.

Diseases and Pests of Silkworm:

The profitable silk industry is threatened by various diseases caused by the virus, fungal, bacterial and protozoan infections but also by insect predators, birds and other higher animals. Ants, crows, kites, rats, feed upon silk worms thereby causing a great loss to silk industry. Pebrine, is a dangerous disease to in silkworms and the causative organism is *Nosema bombycis* , a protozoan. This silkworm disease is transmitted through the egg of the mother silkworm and also through ingestion of contaminated food. Flacherie generally occurs in the mature larvae and is caused mainly by bacteria like *Streptococcus* and *Staphylococcus*. Grasserie is a most dominant and serious viral disease. It is caused by *Bombyx mori* nuclear polyhedrosis virus (BmNPV) a *Baculovirus*, which belongs to sub group 'A' of the Baculoviridae. Among the fungal diseases, white muscardine is common. This disease is caused by fungus *Beauveria bassiana*.

12.4 Apiculture

Ever since the beginning of civilization, man has been trying to make use of organisms around him for various purposes and to rear them for increasing their number. One of the finest discoveries is our knowledge regarding the procurement of honey collected by honey bees. Care and management of honey bees on a commercial scale for the production of honey is called **Apiculture** or **Bee Keeping**. The word 'apiculture' comes from the Latin word '*apis*' meaning bee. Bees are reared in apiaries that are areas where a lot of bee hives can be placed. There are five well recognized types of bees in the world. They are *Apis dorsata* (Rock bee), *Apis florea* (Little bee), *Apis indica* (Indian bee), *Apis mellifera* (European bee) and *Apis adamsoni* (African bee).

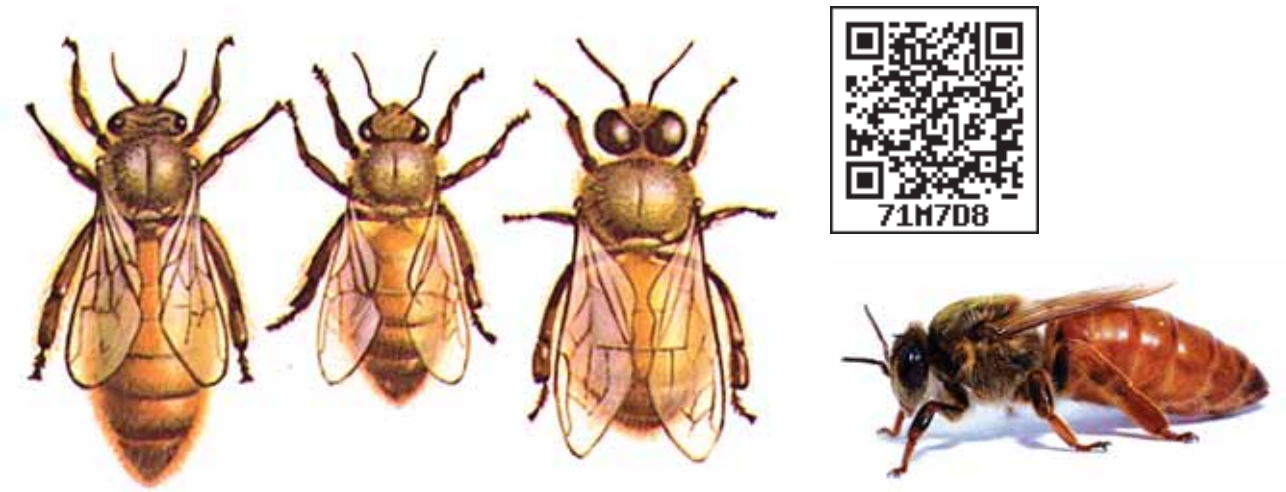
Social organization of honey bees

In honey bees, a highly organized division of labour is found. A well developed honey bee colony consists of the Queen, Drones and Workers (Figure 12.4). All the three types depend on each other for their existence. There is normally one queen, 10,000 to 30,000 workers and few hundred drones (male bees) in a colony.

Queen bee is a functional female bee present in each hive and feeds on Royal Jelly. Its sole function is to lay eggs throughout its life span. The virgin queen bee mates only once in her life. During the breeding season in winter, a unique flight takes place by the queen bee followed by several drones. This flight is called ***"nuptial flight".*** The queen bee produces a hormonal chemical substance called pheromone. The drones in the area are attracted to the pheromone and mating takes place. During mating, the drone releases large number of sperms for sufficient fertilization. In a life span of two to four years, a queen bee lays about 15 lakh eggs. When the queen bee loses its capacity to lay eggs, another worker bee starts feeding on the Royal Jelly and develops into a new queen.

Among the honey bees, **workers** are sterile females and smallest but yet function as the main spring of the complicated machinery in the colony. Worker bee lives in a chamber called 'Worker Cell' and it takes about 21 days to develop from the egg to adult and its lifespan is about six weeks. Each worker has to perform different types of work in her life time. During the first half of her life, she becomes a nurse bee attending to indoor duties such as secretion of royal jelly, prepares bee-bread to feed the larvae, feeds the queen, takes care of the queen

Honey bee uses its long-tube like tongue to extract sugary liquid called nectar from the flowers. The nectar is stored in the stomach and the enzyme *invertase* transforms it into honey. This increases the storage life of honey and also contributes to its medicinal value.



Queen Worker Drone Queen bee - Lateral view

Figure 12.4 Social organization of honey bees

and drones, secretes bees wax, builds combs, cleans and fans the bee hive.

Then she becomes a soldier and guards the bee hive. In the second half her life lasting for three weeks, she searches and gathers the pollen, nectar, propolis and water.

The **drone** is the functional male member of the colony which develops from an unfertilized egg. It lives in a chamber called drone cell. Drones totally depend on workers for honey. The sole duty of the drone is to fertilize the virgin queen hence called "King of the colony". During swarming (the process of leaving the colony by the queen with a large group of worker bees to form a new colony) the drones follows the queen, copulates and dies after copulation.

Structure of a Bee Hive

The house of honey bee is termed as bee hive or comb. The hive consists of hexagonal cells made up of wax secreted by the abdomen of worker bees arranged in opposite rows on a common base. These hives are found hanging vertically from the rocks, building or branches of trees (Figure.12.4). The young stages of honey bees accommodate the lower and central cells of the hive called the **brood cells**. In *Apis dorsata*, the brood cells are of similar in size and shape but in other species, brood cells are of three types *viz*., queen cell for queens, worker cell for workers and drone cells for drones (Figure.12.5). The cells are intended for storage of honey and pollen in the upper portion of the comb whereas the lower portions are for brood rearing.

Methods of Bee keeping

The main objective is to get more and more quality honey. There are two methods used by apiculturists. They

Bees teach us a lesson to work with cooperation. Imagine the hardwork of the bees! A single honey bee travels about double the distance of the circumference of the earth's globe for preparing 453.5ml of honey.

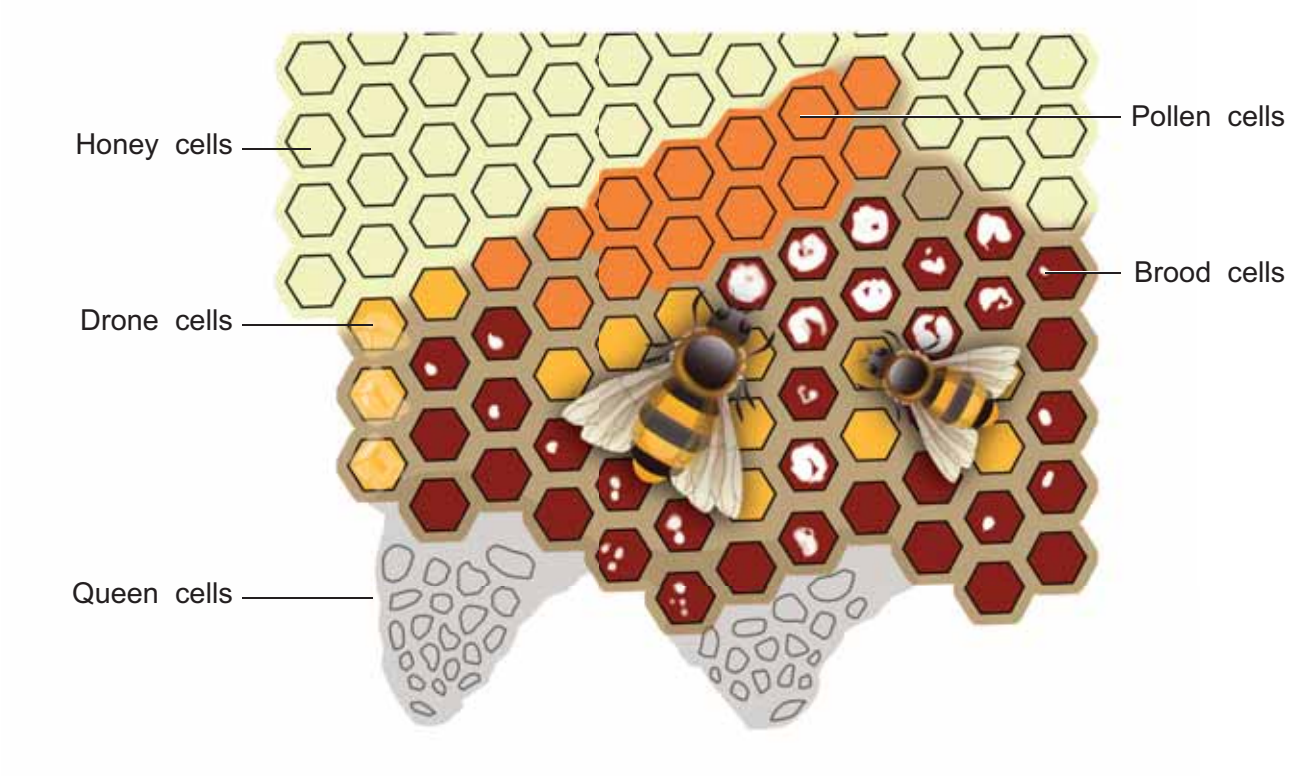


Figure 12.5 Structure of a hive showing various cells

are indigenous method and the modern method. In indigenous method, the honey extracted from the comb contains wax. To overcome the drawbacks of the indigenous method, the modern method has been developed to improve the texture of hives. In India, there are two types of beehives in practice namely, **Langstroth** and **Newton.** The Langstroth bee hive is made up of wood and consists of six parts (Figure 12.6) 1) **Stand** is the basal part of the hive on which the hive is constructed. The stands are adjusted to make a slope for rain water to drain 2) **Bottom board** is situated above the stand and forms the proper base for the hive. It has two gates, one gate functions as an entrance while the other acts as an exit. 3) **Brood chamber** is the most important part of the hive. It is provided with 5 to 10 frames arranged one above the other through which the workers can easily pass. The frame is composed of wax sheet which is held in vertical position up by a couple of wires. Every sheet of wax is known as Comb Foundation. The comb foundation helps in obtaining a regular strong worker brood cell comb which can be used repeatedly. 4) **Super** is also a chamber without cover and base. It is provided with many frames containing comb foundation to provide additional space for expansion of the hive. 5) **Inner cover** is a wooden piece used for covering the super with many holes for proper ventilation. 6) **Top cover** is meant for protecting the colonies from rains. It is covered with a sheet which is plain and sloping.

Besides the above primary equipments, other accessory equipments are used in beekeeping **Queen Excluder** is utilized to prevent the entry of queen

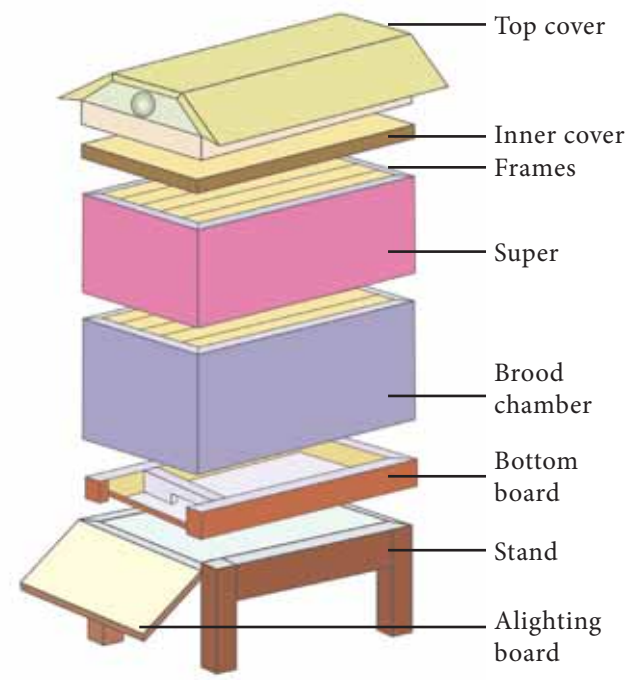


Figure 12.6 - Langstroth bee hive

bee from the brood chamber into the super chamber. **Comb foundation** is a sheet of bee wax, on both sides of which the exact shape of different cells of the comb is made in advance. **Bee gloves** are used by bee keepers for protecting their hands while inspecting the hives. **Bee veil** is a device made of fine nettings to protect the bee-keeper from bee sting. **Smoker** is used to scare the bees during hive maintenance and honey collection by releasing smoke. **Hive Tool** is a flat, narrow and long piece of iron which helps in scraping excess propolis or wax from hive parts. **Uncapping knife** is a long knife which helps in removing the cap from the combs as a first step in honey extraction. **Bee brush** is a large brush often employed to brush off bees from honey combs particularly at the time of extraction. **Queen introducing cage** is a pipe made of wire nets used for keeping the queen for about 24 hours for acquaintance with the hive and worker bees. **Feeder** is a basin with sugar syrup covered by grass to feed the bees during drought season. The grass prevents the bees from sinking into the syrup. **Honey Extractor** is a stainless-steel device which spins the combs rapidly to extract honey. **Hive Entrance Guard** is a device similar to queen excluder in front of the hive entrance which prevents the escape of queen during warming season.

Products of bee keeping and their economic importance

The chief products of bee keeping industry are honey and bee wax.

Honey is the healthier substitute for sugar. The major constituents of honey are: levulose, dextrose, maltose, other sugars, enzymes, pigments, ash and water. It is an aromatic sweet material derived from nectar of plants. It is a natural food, the smell and taste depends upon the pollen taken by the honey bee. It is used as an antiseptic, laxative and as a sedative. It is generally used in Ayurvedic and Unani systems of medicine. It is also used in the preparation of cakes, breads and biscuits

Bee wax is secreted by the abdomen of the worker bees at the age of two weeks. The wax is masticated and mixed with the secretions of the cephalic glands to convert it into a plastic resinous substance. The resinous chemical substance present in the wax is called **propolis** which is derived from pollen grains. The pure wax is white in colour and the yellow colour is due to the presence of carotenoid pigments. It is used for making candles, water proofing materials, polishes for floors, furniture, appliances, leather and taps. It is also used for the production of

comb foundation sheets in bee keeping and used in pharmaceutical industries.

12.5 Lac Culture

The culture of lac insect using techniques for the procurement of lac on large scale is known as Lac culture. Lac is produced by the lac insect *Tachardia lacca* previously known as *Laccifer lacca*. It is a minute, resinous crawling scale insect which inserts its probosics into the plant tissues and sucks juice, grows and secretes lac from the hind end of the body as a protective covering for its body. Moreover the insect is a parasite on host plants i.e., Karanagalli (*Acacia catechu*), Karuvelai (*Acacia nilotica*) and Kumbadiri (*Schleichera oleosa*). The quality of lac depends upon the quality of the host plant. The female lac insect is responsible for large scale production of lac, which is larger than the male lac insect.

After copulation, the male insect dies. The female develops very rapidly after fertilization and lays about 200 to 500 eggs (Figure. 12. 7). Eggs hatch into larvae after six weeks. The mass emergence of larvae from the egg in search of a host plant is called **'swarming'**. After settling on the host, the larvae start feeding continuously and the secretion of lac also starts simultaneously. Gradually the larvae become fully covered by lac. Then the larvae moult in their respective cells (chamber). The shapes of the cells are different for male and female insects, males are elongated whereas and the female are oval. Some insects are natural

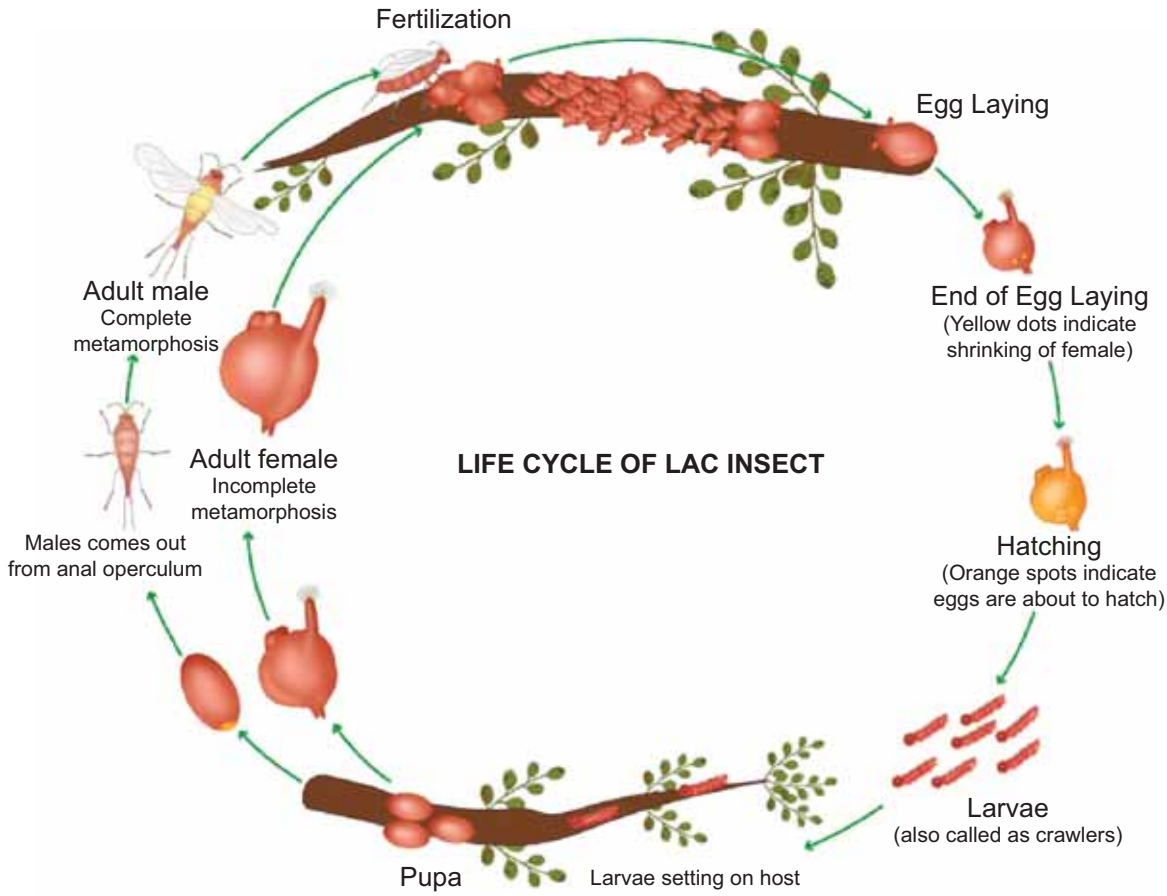


Figure 12. 7 – Life cycle of lac insect

predators of lac insects. The caterpillars of these parasites feed upon lac insects showing hyper-parasitism.

Hyperparasitism - A condition in which a secondary parasite develops within a previously existing parasite or a hyperparasite is the parasite whose host is also a parasite.

Lac cultivation is a complicated process, so the cultivators should know well about the inoculation, swarming period and harvesting of lac. The process of introducing lac insect on the host plant is called inoculation. Before inoculation, pruning of the host plant is done. The twigs having brood lac, i.e., lac insect about 20 cm in length are attached to fresh host plants. The lac insect then repeats its life cycle. The collection of lac from the host plant is known as harvesting. Harvesting may be done before swarming (immature) or after swarming (mature). Immature harvesting produces 'Ari lac' whereas mature harvesting produces the mature lac. Lac cut from the host plant is called 'Stick lac'. The lac present on the twig is scraped and collected. After grinding, the unnecessary materials like dusts and fine particles are removed. The resultant lac is called 'seed lac'. The seed lac is sun dried and then melted to produce 'shellac'.

Economic importance of Lac

a. Lac is largely used as a sealing wax and adhesive for optical instruments. It is used in electric industry, as it is a good insulator.
b. It is used in preparations of shoe and leather polishes and as a protective coating of wood.
c. It is used in laminating paper board, photographs, engraved materials and plastic moulded articles.
d. Used as a filling material for gold ornaments

12.6 Aquaponics

Aquaponics is a technique which is a combination of aquaculture (growing fish) and hydroponics (growing plants in non-soil media and nutrient-laden water). Aquaponics may also prevent toxic water runoff. It also maintains ecosystem balance by recycling the waste and excretory products produced by the fish. In India, aquaponics was started in 2013. Some primary methods of aquaponic gardening that are in use nowadays are as follows: (i) **Deep water culture** is otherwise known as raft based method. In this method a raft floats in water. Plants are kept in the holes of raft and the roots float in water. This method is applicable for larger commercial scale system. By this method fast growing plants are cultivated. (ii) **Media based method** involves growing plants in inert planting media like clay pellets or shales. This method is applicable for home and hobby scale system. Larger number of fruiting plants, leafy green plants, herbs and other varieties of plants can be cultivated (Figure 12. 8) (iii) **Nutrient Film technique** involves the passage of nutrient rich water through a narrow trough or PVC pipe. Plants are kept in the holes of the pipe to allow the roots to be in free contact with in the water stream. (iv) **Aqua vertica** is otherwise known as vertical aquaponics. Plants are stacked on

the top of each other in tower systems. Water flows in through the top of the tower. This method is suitable for growing leafy greens,

a. Growing fish or other aquatic animals and plants together in an integrated system. The fish wastes provides nutrients for the plants and the plants filter the water. Additionally bacteria break down by-products such as ammonia.

b. Growing plants in a nutrient solution instead of soil. Fish kept in the water provide the required nutrients.

Write the appropriate scientific terms for above (a) and (b) and differentiate between them..

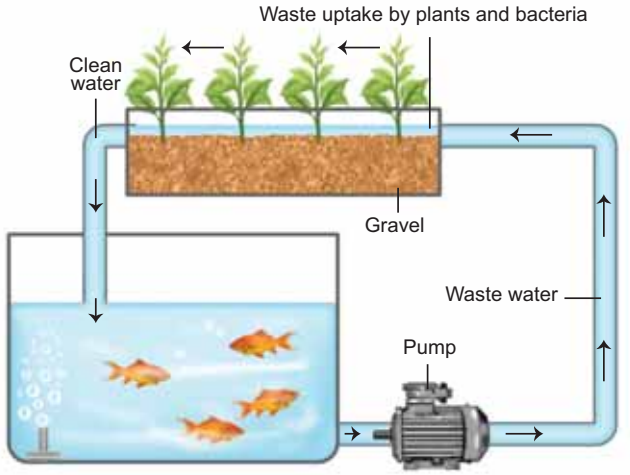
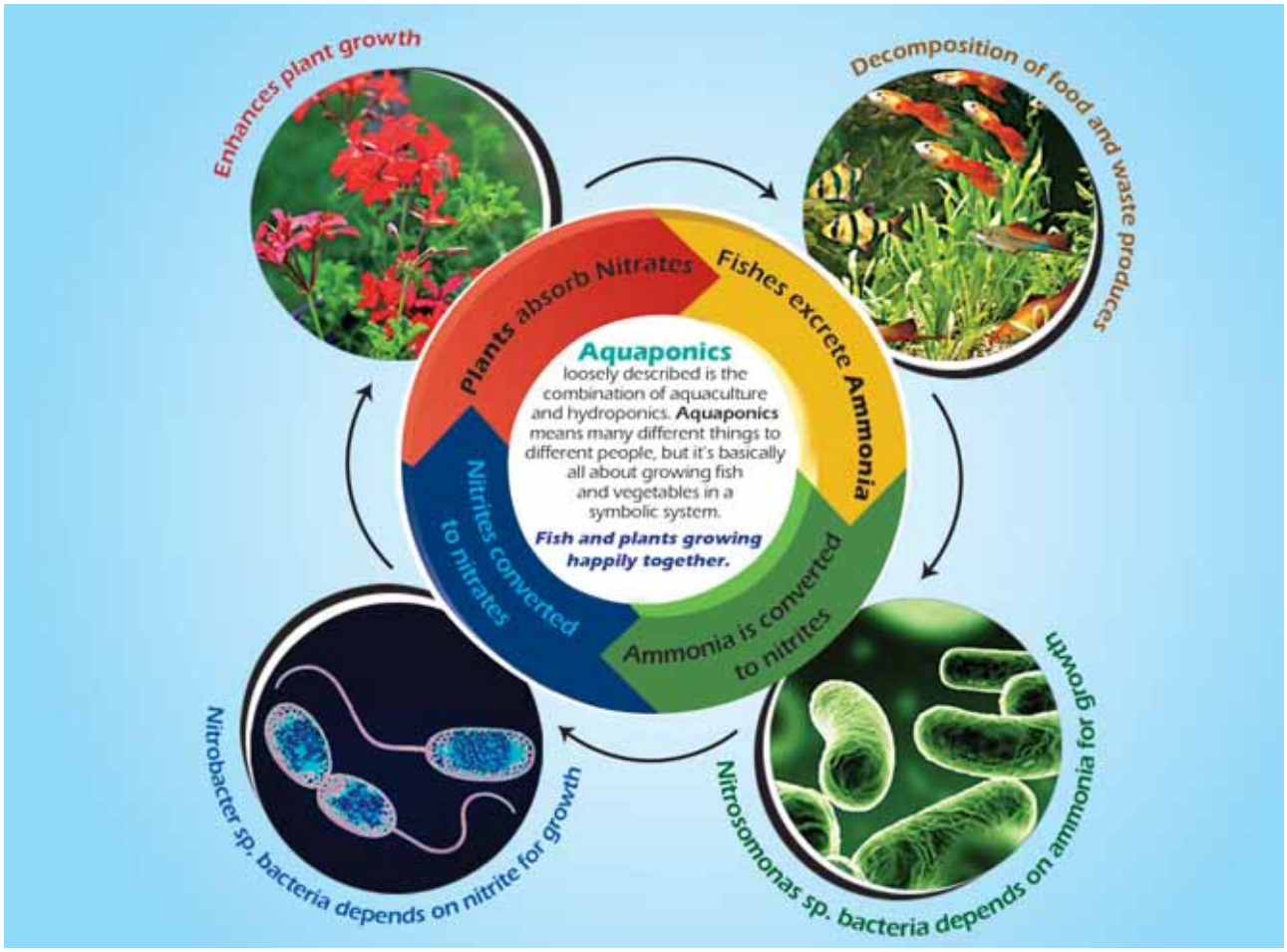


Figure12. 8 Aquaponics – Media based method

strawberries and other crops that do not need supporting solid substratum to grow.

Advantages of Aquaponic gardening

Water conservation: No need of water discharge and recharge as the water is maintained by recycling process.



Soil: Bottom soil may be loaded with freshwater. Microbes in water can convert the waste materials into usable forms like ammonia into nitrates which are used by the plants. Thus the soil fertility is maintained

Pesticides: In this system use of pesticides is avoided and hence it is eco-friendly.

Weeds: Since the plants are cultured in confined conditions, growth of weeds is completely absent. The utilization of nutrient by plants is high in this method

Artificial food for fishes: In this system plant waste and decays are utilized by fishes as food. So, the need for the use of supplementary feed can be minimized.

Fertilizer usage: Artificial or chemical fertilizers is not required for this system since the plants in the aquaponics utilize the nutrients from the fish wastes dissolved in water

Cultivable fishes like tilapia, trout, koi, gold fish, bass etc., are cultured in aquaponics. Common cultivable plants like tomato, pepper, lettuce, cucumber, and rose are co-cultivated in this method.

12.7 Aquaculture

Aquaculture has been practiced in varying forms for centuries dating to the time of the Phoenicians. India offers a huge potential for aquaculture development. Fish culture received notable attention in Tamil Nadu in 1911. Aquaculture is a branch of science that deals with the farming of aquatic organisms such as fish, molluscs, crustaceans and aquatic plants.

On the basis of source, aquaculture can be classified into three categories. They are (a) **Freshwater aquaculture** (b) **Brackish water aquaculture** (c) **Marine water aquaculture**. Culturing of fishes is called fish culture or pisciculture. Inland water bodies include freshwater bodies like rivers, canals, streams, lakes, flood plain wetlands, reservoirs, ponds, tanks and other derelict water bodies and ponds constructed for fresh water aquaculture. The pH of the freshwater should be around neutral and salinity below 5 ppt (parts per thousand).

Brackish water fishes spend most of its life in river mouths (estuaries) back waters, mangrove swamps and coastal lagoons. Estuarine fish are more common in Bengal and Kerala. Culturing of animals in the water having salinity range 0.5 – 30 ppt are called as brackish water culture. Fishes cultured in brackish water are Milk fish (*Chanos Chanos)*, Sea bass ('Koduva'), Grey mullet ('Madavai'), *Pearl spots ('Kari'meen)* etc,

Marine Fisheries deal with fishing operations along seacoasts. The Indian subcontinent approximately has a 5600 kms long coastline. About 80% of India's marine fish are supplied by the west coast and the remaining 20% by the east coast. The premier varieties are mackerels, sardines, sharks, and catfish. Marine edible fishes of Tamilnadu coast include both cartilaginous and bony fishes. Culturing of animals in the water salinity ranges from 30 - 35% is called Mariculture. Some fishes like *Chanos* sp, *Mugil cephalus* are cultured here. Culturing of animals in the salinity ranges from 36 - 40% is called Metahaline culture. Eg, Brine shrimp (*Artemia salina)*. Artemia is commonly known as the brine shrimp. It is a crustacean and

lives in high saline waters because of its high osmoregulatory capacity.

12.7.1 Fish culture

Characteristics of cultivable fishes

The special characteristic features of cultivable fishes are:

i. Fishes should have high growth rate in short period for culture.
ii. They should accept supplementary diet.
iii. They should be hardy enough to resist some common diseases and infection of parasites.
iv. Fishes proposed for polyculture should be able to live together without interfering or attacking other fishes.
v. They should have high conversion efficiency so that they can effectively utilize the food.

Types of cultivable fish

Cultivable fish are of 3 types(Figure 12. 9).

a. Indigenous or native fresh water fishes (Major carps, *Catla*, *Labeo*, *Clarias*)
b. Salt water fishes acclimatized for fresh water (*Chanos*, Mullet).
c. Exotic fishes or imported from other counties (Common carps)

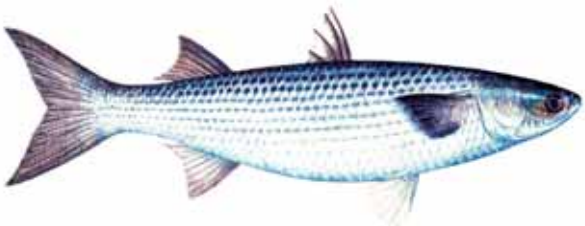
Among these, major carps have proved to be best suited for culture in India, because the carps

1. Feed on zooplanktons and phytoplanktons, decaying weeds, debris and other aquatic plants.
2. They can survive in turbid water with slightly higher temperature
3. Can tolerate O_2 variations in water.
4. Can be transported from one place to other easily.
5. They are highly nutritive and palatable.

External factors affecting fish culture

The factors that affect fish culture are temperature, light rain, water, flood, water current, turbidity of water, pH hardness, salinity and dissolved O_2. Light and temperature also play an important role in fish breeding.

Catla



Mullet

Common carps

Figure 12. 9 Different types of freshwater cultivable fishes

Management of fish farm

To culture fish, one should have an idea about different stages of fish culture such as topographic situation, quality, source, physical, chemical and biological factors of water. Breeding, hatching, nursing, rearing and stocking fishes in ponds has to be managed properly. Keeping in view the various stages of fishes, the following different types of ponds have been recommended to manage them.

Breeding pond

The first step in fish culture is the breeding of fishes, therefore, for proper breeding special types of ponds are prepared called breeding ponds. These ponds are prepared near the rivers or other natural water resources.

Types of breeding

Depending on the mode of breeding, they are divided into

1. **Natural breeding** (Bund breeding)

These are special types of ponds where natural riverine conditions or any natural water resources are managed for breeding of culturable fishes. There bundhs are constructed in large low-lying areas that can accommodate large quantity of rain water. The shallow area of such bundhs is used as spawning ground.

2. **Induced breeding**

The fish seed is commonly collected from breeding grounds but does not guarantee that all fish seeds belong to the same species. Hence advanced techniques have been developed to improve the quality of fish seed by artificial method of fertilization and induced breeding. Artificial fertilization involves removal of ova and sperm from female and male by artificial mechanical process and the eggs are fertilized. For artificial fertilization the belly of mature female fish is held upward. Stripping is done with the thumb of the right hand from the anterior to posterior direction for the ejection of eggs due to force. In this way eggs are collected separately. Further, the male fish is caught with its belly downwards. The milt of fish is striped and collected separately, and then the eggs are fertilized.

Induced breeding is also done by hypophysation (removal of pituitary gland). The gonadotropin hormone (FSH and LH) secreted by the pituitary gland influences the maturation of gonads and spawning in fishes. Pituitary gland is removed from a healthy mature fish. Pituitary extract is prepared by homogenising in 0.3% saline or glycerine and centrifuged for 15 minutes at 8000rpm. The supernatant is injected intramuscularly at the base of the caudal fin or intra-peritonealy at the base of pectoral fin. Male and female fishes start to spawn (release of gametes) and eggs are fertilized. The fertilized eggs are removed from the spawning place and kept into hatching **hapas**.

Fish seed

Fish seed is collected from breeding ponds. The spawn collecting net is commonly called Benchijal (Shooting net) and transferred to the hatching pits

Hatching pit

The fertilized eggs are kept in hatching pits. The hatching pits should be nearer to the breeding grounds, should be smaller in size with good quality water. There are two types of hatching pits, hatcheries are

Figure 12. 10 A fish pond-showing fish breeding hapas

small sized pond in which unfertilized eggs are transferred and hatching happens. Hatching hapas are rectangular trough shaped tanks made up of mosquito net cloth supported by bamboo poles and fixed in the river (Figure 12.10).

Nursery pond

The newly hatched fries are transported from the hatching happa to nursery ponds where they grow into fingerlings.

Rearing pond

Fingerlings are transferred to rearing ponds that is long and narrow and allows long distance swimming. The rearing pond should be free from toxicants and predators. Antibiotics are used for washing the fingerlings and then transferred to the stocking ponds.

Stocking ponds

Stocking ponds should be devoid of weeds and predatory fishes. Proper organic manuring should be done to increase the production with cow dung and chemical fertilizing should also be done.

Harvesting

Harvesting is done to capture the fishes from the water. Well grown fishes are taken out for marketing. Small sized fishes are again released into the stocking ponds for further growth. Different methods of fishing are carried out to harvest fishes. These include Stranding, Angling, Traps, Dipnets, Cast nets, Gill nets, Drag nets and purse nets. The harvested fishes are preserved by refrigeration, Deep freezing, freeze drying, sun drying, salting, smoking and canning.

Composite fish farming

Few selected fishes belonging to different species are stocked together in proper proportion in a pond. This mixed farming is termed composite fish farming or polyculture. The advantages include,

1. All available niches are fully utilized.
2. Compatible species do not harm each other.
3. No competition among different species is found.
4. *Catla catla, Labeo rohita* and *Cirrhinus mrigala* (surface feeder) are the commonly used fish species for composite fish farming.

Exotic fishes

The fishes imported into a country for fish culture are called exotic fishes and such fish culture is known as exotic fish culture. Examples of such exotic fishes introduced in India are *Cyprinus carpio* and *Oreochromis mossambicus*.

Disease Management

Diseases can be of viral or bacterial origin. Regular monitoring of parameters like water quality, aeration, regular feeding, observation for mortality should be checked. Parasitic infestations and microbial infections should be observed periodically.

Economic importance of fish

Fishes frrm a rich source of protein food and provide a good staple food to tide over the nutritional needs of man. Fish species such as sardines, mackerel, tuna, herrings have high amino acids concentrations particularly histidine which is responsible for the meaty flavor of the flesh. It is rich in fat such as omega 3 fatty acids. Minerals such as calcium, magnesium, phosphorus, potassium, iron, manganese, iodine and copper. Some of the fish by - products are;

Fish oil is the most important fish by product. It is derived from fish liver and from the fish body. Fish liver oil is derived from the liver which is rich in vitamin A and D, whereas fish body oil has high content of iodine, not suitable for human consumption, but is used in the manufacture of laundry soaps, paints and cosmetics.

Fish meal is prepared from fish waste after extracting oil from the fish. The dried wastes are used to prepare food for pig, poultry and cattle. The wastes obtained during the preparation of fish meal are widely used as manure.

Isinglass is a high-grade collagen produced from dried air bladder or swim bladder of certain fishes viz. catfish and carps. The processed bladder which is dissolved in hot water forms a gelatin having adhesive property. It is primarily used for clarification of wine, beer and vinegar.

Why are fish so efficient at converting feed to flesh?

12.7.2 Prawn Culture

Most important aquatic crustacean is prawn, which is widely cultured prawn flesh is palatable and rich in glycogen, protein with low fat content.

Types of prawn fishery

1. Shallow water prawn fishery – located on the west coast restricted to shallow waters.

2. Estuaries and back waters or saline lake prawn fishery - The area of production of prawns are the back waters seen along the Western coast, Ennur, Pulicat, Chilka lake and Estuaries of Ganga and Brahmaputra rivers.
3. Freshwater prawn fishery - Prawns are caught from the rivers and lakes throughout India.
4. Marine prawn fishery – Most of the marine prawns are caught along the Indian coast belonging to the family Penaeidae.

Species of prawn

A number of species of prawn are distributed in water resources such as *Penaeus indicus, Penaeus monodon, Metapenaeus dobsoni and Macrobrachium rosenbergii.*

Culture of freshwater prawn

Macrobrachium rosenbergii (Figure 12.11) is commonly seen in rivers, fields and low-saline estuaries. The prawn collected from ponds, river, and paddy fields are transferred to the tanks which are aerated. For fertilization, one pair of prawn are kept in a separate tank. After mating, the eggs are laid. Spawning tanks of different sizes should be prepared with proper aeration. Temperature (24^0 C – 30^0 C) and pH (7-8) should be maintained in the hatching tank. The eggs hatch into first and second stage larva. Artificial feed is supplied. Young ones of 5cm length (60 days old) can be reared in fresh or slightly brackish water ponds and rice fields. Harvesting of prawns can be done twice in a year.

Culture of marine prawn

Several factors that determine the success of marine prawn culture includes selection of site, water quality, soil quality and availability of seed.

Preparation of farm

For the preparation of ponds for algal growth and for the subsequent stocking of prawns it is essential to drain off the water and sundry the bottom followed by light tilling. Agricultural lime should be applied to absorb excess CO_2 and to supply calcium which is required for moulting. Fertilizers like rice, bran, poultry, and cattle dung are used to increase the fertility of the soil. Prawns are commonly caught in crafts and gears using different types of nets such as cast nets, bag nets, drag nets, trawl nets

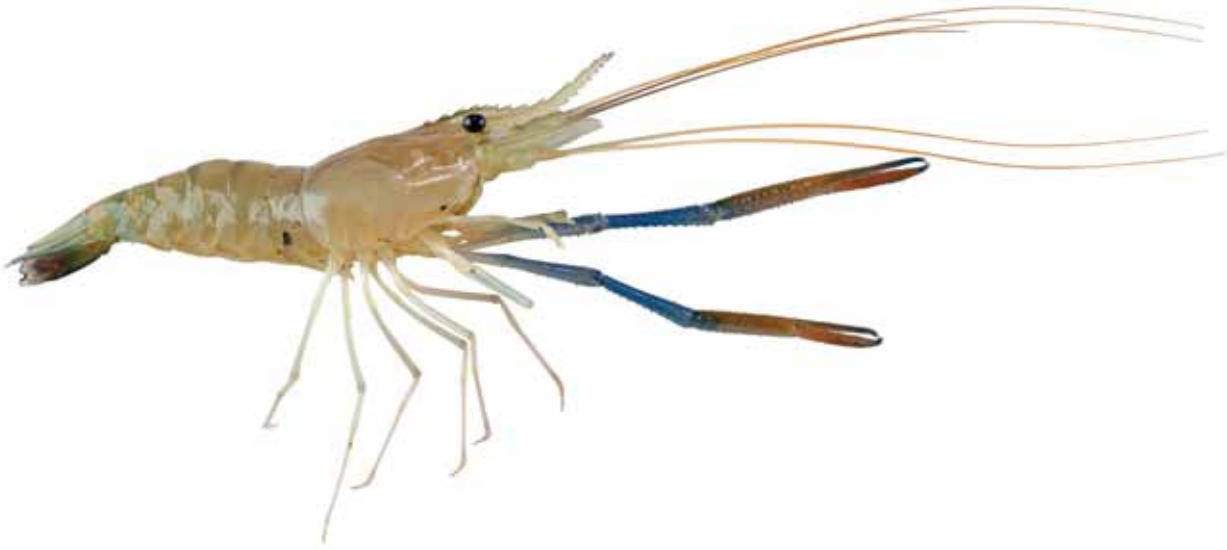


Figure 12. 11 *Macrobrachium rosenbergii*

and barrier nets. Preservation of prawns is done by peeling and deveining or by cooking and peeling.

12.7.3 Pearl Culture

Pearl is a white, highly shining globular concretion found within the shell of an Oyster. Pearl oysters are sedentary animals. In India it was cultured for the first time in 1973 at Thoothukudi. Pearl oysters are found along the coast of Kanyakumari and in the Gulf of Kutch. High quality pearls are obtained from pearl oysters of Genus *Pinctada* that can be cultured in the salinity range of 30 ppt in racks, raft and long line methods. Freshwater bivalve *Lamellidens* is also used in artificial pearl culture. Mostly the pearl oysters inhabit the ridges of rocks or dead corals, forming extensive pearl banks. These pearl beds produce best quality of pearls.

Pearl Formation

When a foreign particle accidently enters into the space between mantle and shell of the oyster, it adheres to the mantle. The mantle epithelium encloses it like a sac and starts to secrete concentric layers of nacre around it as a defensive mechanism. Nacre is secreted continuously by the epithelial layer of the mantle and is deposited around the foreign particle and over a period time

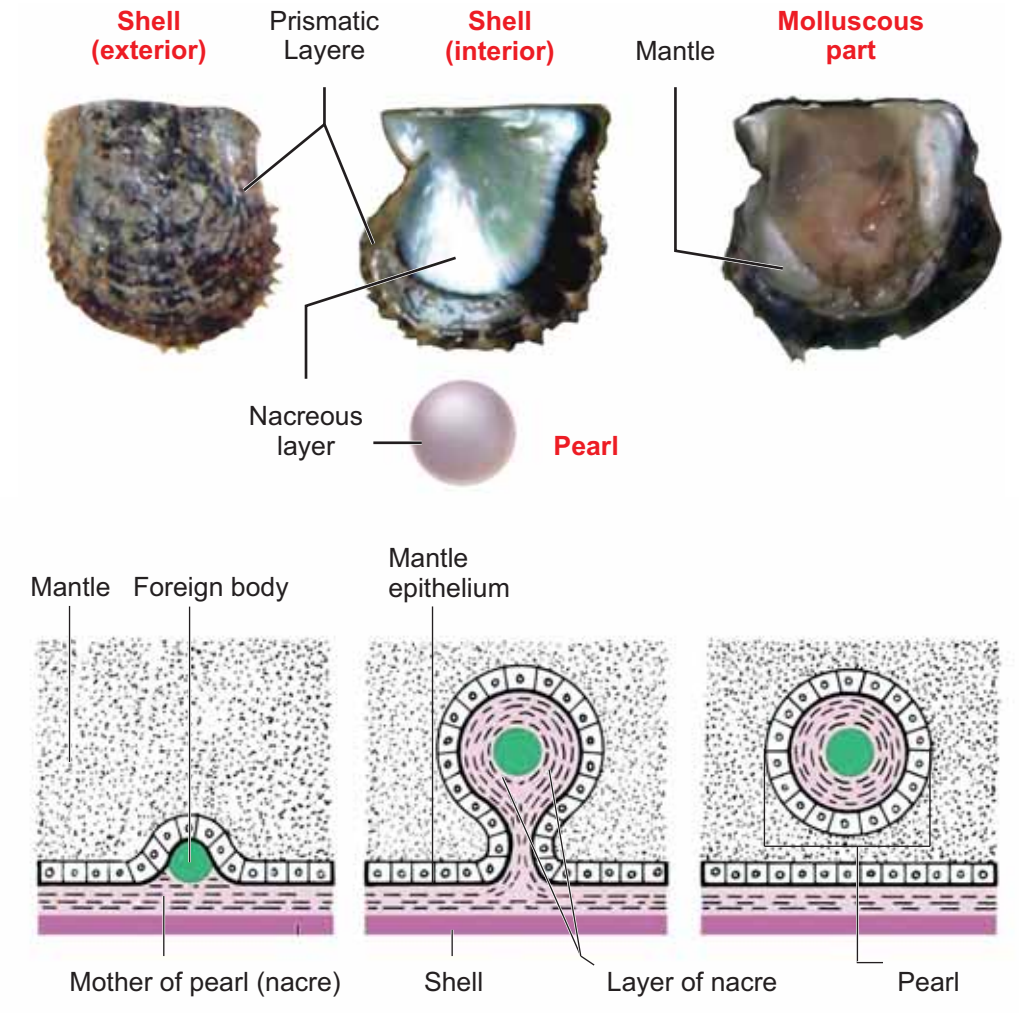


Figure 12. 12 Pearl and Pearl Formation

the formation of repeated layers of calcium carbonate makes the hard and glossy pearl. When the pearl enlarges the oyster dies. The shell is then carefully opened and the pearls are manually separated and graded (Figure 12. 12).

Programming of Pearl Industry and Artificial Insertion of Nucleus

This can be achieved by an artificial device to insert the nucleus as foreign particle in the shell of oyster has proved useful for the production of pearls in greater number.

i. Collection of oysters

Oysters are caught by special type of cages (84 x 54 x 20 cm) by covering a heavy wire frame with two centimeter wire mesh. This cage is dipped into a sand-cement mixture providing rough surface to the cages to which free swimming spat get easily stuck up. These cages are suspended at a depth of 6 meters. From July to November, where spats are easily available. These collected oysters are now transferred to rearing cages.

ii. Rearing of oysters

The collected oysters are stocked and reared in special type of cage called as rearing cage. These cages are well protected from enemies of oysters like Octopus, Eel, Devil fishes etc. The collected oysters are first cleaned and then placed into the culture cages for a period of about 10 to 20 days to recover from the strain due to excessive handling and for the physiological adjustment to the shallow water conditions.

iii. Insertion of nucleus

In this method, a piece of mantle of living oyster is cut off and inserted together with a suitable nucleus inside the living tissue of another oyster. Following steps are taken for the insertion of nucleus.

a. Fitness of oyster for operation

The selected oysters for the insertion of nucleus should be healthy and strong enough to overcome the stress during operation

b. Preparation of graft tissues

The piece of tissue which is inserted inside the mantle is called as 'GRAFT' tissue. The outer edges of these graft squares must be known because nacre secreting cells are found only on the outer surface of the mantle so it is essential to keep the outer surface in contact with the inserted nucleus.

c. Preparation of nucleus

Any small particle may function as nucleus to initiate the pearl formation but it is reported that calcareous nucleus is the best because the deposition of nacre was found to be more on calcarious nucleus.

d. Insertion of nucleus

For the insertion of nucleus, oysters are fixed in a desk clamp in the position of right valve facing upward. Mantle folds are smoothly touched to expose the foot and the main body mass, followed by an incision into the epithelium of the foot and a slender channel into the main mass one graft tissue which functions as a bed for the nucleus.

e. Post operation care

Nucleated oysters are placed into cages and suspended into sea water and attached with floating rafts to a depth of 2 to 3 metres for about 6 to 7

days to recover from the shocks due to operation. This period of 6 to 7 days is known as 'Recovery period'. About 3000 to 3600 nucleated oysters are kept in different cages suspended in sea water at 2 to 3 meters depth for 3 to 6 years and undisturbed except at the time of clearing and inspection.

iv. Harvesting of pearl

Pearls are harvested in the month of December to February which may slightly vary according to climatic conditions. After the completion of 3 years of the insertion of nucleus, pearl oysters are harvested from the sea and the pearls are taken out from the shell.

v. Clearing of pearls

After taking out the pearls from the oysters shell they are washed properly, cleared with the soap solution.

Composition of pearl

Pearl comprises of water, organic matter, calcium carbonate and the residue.

(1) Water: 2-4% (2) Organic matter: 3.5-5.9%

(3) Calcium carbonate: 90% (4) Residue: 0.1-0.8% carbonate: 90%

Quality of pearl

The pearls obtained are of variable shapes and sizes. They may be white, or cream red or pink red in colour. The spherical pearls of rainbow colour are rarely found. The best quality of pearl is obtained from marine oysters. Pearl obtained from freshwater bivalves are not as valuable as those obtained from the marine oysters (Mishra, 1961).

12.8 Animal Husbandry and Management

Animal husbandry is the practice of breeding and raising livestock cattles like cows, buffaloes, and goats and birds etc. that are useful to human beings. Parameters such as adequate ventilation, temperature, sufficient light, water and proper housing accommodation should be taken into account to maintain dairy and poultry farms. Animals should be cared and protected from diseases. Records should be maintained after the regular visits by Veterinarian. More over the selection of good breeds with high yielding potential combined and resistance to diseases is very important.

Animal Breeding

Human beings have been depending on animals and animal products for food from very early times. Generally high yielding animals produced by hybridization are reared in poultry and dairy farms. In earlier days, animals were produced and selected based on specific characters. With the gain in knowledge on the principles of heredity and genetics, human beings have been successful in rearing animals with the superior qualities through hybridization experiments. Complex issues are faced by the animal breeder during hybridization experiments. Hence animals with maximum desirable characters should be selected.

A group of animals related by descent and with similar characters like general appearance, features, size etc., are said to belong to a breed. Why should we breed

animals? Through animal breeding, improved breeds of animals can be produced by improving their genotype through selective breeding.

Objectives of Animal breeding:

a. To improve growth rate
b. Enhancing the production of milk, meat. Egg etc.,
c. Increasing the quality of the animal products
d. Improved resistance to diseases
e. Increased reproductive rate

Methods of Animal breeding:

There are two methods of animal breeding, namely inbreeding and outbreeding

1. Inbreeding: Breeding between animals of the same breed for 4-6 generations is called inbreeding. Inbreeding increases homozygosity and exposes the harmful recessive genes. Continuous inbreeding reduces fertility and even productivity, resulting in "inbreeding depression". This can be avoided by breeding selected animals of the breeding population and they should be mated with superior animals of the same breed but unrelated to the breeding population. It helps to restore fertility and yield.

2. Outbreeding: The breeding between unrelated animals is called outbreeding. Individuals produced do not have common ancestors for 4-6 generations. Outbreeding helps to produce new and favourable traits, to produce hybrids with superior qualities and helps to create new breeds. New and favourable genes can be introduced into a population through outbreeding.

i. **Out crossing**: It is the breeding between unrelated animals of the same breed but having no common ancestry. The offspring of such a cross is called outcross. This method is suitable for breeding animals that are below average in productivity.

ii. **Cross breeding:** Breeding between a superior male of one breed with a superior female of another breed. The cross bred progeny has superior traits (hybrid vigour or heterosis.)

iii. **Interspecific hybridization:**

In this method of breeding mating is between male and female of two different species. The progeny obtained from such crosses are different from their parents, and may possess the desirable traits of the parents. Have you heard about Mule? It was produced by the process of interspecific hybridization between a male donkey and a female horse.

Controlled breeding experiments

Artificial insemination:

Artificial insemination is a technique in which the semen collected from the male is injected to the reproductive tract of the selected female. Artificial insemination is economical measure where fewer bulls are required and maximum use can be made of the best sire.

Thawing means to melt or become liquid. When the semen collected for artificial insemination is taken to far off places/stored for a long time in frozen condition it should be brought to room temperature slowly before use. This process is called thawing.

Advantages of artificial insemination

i. It increases the rate of conception
ii. It avoids genital diseases
iii. Semen can be collected from injured bulls which have desirable traits.
iv. Superior animals located apart can be bred successfully.

Multiple ovulation embryo transfer technology (MOET)

It is another method of propagation of animals with desirable traits. This method is applied when the success rate of crossing is low even after artificial insemination. In this method Follicle stimulating hormone (FSH) is administered to cows for inducing follicular maturation and super ovulation. Instead of one egg per cycle, 6-8 eggs can be produced by this technology. The eggs are carefully recovered non-surgically from the genetic mother and fertilized artificially. The embryos at 8-32 celled stages are recovered and transferred to a surrogate mother. For another round of ovulation, the same genetic mother is utilized. This technology can be applied to cattle, sheep and buffaloes. Advantage of this technology is to produce high milk yielding females and high-quality meat yielding bulls in a short time.

Breeds of Dairy animals

Dairying is the production and marketing of milk and its products. Dairy operation consists of proper maintenance of cattle, the collection and processing the milk and its by products. There are 26 well defined breeds of cattle and 6 breeds of buffaloes in India. Cattles are classified under three groups based on the purpose they serve to man (Figure 12. 13). They are

i. **Dairy breeds or Milch breeds**: They are high milk yielders with extended lactation. Eg., Sindhi, Gir, Sahiwal, Jersy, Brown Swiss, Holstein cattle.
ii. **Draught purpose breeds**: Bullocks are good for draught purpose. Eg. Kangeyam, Malvi.
iii. **Dual Purpose breeds**: Cows are meant for yielding more milk and bullocks are used for better drought purpose. Eg. Ongole, Hariana.

Vechur breed is the smallest breed of Cow as per World Guinness Records.

Average length: 124cms

Average height: 87 cms

Origin: Vechur village, Kottayam District of Kerala

It produces large amount of milk in relation to the food consumption

To meet the milk demand of the growing population, milk breeds are preferred by farmers in small scale farms. Goats are also used all over India for supplementing deficiencies in milk production. Some of the breeds of cattle that are good milkers are Jamunapari in Ganga-Jamuna riverine tracts, Beetal in Punjab, Bar–bari in Uttarpradesh.

Common diseases of cattle: A healthy animal eat, drinks and sleeps well regularly. Healthy cattle appear bright, alert and active in their movement with a shiny coat. Cattle are affected by a large number

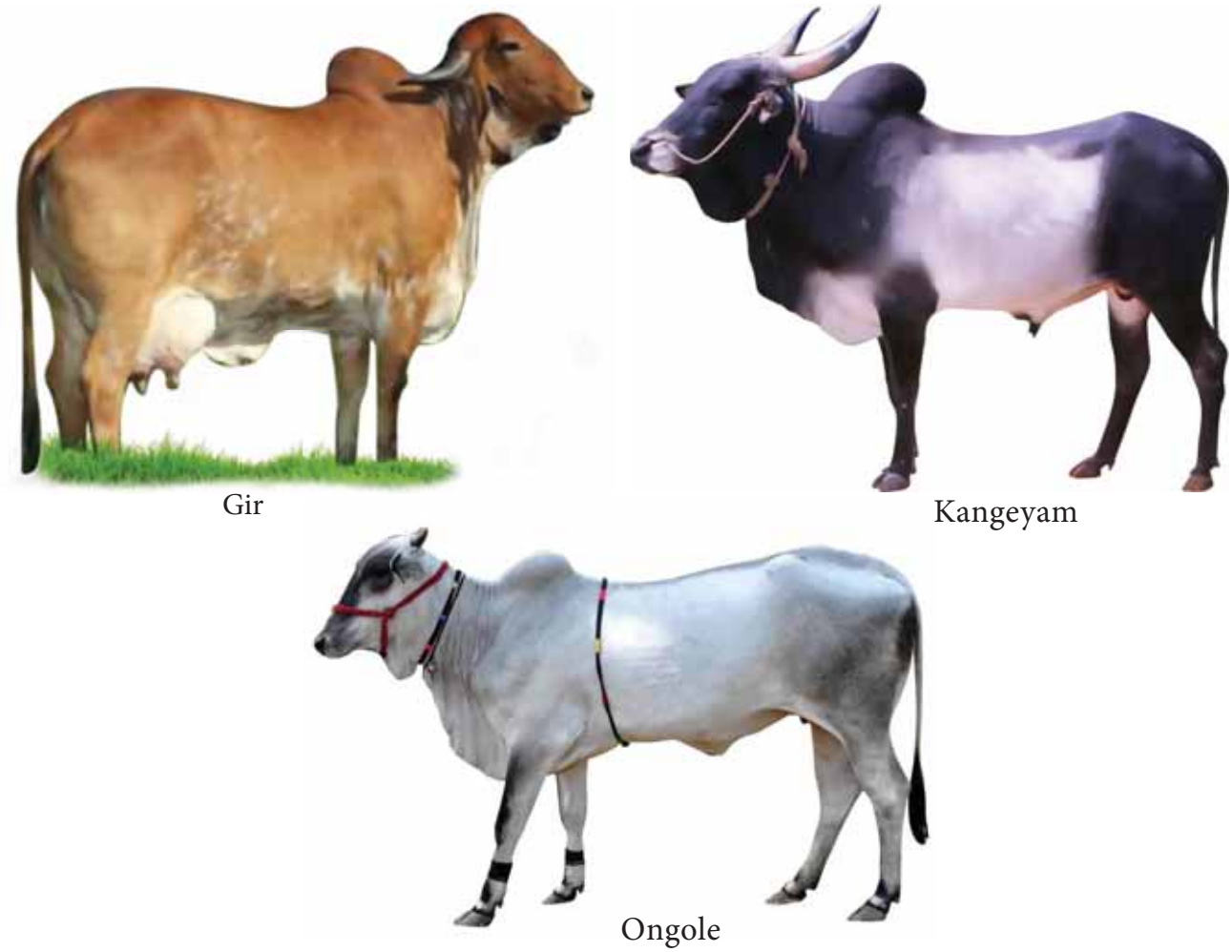


Figure 12. 13 Different breeds of cattle

of diseases. Cattle in ill health appear dull, restless and change posture frequently with drop in milk yield. The main diseases of dairy cattle are rinderpest, foot and mouth disease, cow pox, hemorrhagic fever, anthrax.

Uses of dairy products:

Milk products: Milk is produced by dairy animals which is an emulsion of fat and lactose. Milk also contains enzymes which are destroyed during pasteurization. Milk is a rich source of vitamin A, B_2, B_1, and deficient in Vitamin C. Due to its high nutrition value, it serves as a complete food for infants. Dairy products such as yoghurt, cheese, butter, ice cream, condensed milk, curd, and milk powder processed from milk make dairy, a highly farming attraction.

India is the largest producer of Milk, globally.

India has many popular indigenous breeds of cows and buffaloes.

Prominent indigenous cow breeds in India - Gir, Red sindhi, Sahiwal, Hallikar, Amritmahal, Khillari, Kangayam, Bargur, Umblachery, Pulikulam, Alambadi, Tharparkar, Haryana, Kankrej, Ongole, Krishna valley and Deoni.

Meat: Meat is rich in protein and also contains many minerals like iron, zinc,

vitamins and selenium. It also contains vitamins needed for human diet.

Land management: Grazing of livestock is sometimes used as a way to control weeds and undergrowth.

Manure: Manure can be spread on agriculture fields to increase crop yields.

Poultry Farming

The word poultry refers to the rearing and propagation of avian species such as chicken, ducks, turkeys, geese, quail and guinea fowls. The most common and commercially farmed birds are chicken and ducks. Poultry farming is essential for the purpose of meat, eggs and feather production. Commercial poultry farming is also profitable. In this part we are discussing about an overview of the chicken and duck breeds, farming practices and its advantages.

Types of Chicken breeds: There are more than 100 breeds. The commonly farmed chicken breeds are categorized into five based on the purpose for which it is farmed. They are egg layers, broiler type, dual type, games and ornamental types (Figure 12.14).

1. **Egg layers:** These are farmed mainly for the production of egg.

Leghorn: This is the most popular commercial breed in India and originated from Italy. They are small, compact with a single comb and wattles with white, brown or black colour. They mature early and begin to lay eggs at the age of 5 or 6 months. Hence these are preferred in commercial farms. They can also thrive well in dry areas.

Chittagong: It is the breed chiefly found in West Bengal. They are golden or light yellow coloured. The beak is long and yellow in colour. Ear lobes and wattles are small and red in colour. They are good egg layers and are delicious.

2. **Broiler type:** These are well known for fast growth and soft quality meat.

White Plymouth rock: They have white plumage throughout the body. It is commonly used in broiler production. This is an American breed. It is a fast growing breed and well suitable for growing intensively in confined farms.

3. **Dual purpose breeds:** These are for both meat and egg production purpose.

Brahma: It is a breed popularly known for its massive body having heavy bones, well feathered and proportionate body. Pea comb is one of the important breed characters. It has two common varieties namely, Light Brahma and Dark Brahma.

4. **Game breeds:** Since ancient times, special breed of roosters have been used for the sport of cockfighting.

Aseel: This breed is white or black in colour. The hens are not good egg layers but are good in incubation of eggs. It is found in all states of India. Aseel is noted for its pugnacity, high stamina, and majestic gait and dogged fighting qualities. Although poor in productivity, this breed is well-known for their meat qualities.

5. **Ornamental breeds:** Ornamental chicken are reared as pets in addition to their use for egg production and meat.

Silkie: It is a breed of chicken has a typical fluffy plumage, which is said to feel like silk and satin. The breed has

Leghorn-Hen and Cock

White plymouth rock Hen and Cock

Light brahma Hen and cock

Silkie

Aseel - Hen and cock

Figure 12. 14 Different types of chicken breeds

numerous additional special characters, such as black skin and bones, blue earlobes, and five toes on each foot, while the majority chickens only have four. They are exhibited in poultry shows, and come out in various colours. Silkies are well recognized for their calm, friendly temperament. Silkie chicken is especially simple to maintain as pets.

Types of Poultry farming: There are different methods used to rear both broiler and layer chicken. The types of poultry farming are Free range farming, Organic method, Yarding method, Battery cage method and Furnished cage method

Among these, Battery cage method is widely used in large scale poultry farms. The Free range, Organic and Yarding methods are eco-friendly and the eggs produced by such farming practices are preferred in the market.

Stages involved in rearing:

There are some steps involved in rearing of chicken.

1. Selection of the best layer: An active intelligent looking bird, with a bright comb, not obese should be selected.
2. Selection of eggs for hatching: Eggs should be selected very carefully. Eggs should be fertile, medium sized, dark brown shelled and freshly laid eggs are preferred for rearing. Eggs should be washed, cleaned and dried.
3. Incubation and hatching: The maintenance of newly laid eggs in optimum condition till hatching is called incubation. The fully developed chick emerges out of egg after an incubation period of 21 – 22 days. There are two types of incubation namely natural incubation and artificial incubation.In the natural incubation method, only a limited number of eggs can be incubated by

a mother hen. In artificial incubation, more number of eggs can be incubated in a chamber (**Incubator**).

3. Brooding

Caring and management of young chicks for 4 – 6 weeks immediately after hatching is called brooding. It can also be categorized into two types namely natural and artificial brooding.

4. Housing of Poultry

To protect the poultry from sun, rain and predators it is necessary to provide housing to poultry. Poultry house should be moisture- proof, rat proof and it should be easily cleanable and durable.

5 Poultry feeding: The diet of chicks should contain adequate amount of water, carbohydrates, proteins, fats, vitamins and minerals.

Poultry products: The main products of poultry farming are eggs and meat. In India, the primary aim of poultry farming is to obtain eggs. The eggs and poultry meat are the richest sources of proteins and vitamins.

Poultry byproducts:

The feathers of poultry birds are used for making pillows and quilts. Droppings of poultry can be used as manure in fields. The droppings are rich in nitrogen, potash and phosphates.

A number of poultry byproducts like blood-meal, feather meal, poultry by-product meal and hatchery by-product meal are used as good sources of nutrients for meat producing animals and poultry. These byproducts supply proteins, fats, vitamins and good amount of minerals.

Poultry diseases: Ranikhet, Coccidiosis, and Fowl pox are some common poultry diseases.

Benefits of Poultry farming:

The advantages of poultry farming are

- It does not require high capital for construction and maintenance of the poultry farming.
- It does not require a big space.
- It ensures high return of investment within a very short period of time.
- It provides fresh and nutritious food and has a huge global demand.
- It provides employment opportunities for the people.

Chickens communicate with more than 24 vocalizations, each with a distinct meaning, including warning their friends about different types of predators or letting their mothers know whether they're comfortable

Duck Farming

Duck is an aquatic bird and forms only 6% of our country's poultry population. There are about 20 breeds of ducks. The native one includes Indian Runner and Syhlet meta. The exotic breeds include Muscori, Pekin, Aylesbury and Campbell. Domesticated ducks have been derived from the wild duck named Mallard (*Anas boscas*). Farming ducks is profitable as it can be combined with aquafarming practices.

Peculiarity of ducks:

The body is fully covered with oily feathers. They have a layer of fat under their skin which prevents it from getting wet. They lay eggs at night or in the morning. The ducks feed on rice bran, kitchen wastes, waste fish and snails.

Types of breeds: There are three types of ducks depending on the purpose for which it is formed. They are meat productive duck

breeds, egg productive duck breeds, and breeds for both meat and egg production.

Advantages of duck farming:

They can be reared in small backyards where water is available and needs less care and management as they are very hardy. They can adapt themselves to all types of environmental conditions and are breed for feed efficiency, growth rate and resistance to diseases.

Activity

Students can construct their own aquaponic system with materials available in their laboratory. An old aquarium or any water tight container can be converted into simple aquaponics system

Materials Required:

Aquarium tank/ any water tight container, a floating Styrofoam platform (thermocol), growing medium-coconut fibre. An air pump and air stone, nutrient solution (vermiwash or can buy commercially available nutrient solution), plastic cups and seeds

Cut a floating thermocol platform to fit the tank. Make holes on the platform to insert plastic cups with the growing medium. Fill the aquarium tank with water and nutrients. An air pump supplies air to the air stone that bubbles the nutrient solution and supplies oxygen to the roots. Place the floating platform on top of the nutrient solution and place the plastic cups with plants into the holes in the platform

Now your simple hydroponics system is ready... to build a aquaponic system fishes can be introduced into the tank instead of nutrient solution.

Summary

Economic Zoology involves the study of application of animals for human welfare. The need of Zoology is to improve our economic condition, to provide food security and employment opportunities. Based on the economic importance, animals can be categorized as animals for food and food products, economically beneficial animals, Animals of aesthetic importance and Animals for scientific research. Vermiculture is the process of using earthworms to decompose organic food waste, into a nutrient-rich material capable of supplying necessary nutrients to sustain plant growth. Sericulture is the production of silk from the silk worm. It is an agro-based industry comprising three main components. They are cultivation of food plants for the silkworms, rearing of silkworms and reeling and spinning of silk. Care and management of honey bees for the production of honey is called Apiculture. Lac is produced by the lac insect.

Aquaponics is a combined technique of aquaculture and hydroponics. It prevents toxic water runoff and also maintains ecosystem balance by recycling the waste and excretory products produced by the fish. Aquaculture deals with the farming of aquatic organisms such as fish, molluscs, crustaceans and aquatic plants. On the basis of water resources, aquaculture can be classified into Freshwater aquaculture, brackish water aquaculture and Marine water aquaculture. It includes culture of fishes, prawn, crab and oyster.

Animal husbandry is the practice of breeding and raising livestock cattles like cows, buffaloes, and goats and birds

etc. that are useful to human beings. Dairying is the production and marketing of milk and its products. Dairy operation consists of proper maintenance of cattle, collection and processing the milk and its byproducts. Poultry refers to the rearing and propagation of avian species such as chicken, ducks, turkeys, geese, quail and guinea fowls. The commonly farmed chicken breeds are categorized into five based on the purpose for which it is farmed. They are egg layers, broiler type, dual type, games and ornamental types.

Glossary

Biological indicator – refers to organisms, species or community whose characteristics show the presence of specific environmental conditions.

Endemism – is the ecological state of a species being unique to a defined geographic location, and not found elsewhere.

Drilosphere – is the part of the soil influenced by earthworm secretions, burrowing and castings.

Brood – a family of birds produced at one hatching or birth.

Hapa – is a cage like, rectangular or square net impoundment placed in a pond for holding fish for various purposes. They are made of fine mesh netting material.

Evaluation

1. Which one of the following is not related to vermiculture?
   a. Maintains soil fertility
   b. Breakdown of inorganic matter
   c. Gives porosity, aeration and moister holding capacity
   d. Degradation of non biodegradable solid waste
   a. a and b is correct
   b. c and d is correct
   c. b and d is not correct
   d. a and c is not correct
2. Which one of the following is not an endemic species of earthworm?
   a. *Perionyx*
   a. *Lampito*
   b. *Eudrillus*
   c. *Octochaetona*
3. Match the following
   1. *Bombyx mori* -
      a) Champa - I) Muga
   2. *Antheraea assamensis* -
      b) Mulberry - II) Eri
   3. *Antheraea mylitta* -
      c) Arjun - III)Tassar
   4. *Attacus ricini* -
      d) Castor - IV) Mulberry

   Select the correct one.

   A) 1 – b – IV B) 2 – a – I
   C) 3 - c - III D) 4 - d - II
4. Silk is obtained from ….
   a. *Laccifer lacca*
   b. *Nosema bombycis*
   c. *Attacus ricini*
   d. *Attacus mylitta*
5. **Assertion:** Nuptial flight is a unique flight taken the queen bee followed by several drones.

   Reason: The queen bee produces a chemical substance called pheromone. The drones in that area are attracted to the pheromone and then mating takes place.

a. Assertion and reason is correct but not related
b. Assertion and reason is incorrect but related
c. Assertion and reason is correct but related
d. Assertion and reason is incorrect but not related

6. Rearing of honey bee is called
a. Sericulture b. Lac culture
c. Vermiculture d. Apiculture

7. Which of the statement regarding Lac insect is TRUE?
a. A microscopic, resinous crawling scale insect
b. Inserts its proboscis into plant tissue suck juices and grows
c. Secretes lac from the hind end of body.
d. The male lac insect is responsible for large scale production of lac.

8. Aquaponics is a technique which is
a. A combination of aquaculture and fish culture
b. A combination of aquaculture and hydroponics
c. A combination of vermiculture and hydroponics
d. A combination of aquaculture and prawn culture.

9. Prawn belongs to the class
a. crustacea b. Annelida
c. Coelenterata d. Echinodermata

10. Pearl oyster belongs to the Class
a. Gastropoda b. Cephalopoda
c. Scaphapoda d. Pelecypoda

11. Inland fisheries are
a. deep sea fishing
b. capturing fishes from sea coast
c. Raising and capturing fishes in fresh water
d. oil extraction from fish

12. Induced breeding technique is used in
a. Marine fishery
b. Capture fishery
c. Culture fishery
d. Inland fishery

13. Isinglass is used in
a. Preparation
b. Clearing of wines
c. Distillation of wines
d. Preservation of wines

14. Animal husbandry is the science of rearing, feeding and caring, breeding and disease control of animals. It ensures supply of proper nutrition to our growing population through activities like increased production and improvement of animal products like milk, eggs, meat, honey, etc.
a. Poultry production depends upon the photoperiod.Discuss
b. Polyculture of fishes is of great importance.

15. Assertion: The best quality of pearl is known as lingha pearl and obtained from marine oysters.
Reason: Nacre is secreted continuously by the epithelial layer of the mantle and deposited around the foreign particle
a. Assertion is true, Reason is false
b. Assertion and Reason are false
c. Assertion is false But Reason is true
d. Assertion and Reason are true

16. Choose the correctly matched pair
    1. Egg layers – Brahma
    2. Broiler types - Leghorn
    3. Dual purpose – White Plymouth rock
    4. Ornamental breeds – Silkie
17. Write the advantages of vermicomposting.
18. Name the three castes in a honey bee colony
19. Name the following
    i. The largest bee in the colony
    ii. The kind of flight which the new virgin queen takes along with the drones out of the hive
20. What are the main duties of a worker bee?
21. What happens to the drones after mating flight?
22. Give the economic importance of Silkworm
23. What are the Nutritive values of fishes?
24. Give the economic importance of prawn fishery
25. Give the economic importance of lac insect
26. List any three common uses of shellac.
27. Name any two trees on which lac insect grows.
28. What is seed lac?
29. Define cross breeding.
30. What are the advantages of artificial insemination?
31. Discuss the various techniques adopted in cattle breeding?
32. Mention the advantages of MOET.
33. Write the peculiar characters of duck.

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CHAPTR 8 EXCRETION

1. Main function of uriniferous tubules (MP PMT 1990)
   a. Concentration of urine
   b. Passage of urine
   c. Reabsorption of useful substances from glomerular filtrate
   d. Removal of urea and other waste from blood

2. The mechanism of urine formation in nephrone involves (CPMT 1992)
   a. Utrafiltration
   b. Secretion
   c. Reabsorption
   d. All of above

3. Which hormone induced the process of reabsorption from glomerulus? (JKCMME 92)
   a. Oxytosin
   b. Vasopressin
   c. Relaxin
   d. Calcitonin

4. Glucose is reabsorbed from glomerular filtrate through (CBSE 1993)
   a. Active transport
   b. Passive transport
   c. Osmosis
   d. Diffusion

5. Part not belonging to uriniferous tubule is
   a. Glomerules
   b. Henle's loop
   c. Distal convoluted tubule
   d. Connecting tubule

6. The two kidneys lie (MP PMT 1995)
   a. At the level of ovaries
   b. At the same level
   c. Left kidney at a higher level than the right one
   d. Right kidney at a higher level than the left one

7. Which blood vessel takes blood away from kidney? (DPMT 1996)
   a. Renal portal vein
   b. Renal vein
   c. Afferent arteriole
   d. Efferent arteriole

8. Which hormone influences the activity of kidney? (BHU 1996)
   a. Vasopressin
   b. Thyroxin
   c. Vasopressin and aldosterone
   d. Gonadotrophin

9. Excretory product of birds and reptiles is (CPMT 1998)
   a. Urea **b. Uric acid**
   c. Ammonia d. Creatinin

10. Blood which leaves liver and passes towards heart has higherconcentration of (BHU 1999)
    a. Bile b. Oxygen
    c. RBCs **d. Urea**

11. Urea is transformed through (AIIMS 2000)
    a. RBCs b. WBCs
    c. blood plasma d. All of above

12. A person undergoing prolonged fasting his urine will be found to contain abnormal quantities of (MP PMT 2005)
    a. Fats b. Amino acid
    c. Glucose **d. Ketones**

13. The net pressure gradient that cause the fluid to filter out the glomerulus into the capsule is (PMT 2005)

a. 50 mm hg b. 75 mm hg

c. 20 mm hg d. 30 mm hg

14. In ornithine cycle which of the following waste are removed from the blood? (PMT 2005)
    a. CO_2 and urea
    b. Ammonia and urea
    c. CO_2 and ammonia
    d. Urea and urine
15. Angiotensinogen is a protein produced and secreted by. (AIPMT 2006)
    a. Juxtaglomerular (JG) cells
    b. Macula densa cells
    c. Endothelial cells of blood vessels
    d. Liver cells
16. A person who is in a long hunger strike and is surviving only on water will have (AIPMT 2007)
    a. Less amino acids in his urine
    b. More glucose in his blood
    c. Less urea in his urine
    d. More sodium in his urine
17. Uric acid is the chief nitrogenous component of the excretory product of (AIIPMT 2009)
    a. Earthworm **b. Cockroach**
    c. Frog d. Man
18. The principal nitrogenous excretory compound in human is synthesized (AIIPMT 2010)
    a. in kidney but eliminated mostly though liver
    b. in kidney as well as eliminated by kidneys
    c. in the liver but eliminated mostly though kidneys
    d. In the liver and also eliminated mostly by the same bile
19. Uricotelic mode of excreting nitrogenous waste is found in (AIIPMT 2011)
    a. Reptiles and birds
    b. Birds and annelids
    c. Amphibians and reptiles
    d. Insects and amphibians
20. A fall in glomerular filtration rate (GFR) (AIPMT 2012)
    a. Juxtaglomerular cells to release rennin
    b.Adrenal cortex to release aldosterone
    c. Adrenal medulla to release adernaline
    d.Posterior pituitary to release ADH
21. Haemodialysis is also called as artificial (Har.PMT 2002,)
    a. Liver b. Lung
    c. Heart d**. Kidney**
22. Which one is an accessory excretory organ? (CET 2002)
    a. Liver b. Stomach
    c. intestine d. Heart
23. Part of nephron involved in active reabsorption of sodium is (JIPMER 2002/NEET 2016)
    a. PCT
    b. Ascending limb of Henle's loop
    c. Bowman's capsule d. DCT
24. Haemodialysis helps the paitent having (JIPMER 2004)
    a. Goitre b. Anaemia
    c**. Uremia** d. Diabetes
25. Lungs expel (MH 2005)
    a. CO_2 b. H_2O
    c. CO_2 and water **d. CO_2 and water vapour**

26. The glomeruli are continued to the (CPMT 88)
    a. Medulla b. Calyces
    c. Cortex d. Renal Pelvis

27. The kidney of adult mammals is (MP PMT 99)
    a. Opisthonephron
    b. pronephros
    c. Mesonephros
    d. Metanephros

28. A kidney stone is (CPMT 88,)
    a. Blockage by fats
    b. Deposition of sand in kidney
    c. A salt such as oxalate crystallised in pelvis
    d. Blockage by proteins

29. Which of the following is both osmoregulator as well as nitrogenous product (DPMT 07)
    a. NH_3 **b. Urea**
    c. Uric acid d. All of these

30. Which of these is not a ketone body (CPMT 04)
    a. Acetoacetic acid
    b. Acetone
    c**. Succinic acid**
    d. Betahydroxybutyric acid

31. Excretory organs of cockroach are
    a. Malpighian corpuscles
    b**. Malpighian tubules**
    c. Hepetic caecae
    d. Green glands

32. Juxtaglomerular cells of renal cortex synthesize a hormone called: (BHU 2007)
    a. ADH b. Oxytocin
    c. Renin d. Urochrom

33. Which blood vessel carries least amount of urea? (HAR PMT 2005)
    a. Pulmonary vein
    b. renal artery
    c. renal vein
    d. Hepatic portal vein

34. Human urine is usually acidic because: (RE-AIPMT 2015)
    a. hydrogen ions are activity secreted into the filtrate
    b. the sodium transporter exchanges one hydrogen ion for each sodium ion, in peritubular capillaries
    c. excreted plasma proteins are acidic
    d. potassium and sodium exchange generates acidity

35. Grafted kidney may be rejected in a patient due to (RE-AIPMT 2015)
    a. Innate immune response
    b. Humoral immune response
    c. Cell-mediated immune response
    d. Passive immune response

36. Human urine is usually acidic because: (RE-AIPMT 2015)
    a. hydrogen ions are actively secreted into the filtrate.
    b. the sodium transported exchanges one hydrogen ion for each sodium ion, in peritubuar capaillaries.
    c. excreted plasma proteins are acidic
    d. potassium and sodium exchange generates acidity.

37. In mammals, which blood vessel would normally carry largest amount of urea?

(AIPMT/NEET 2016)

a. Renal Vein

b. Dorsal Aorta

c. **Hepatic Vein**

d. Hepatic Portal Vein

38. Which of the following statement is correct? (NEET 2017)

a. The descending limb of loop of Henle is impermeable to water.

b. The ascending limb of loop of Henle is permeable to water

c. The descending limb of loop of Henle is permeable to electrolytes.

d. The ascending limb of loop of Henle is impermeable to water

CHAPTER 9

LOCOMOTION AND MOVEMENT

1. Which is the longest bone of fore limb? (CPMT- 2002)

a. Humerus

b. Femur

c .Carpals

d. Fibula

2. In which bone triangular acromion is present? (CPMT- 2002)

a. Radias **b. Scapula**

c. Femur d. Humerus

3. Humerus bone is found: (DPMT- 1985)

a. Radius b.Ulna

c. Arm d. Fore arm

4. Hinge joint occurs between: (CPC – 2003)

a. Humerus and radio-ulna

b. Femur and pelvic girdle

c. Humerus and Pectoral girdle

d. Skull and atlas

5. Total number of vertebrae in human skeleton. (JIMERT 2002)

a. 30 b. 32

c**. 33** d. 35

6. Number of bones present in an arm is: (AFMC – 2004)

a. 30 b. 32

c. 35 d. 40

7. Ribs are attached to: (Wardha- 2001)

a. Scapula **b. Sternum**

c. Clavicle d. Ilium

8. In humans, coccyx is formed by the fusion of vertebrae

a. 3 **b. 4**

c. 5 d. 6

9. What is formed by the bones of pectoral girdle, pelvic girdle and limbs? (CPMT- 1987)

a. Body skeleton

b. External skeleton

c. Axial skeleton

d. Appendiculr skeleton

10. Number of floating ribs in human body is: (JIPMER- 2000)

a. 6 pairs b. 5 pairs

c. 3 pairs **d. 2 pairs**

11. Ankle joint is: (Pb.PMT- 1997)

a. Pivot joint

b. Ball and socket joint

c. Hinge joint

d. Gliding joint

12. Sarcomere is distance between: (BHU-2001 , RPMT- 2002)

a. Two I- bands

b. A and I bands

c. Two consecutive Z- lines

d. Z and A bands

13. Which is the skull bone?
    a. Atlas b. Femur
    c. Tibia **d. Nasal**

14. How many bones are there in appendicular skeleton? (BV – 2003)
    a. 80 b. 120
    c. 126 d. 206

15. Where is hinge joint found? (APMEE- 2002)
    a. Elbow and shoulders
    b. Elbow and Knee
    c. Atlas and odontoid process
    d. Knee and ankle

16. Number of ball and socket joints present in human body is:
    a. 2 b. 4
    c. 5 d. 8

17. Synovial joints is:
    a. Ball and socket joint
    b. Pivot joint
    c. Hinge joint
    d. A11 the above

18. Give the number of Cranium bones? (JKCMEE – 2005)
    a. 8 b. 10
    c. 14 d. 20

19. Cervical vertebrae are located in: (HPPMT – 2005)
    a. Thoracic region
    b. Abdominal region
    c. Neck region
    d. Hip region

20. Lumbar vertebrae are located in: (HPPMT – 2005)
    a. region
    b. Thorax
    c. Abdominal region Neck
    d. Hip region

21. Ratio of which is more in red muscle? (JIPMER -2002)
    a. Myoglobin b. Actin
    c. Myosin d. Albumin

22. Friction is lessened in ball and socket joint by (MPPMT -1990)
    a. Coelomic fluid
    b. Synovial fluid
    c. Pericardial fluid d. Mucin

23. Each half of pelvic girdle is made of (MPPMT -1998)
    a. Ischium b. Ilium
    c. Pubis **d. All the above**

24. Extremities of long bones possess cartilage
    a. Calcified b. Fibrous
    c. Elastic **d. Hyaline**

25. Glenoid cavity is found in (A.M.U.–2000)
    a. Pelvic girdle b. Skull
    c. Pectoral girdle d. Sternum

26. An example of gliding joints is (MPPMT -1992)
    a. Humerus and glenoid cavity
    b. Femur and tibio-fibula
    c. Occipital condyle and odontoid process
    d. Zygapophyses of adjacent vertebrae.

27. During muscle contraction
    a. Size of a-bands remains the same
    b. Size of H-zone becomes smaller
    c. Size of I-bands decreases
    d. All the above

28. Substance that accumulates in a fatigued muscle is (Har.PMT 2003)
a. Pyruvic acid **b. Lactic acid**
c. CO2 d. ADP

29. Lack of the relaxation between successive stimuli in sustained muscle contraction is known as (AIPMT /NEET 2016)
a. Fatigue b. **Tetanus**
c. Tonus d. Spasm

30. Which ion is essential for muscle contraction? (Pb.PMT 2000)
a. Na b. K
c. Ca d. Cl_2

31. Ends of long bones are covered by (Bhi.P.M.T-2001)
a. Ligaments **b. Cartilage**
c. Muscles d. Blood cells

32. Acromion process is part of (B.V. 2003)
a. Vertebral column
b. Pelvic girdle
c. Femur
d. Pectoral girdle

33. In mammals the lower jaw is made of
a. Maxilla b. Dentary
c. Mandible d. Ethmoid

34. Inter-articular disc occur in (B.H.U. -1997)
a. Wall of heart
b. Wall of liver
c. Pubic symphysis
d. In between two vertebrae

35. Acetabulum is part of (C.E.T. chd. 2000)
a. Pelvic girdle
b. Pectoral girdle
c. Form arm
d. Upper arm

36. The functional unit of contractile system of a striated muscles is (C.M.E.E.-2004)
a. Sarcomere b. Z-band
c. Cross bridge d. Myofibril

37. Fibrous joints are present between (M.P.P.M.T. -2000)
a. Thumb and metatarsal
b. Humerus and radio-ulna
c. Bones of skull
d. Glenoid cavity and pectoral girdle

38. Joint of sternum and ribs is
a. Cartilaginous
b. Fibrous joint
c. Angular joint
d. Hinge joint

39. During vigorous exercise, glucose is converted into (C.P.M.T.- 2000)
a. Glycogen b. pyruvic acid
c. Starch **d. Lactic acid**

40. Synovial fluid is present in (Har. P.M.T. – 2000)
a. Spinal cavity
b. Cranial cavity
c. Freely movable joints
d. Fixed joints

41. Synovial fluid is secreted by (B.V.-2001)
a. Blood b. Cartilage
c. Bone **d. Synovial membrane**

42. Iliac of pelvic girdle is articulated with sacrum for (B.H.U-2001)
a. Bending b. Jumping
c. Support d. Running

43. Anisotropic band are made up of (A.M.U.- 2001)
a. Myosin filaments
b. Actin filaments

c. Elastin filaments

d. Both A and B

44. Socket in pelvic girdle in which head of femur articulates is formed by fusion of
    a. Ischium and pubis
    b. Ilium and pubis
    c. Ilium and ischium
    d. Both a and b

45. The movable skull bone is
    a. Maxilla b. Vomer
    c. Mandible d. All the above

46. Gliding joint occur between (B.V. – 2002)
    a.Prezygapophysis and postzygapophysis
    b. Acetabulum and femur
    c. Pelvis girdle and femur
    d. Humerus and radius.

47. Red muscle are rich in (J.I.P.M.E.R.-2002)
    a. Golgi bodies
    b. Mitochondria
    c. Lysomomes
    d. Ribosomes.

48. Joint between atlas and axis is (A.F.M.C. – 2003)
    a. Pivot b. Hinge
    c. Angular d. Saddle

49. The longest bone amongst the following is (B.V – 2003)
    a. Radius b. ulna
    c. Humerus **d. Femur**

50. Joint between metacarpals and phalanges is (B.V – 2003)
    a. Ball and socket b. Pivot
    c. Saddle **d. Hinge**

51. ATP-ase needed for muscle contraction is present over
    a. Actin b. Troponin
    c. Myosin d. Actin

52. Make correct pairs from the column -1 and column – II. (Odisha JEE – 2010)

Column -I	Column – II
Types of synovial joint	Bones involved
(P) Ball and socket	(i) Carpal and metacarpal of thumb
(Q) Hinge	(ii) Atlas and axis
(R) Pivot	(iii) Frontal and parietal
(S) Saddle	(iv) Knee
	(v) Humerus and pectoral girdle

    a. (P-ii) (Q-iv) (R-ii)(S-v)
    b. (P-ii) (Q -iii) (R- i) (S – v)
    c. (P-iii)(Q-v) (R-iv)(S-ii)
    d. (P-v) (Q -iv) (R- ii) (S – i)

53. Major protein in the thick filament of skeletal muscle fiber is (MP PMT 2011)
    a. Tropomyosin **b. Myosin**
    c. Actin d. Troponin

54. True joints are (Wardha 2005)
    a. Synchondroses b. Syndesmoses
    c. Synovial d. Ball and socket

55. The pivot joint between atlas and axis is a type of (NEET-2016)
    a. cartilaginous joint
    b.**synovial joint**
    c.saddle joint
    d. fibrous joint

56. Name the ion responsible for unmasking of active sites for cross-bridge activity during muscle contraction (NEET-2016)
    a. sodium b.potassium
    c.calcium d.magnesium

57. Sliding filament theory can be best explained as (NEET 2015)
    a. when myofilaments slide pass each other actin filaments shorten while myosin filaments do not shorten
    b. actin and myosin filaments shorten and slide pass each other
    c. actin and myosin filaments do not shorten but rather slide pass each other
    d. when myofilaments slide pass each other myosin filaments shorten while actin filaments do not shorten

58. Osteoporosis is an age related disease of skeletal system, may occur due to (NEET 2016)
    a. decreased level of oestrogen
    b. accumulation of uric acid leading to inflammation of joints
    c. immune disorder affecting neuromuscular junction leading to fatigue
    d. high concentration of Ca^{++} and Na^{++}

59. Smooth muscles are (Re-NEET. 2016)
    a. involuntary, fusiform, non-striated
    b. voluntary, multinucleated, cylindrical
    c. Involuntary, cylindrical, striated
    d. Voluntary, spindle shaped, uninucleated,

60. Glenoid cavity articulates (AIPMT 2015)
    a. Scapula with acromion
    b. clavicle with scapula
    c. humerus with scapula
    d. clavicle with acromion

61. Which of the following joints would allow no movements? (AIPMT Retest 2015)
    a. Fibrous joint
    b. cartilaginous joint
    c. synovial joint
    d. ball and socket joint

62. Which of the following is not a function of the skeletal system? (AIPMT Retest 2015)
    a. Production of erythrocytes
    b. storage of minerals
    c. production of body heat
    d. locomotion

Chapter 10

Neural control and coordination

1. Given below is a table comparing the effects of sympathetic and parasympathetic nervous system for four features (1-4) which one feature is correctly described? (A.I.I.M.S.2006)

	sympathetic	parasympathetic
a. Salivary gland	inhibit secretion	stimulate secretion
b. pupil of the eye	**dilate**	**constricts eye**
c. heart	rate decreases	increases
d. intestinal	stimulates	inhibits peristalsis

2. Cranial nerves supplying eyes muscles are: (Pb.P.M.T.1997)
    a. 4, 5, 6 b. 3, 4, 5
    c. 4, 6, 7 **d. 3,4,6**

3. A cranial nerve with maximum branches in the body is (M.P.P.M.T.1997,A.P.M.E.E 1999)
    a. Auditory **b. Trigeminal**
    c. Vagus d. Facial

4. Bowman's glands are located in
    a. Olfactory epithelium of human nose

b. Female reproductive system of cockroach

c. Anterior pituitary

d. Proximal end of uriniferous tubules

5. Which of the following disorder is not hereditary (J.K.C.M.E.E 2005)
   a. sickle cell anaemia

   b. haemophilia

   c. colour blindness

   d. cataract

6. Glands responsible for secreting tears are: (H.P.P.M.T 2005)
   a. glands of moll

   b. lacrimal glands

   c. meibomian glands

   d. glands of zeis

7. Which of the following cranial nerves are mixed: (BHU 2007)
   a. glossopharyngeal b. trigeminal
   c. vagus d. auditory

   a. A,B and C are correct

   b. A andC are correct

   c. A and B are correct

   d. B and D are correct

8. To What the respiratory center of brain are sensitive?
   a. High CO_2 Concentration in blood

   b. Blood supply to brain

   c. High O_2 Concentration in blood
   d. More blood supply to lungs

9. Nasal epithelium is formed of: (C.M.C 2003)
   a. columnar epithelium

   b. keratinised epithelium

   c. pseudostratified epithelium

   d. glandular epithelium

10. Space between piamater and arachnoid is (J.K.C.M.E.E 2003)
    a. subdural b. supra archnoid

    c. eqidural **d. subarachnoid**

11. Which one is mixed nerve?
    a. oculomotor b. trochler

    c. hypoglossal **d. glossopharyngeal**

12. Visual area is located in (A.I.E.E.E 2004)
    a. occipital lobe b. parietal lobe
    c. frontal lobe d. temporal lobe

13. In hypothalamus are located various canters of (J.I.P.M.E.R 2004)
    a. circulation b. sleep

    c. memory **d.body temperature**

14. Which option is correct for the few statements are given for the function of cerebrum, which of few following option is shows all correct statements.
(i) to control the sensitivity, movement, memory, vocabulary etc. through the
(ii) to control the vision and adaptation through the occipital and frontal lobes
(iii) to control the contraction of voluntary muscles through the frontal lobe
(iv) to control the temperature, taste, touch, pain etc, through the parietal lobe
    a. (i),(ii),(iii) b. (iii),(iv),(i)

    c. (i),(iii),(iv) d. (i),(ii)

15. column I lists the part of the human brain and column II lists the functions. Match the two columns and identify the correct choice from those given. (K.C.E.T 2005)

column I	column II
a. cerebrum	p. controls the pituitary

b. cerebellum — q. control vision and hearing

c. hypothalamus — r. control the rate of heart beat

d. midbrain — s. seat of intelligence

t. maintains body posture

a. (a=s);(b=t);(c=p);(d=q)

b. (a=t);(b=s);(c=r);(d=q)

c. (a=t);(b=r);(c=p);(d=q)

d. (a=t);(b=s);(c=q);(d=p)

16. In the resting state of the neural membrane, diffusion due to concentration gradients, if allowed would drive:

a. Na^+ out of the cell

b. K^+ into the cell

c. Na^+ into the cell

d. K^+ and Na^+ out of the cell

17. Injury vagus nerve in human is not likely to affect:

a. gastrointestinal movements

b. cardiac movement

c. tongue movement

d. pancreatic movement

18. Which of the following is not strictly considered as a part of neuron? (C.P.M.T 1998)

a. dendrites **b. myelin sheath**

c. axon d. Nissle's bodies

19. Centers for sense of smell are located (M.P.P.M.T 1999)

a. cerebellum b. midbrain

c. olfactory lobes d. cerebrum

20. Nerve related to diaphragm is (M.P.P.M.T 1999)

a. trigeminal b. vagus

c. glossopharyngeal **d. phrenic**

21. Node of ranvier is the place where (P.M.T 2002)

a. myelin sheath and neurilemma are discontinuous

b. axlemma is absent

c. axlemma is discontinuous

d. myelin sheath is discontinuous

22. which of the following cranial nerve controls the movement of eye ball ? (B.H.U 2002)

a. trocheclar

b. oculomotor

c. abducen

d. all of the given

23. Match the following human spinal nerves in column I with their respective number in column II and choose the correct option

column I	column II
P. cervical nerves	i. 5 pairs
Q. thorocic nerve	ii. 1 pair
R. lumbar nerve	iii. 12 pair
S. coccygeal nerve	iv. 8 pair

a. (P-iv),(Q-iii),(R-i),(S-ii)

b. (P-iii), (Q-i), (R-ii), (S-iv)

c. (P-iv),(Q-i),(R-ii),(S-iii)

d. (P-ii), (Q-iv), (R-i), (S-iii)

24. How many pairs of spinal nerve are found in human? (Guj C.E.T 2006)

a. 33 b. 32

c. 31 d. 30

25. What is Nissl's granule consist of ?

a. DNA b. RNA

c. protein d. lipid

26. Which of the following is correct for motor nerve? (A.I.E.E.E 2004)
    a. trochelar b. hypoglossal
    c. oculomotor **d. All the given**

27. Four healthy people in their twenties got involved in injuries resulting in damage and death of a few cells of the following . Which of the cells are least likely to be replaced by new cells ?
    a. liver cells b. osteocytes
    c. neurons d. malpighian layer of the skin

28. One of the examples of the action of the autonomous nervous system is :
    a. peristalsis of the intestines
    b. knee-jerk response
    c. swallowing of food
    d. pupillary reflex

29. In mammalian eye, the 'fovea' is the center of the visual field, where: (RE-AIPMT 2015)
    a. more roads than cones are found
    b. high density of cones occur but has no rods
    c. the optic nerve leaves the eye
    d. only rods are present

30. Receptor site for neurotransmitters are present on(NEET 2017)
    a. Pre-synaptic
    b. Tips of axons
    c. Post-synaptic membrane
    d. Membrane of synaptic vesicles

CHAPTER 11

Chemical coordination and intergration

1. Match the list-I with list-II

list-I	list-II
p. Adenohypophysis	i. Epinephrine
q. Adrenal medulla	ii. Somatotropin
r. Parathyroid gland	iii. Thymosin
s. Thymus gland	iv. Calcitonin

    a. (p : iv), (q : iii), (r : ii), (s : i)
    b. (p: iii), (q : i), (r : iv), (s : ii)
    c. (p : i), (q: ii), (r : iii), (s : iv)
    d. (p : ii), (q : i), (r : iv), (s : iii)

2. Which one of the following is not a second messenger in hormone action? (AIPMT 2006)
    a. cGMP b. Calcium
    c. Sodium d. cAMP

3. Match item in column-I with those given in column-II

column-I	column-II
p. ADH	a. Pituitary
q. ACTH	b. mineralocorticoid
r. aldosterone	c. diabetes mellitus
s. insulin	d. diabetes inspidus
t. adrenaline	e. vasodilator

    a. (p – d) (q – a) (r – c) (s – b) (t – e)
    b. (p – a) (q – d) (r – b) (s – c) (t – e)
    c. (p – d) (q – a) (r – b) (s – c) (t – e)
    d. (p – d) (q – b) (r – a) (s – c) (t – e)

4. Which of the following indicates correctly matched pairs for column-I and column- II

column-I	column-II
p leydig cells	(i) Tetany

q Hyperthyrodism (ii) GH

r Adenohypophysis (iii) ACTH

s Dwarfism (iv) Testosterone

a. (p – iv) (q – i) (r – iii) (s – ii)

b. (p – i) (q – iv) (r – ii) (s – iii)

c. (p – i) (q – ii) (r – iii) (s – iv)

d. (p – iii) (q – i) (r – iv) (s – ii)

5. Mainly which of the following hormones control menstrual cycle in human being (CET, 1997)

a. FSH, LH, Estrogen

b. oxytocin

c. PTH

d. ACTH

6. On seeing a Tiger, the heart beat and blood pressure increase due to release of hormone: (A.I.I.M.S 2000)

a. Corticoids b. Thyroxine

c. Adrenaline d.Parathormone

7. Match the endocrine gland, given under column-I with their respective position in the body given under column-II choose the answer which gives the correct combination of alphabets of two columns: (K.C.E.T.1998)

column-I (Endocrine glands)	column-II (Position in body)
a. pituitary gland	p. Above kidney
b. Thyroid gland pancreas	q. Inside
c. Adrenal gland	r. On larynx
d. Islets of langerhans	t. At the base of brain

a. (a – t) (b – r) (c – p) (d – q)

b. (a – s) (b – t) (c – p) (d – q)

c. (a – p) (b – q) (c – r) (d – t)

d. (a – q) (b – s) (c – t) (d – p)

8. If Adenohypohysectomy is done in adult, then which of the followings is the correct statement : (CPMT 1996)

a. Gigantism

b. Acromegaly

c. B.M.R will be affected

d. It will affect growth of testis and ovary

9. The immediate cause of induction of ovulation in the human female is the large plasma surge of :

a. LH b. Estrodiol

c. FSH d. Progesterone

10. Glucagon and insulin are: (CMEET 1995)

a. Secreted from same cell and are same in function

b. Secreted from same cells but are opposite in function

c. Antagonistic secretion action and similar function

d. Secreted from different cells but are opposite in function

11. What is the function of enterogastrone?

a. It stimulates the secretion of digestive juices in the stomach

b. It stimulates the flow of pancreatic juice

c. It regulates the flow of bile **d. It inhibits the secretion of gastric juice**

12. Ca+ metabolism is regulated by : (C.P.M.T 1997)

a. ACTH b. Thyroxine

c. Parathormone d. Epinephrine

13. Heavy jaws, long face, long extremities are caused by:

a. under secretion of hormone of posterior lobe of pituitary

b. over secretion of hormone of anterior lobe of pituitary after puberty

c. under secretion of hormone of anterior lobe of pituitary

d. over secretion of hormone of posterior lobe of pituitary

14. FSH and LH hormones together are called: (MPPMT 1997)

a.GTH

b. Stress removing hormones

c. Emergency hormones

d. Neurohormones

15. Deficiency of calciferol causes: (MPPMT 1996)

a. Scurvy b. Leucopenia

c. Rickets d. Leukaemia

16. Which one of the following pairs correctly matches a hormone with disease resulting from its deficiency ? (P.M.T 2003)

a. Relaxin – Gigantism

b. Parathyroid hormone – Tetany

c. Insulin – Diabetes insipidus

d. Prolactin – Cretinism

17. Which one of the following pairs correctly matches a hormone with a disease resulting from its deficiency?

a. Luteinizing hormone – failure of ovulation

b. Thyroxin – Titan

c. Insulin – Diabetes insipidus

d. Parathyroid hormone – Diabetes mellitus

18. Chemically the hormones are

a. Steroids only

b. Proteins, steroids and biogenic amines.

c. Proteins only

d. Biogenic amines only

19. Which of the following hormones is not a secretion product of human placenta?

a. Progesterone b. HCG

c. Prolactin d. Estrogens

20. Feeling the tremors of an earthquake a scared resident of seventh floor of a multistoried building starts climbing down the stairs rapidly. Which hormone initiated this action ?

a. Gastrin b. Thyroxine

c. Adrenaline d. Glucagon

21. Match list-I with list-II and select the correct option.

list-I	list-II
a) Adrenaline	1 Myxoedema
b) Hyperparathyroidism	**2 Accelerates heart beat**
c) Oxytocin	3 Salt – water balance
d) Hypothyroidism	4 Child birth
e) Aldosterone	5 Demineralization

a. (a – 5) (b – 3) (c – 2) (d – 4) (e – 1)

b. (a – 2) (b – 5) (c – 4) (d – 1) (e – 3)

c. (a – 5) (b – 3) (c – 4) (d – 2) (e – 1)

d. (a – 2) (b – 3) (c – 4) (d – 5) (e – 1)

22. Column-I lists the endocrine structure and column-II lists the corresponding hormones match the two column. Identify the correct option those given. (K.C.E.T 2006)

column-I	column-II
a. Hypothalamus	p. relaxin
b. anterior pituitary	q. estrogen
c. testis	r. FSH and LH
d. ovary	s. androgens

t. gonadotropin releasing hormones

a. (a – r) (b – t) (c – s) (d – q)

b. (a – t) (b – r) (c – s) (d – q)

c. (a – p) (b – q) (c – s) (d – r)

d. (a – t) (b – r) (c – q) (d – s)

23. It is the parathyroid gland….
(A.M.U 2006)

a. decreases blood $ca+^2$ level

b. Increases blood $ca+^2$ level

c. promotes collagen synthesis by osteoblasts

d. All of the given

24. Which of the following is not a effect of hypothyroidism?

a. Mental stress b. edema

c. Increases $Ca+^2$ level in blood

d. to be lethargic

25. The amino acid Tryptophan is the precursor for the synthesis of.
(AIPMT /NEET-2016)

a. Melatonin and Serotonin

b. Thyroxine and Triiodothyronine

c. Estrogen and Progesterone

d. Cortisol and Cortisone

26. Which of the following pairs of hormones are not antagonistic (having opposite effects) to each other?
(AIPMT /NEET-2016)

a.Parathormone – Calcitonin

b. Insulin - Glucagon

c. Aldosterone - Atrial Natriuretic Factor

d. Relaxin - Inhibin

27. GnRH, a hypothalamic hormone, needed in reproduction, acts on:
(NEET-2017)

a. anterior pituitary gland and stimulates secretion of LH and FSH

b.posterior pituitary gland and stimulates secretion of oxytocin and FSH

c.posterior pituitary gland and stimulates secretion of LH and relaxin

d.anterior pituitary gland and stimulates secretion of LH and oxytocin

28. Which one of the following hormones though synthesized elsewhere, is stored and released by the master gland?
(NEET-2015)

a. Melanocyte stimulating hormone

b. Antidiuretic hormone

c. Luteinizing hormone

d. Prolactin

29. Which one of the following hormones is not involved in sugar metabolism?
(RE-AIPMT 2015)

a. Glucagon b. Cortisone

c. Aldosterone d. Insulin

30. Hypersecretion of Growth Hormone in adults does not cause further increase in height, because: (NEET-2017)

a. Epiphysis plates close after adolescence

b. Bone lose their sensitivity to Growth Hormone in adults

c. Muscle fibers do not grow in size after birth

d. Growth Hormone becomes inactive in adults

CHAPTER 12

Basic Medical Instrument and techniques

1. Doctors use stethoscope to hear the sound; produced during each cardiac cycle. The second sound is heard when: (RE-AIPMT-2015)

a. AV node receives signal from SA node b. AV valves

c. Ventricular wall vibrate due to gushing of blood from atria

d. **Semilunar valves close down after the blood flows into vessels from Ventricles.**

பாடம் 8 – கழிவுநீக்கம் Excretion	
Nephron	நெஃப்ரான்
Nephron tubules	நெஃப்ரான் நுண்குழல்கள்
Osmoregulation	ஊடுகலப்பு ஒழுங்குபாடு
Ionic regulation	அயனி ஒழுங்குபாடு
Ammonotelic	அம்மோனோடெலிக் – அம்மோனியா நீக்கிகள்
Uriotelic	யூரியோடெலிக் – யூரியா நீக்கிகள்
Uricotelic	யூரிக்கோடேலிக்-யூரிக்அமில நீக்கிகள்
Flamecells	சுடர்ச்செல்கள்
Green glands	பச்சை சுரப்பிகள்
Malpighian tubules	மால்பிஜியன் நுண்குழல்கள்
Renal tubule	சிறுநீரக நுண்குழல்
Proximal Convoluted Tubule	அண்மை சுருள் நுண்குழல்
Distal convoluted Tubule	சேய்மை சுருள் நுண்குழல்
Bowman's capsule	பௌமனின் கிண்ணம்
Hydrostatic pressure	நீர்ம அழுத்தம்
Filtrate	வடி திரவம்
Collecting duct	சேகரிப்பு நாளம்
Micturition	சிறுநீர் வெளியேற்றம்
Renal failure	சிறுநீரக செயலிழப்பு
Renal calculi	சிறுநீரகக் கற்கள்
Ultra filtration	நுண்வடிகட்டுதல்
Interstial fluid	இடையீட்டு திரவம்
Body fluid	உடல் திரவம்
Hypotonic	தாழ் உப்படர்வு
Hypertonic	உயர் உப்படர்வு
பாடம் 9 – இடப்பெயர்ச்சி மற்றும்இயக்கம் (Locomotion and movement)	
Amoeboid movement	அமீபா போன்ற இயக்கம்
Ciliary movement	குறு இழை இயக்கம்
Flagellar movement	நீளிழை இயக்கம்
Muscular movement	தசை இயக்கம்
Myocytes	தசை செல்கள்
Skeletal muscles	எலும்புத் தசை
Visceral muscles	உள்ளுறுப்புத் தசைகள்
Cardiac muscles	இதயத் தசைகள்
Tendon	தசை நாண்
Fascicle	ஃபாசிகிள்
Epimysium	எபிமைசியம்
periusium	பெரிமைசியம்
Endomysium	என்டோமைசியம்
Sarcolemma	சார்கோலெம்மா
Anisotropic bands (A bands)	மாறுபட்டதன்மையுடைய பட்டைகள்
Isotropic bands (I bands)	ஒத்த தன்மையுடைய பட்டைகள்
Muscle fibre	தசையிழை
Myofibril	தசை நுண்ணிழை
Myo filaments	தசை நாண்
Meromyosin	மீரோளமையோசின்
Troponin	ட்ரோபோனின்
Tropomyosin	ட்ரோபோமையோசின்

Sliding – filament hypothesis	சறுக்கும் இழை கோட்பாடு
Neuro muscular junction	நரம்பு தசை சந்திப்பு
Motor end plate	இயக்க முடிவுத் தட்டு
Dark band	அடர்த்தி மிகு பட்டை
Light band	அடர்த்தி குறை பட்டை
Active sites/	செயற்படு பகுதி/செயல் மிகு பகுதி
Cross bridge	குறுக்குப்பாலம்
Power stroke	விசைத்தாக்கம்
Motor unit	இயக்க அலகு
All or none principle	உண்டு அல்லது இல்லை விதி
Isotonic contraction	சமநீளச் சுருக்கம்
Isometric contraction	சம இழுப்புச் சுருக்கம்
Oxidative contraction	ஆக்ஸிஜனேற்ற தசைச் சுருக்கம்
Glycolytic contraction	கிளைக்கோஜன் சிதைவு தசைச் சுருக்கம்
fast fibres	துரித இழைகள்
Slow fibres	மெதுவான இழைகள்
Skeletal system	எலும்பு மண்டலம்
Hydrostatic skeleton	நீர்ம நிலைச் சட்டகம்
Exoskeleton	புறச் சட்டகம்
Endoskeleton	அகச்சட்டகம்
Axial skeleton	அச்சுக் சட்டகம்
Appendicular skeleton	இணையுறுப்புச் சட்டகம்
External auditory meatus	வெளிச் செவித்துளை
Ear ossicles	செவிச்சிற்றெலும்புகள்
Foramen magnum	மண்டையோட்டுப் பெருந்துளை
Neural canal	நரபுக் கால்வாய்
True ribs	உண்மை விலா எலும்புகள்
False ribs	போலி விலா எலும்புகள்
Floating ribs	மிதக்கும் விலா எலும்புகள்
Girdle	வளையம்
Collar bone	காரை எலும்பு
Acromion	ஏகுரோமியன்
Olecranon process	ஓலிகிரானன் நீட்சி
accetalrlum	எலும்புக்குழி
Pubic symphysis	பூப்பெலும்பு இணைவு
Miscle fatigue	தசைக் சோர்வு
Muscle pull	தசைப் பிடிப்பு
Muscular dystrophy	தசைச்சிதைவு நோய்
Rigor mortis	மரண விறைப்பு
Arthritis	மூட்டு வலி
Osteoarthritis	ஆஸ்டியோ மூட்டு வலி
Rheumatiod arthritis	ருமாடிக் மூட்டுவலி
Gout	கௌட்
Osteoporosis	எலும்புப்புரை
Parietal bone	சுவரெலும்பு
Temporal bone	பொட்டெலும்பு
Frontal bone	நெற்றி எலும்பு
Sphenoid	ஆப்புருவ எலும்பு/ஸ்பீனாய்டு
Occipital	பிடரிஎலும்பு
Ethmoid	எத்மாய்டு

Maxilla	மேல்தாடை எலும்பு
Zygomatic	கன்னத்தின் வளையயெலும்பு
Palatine	அண்ணவெலும்பு
Lacrymal	கண்ணீர்ச் சுரப்பியன்மை எலும்பு
Nasal	மூக்கினிடைத்தட்டெலும்பு
Inferior nasal koncha	மூக்கினிடைக்கீழ் காஞ்சா
Mandible	கீழ்த்தாடை எலும்பு
Vomer	இடைராசி எலும்பு
Malleus	சுத்தி எலும்பு
Incus	பட்டடை எலும்பு
Stapes	அங்கவடி எலும்பு
பாடம் –10 : நரம்பு கட்டுப்பாடு மற்றும் ஒருங்கிணைப்பு Neural control and Co- ordination	
Neuron	நியூரான் (நரம்பு செல்)
Sensory neuron	உணர்வு நியூரான்
Motor neuron	இயக்கு நியூரான்
Automatic functions	தானியங்கு வேலைகள்
Afferent neurons	உட்செல் நியூரான்கள்
Efferent neurons	வெளிச் செல் நியூரான்கள்
Inter neurons	இடை நியூரான்கள்
Nissles granules	நிஸ்சல் துகள்கள்
Node of Ranvier	ரான்வியர் முடிச்சு / கணு
Myelin sheath	மயலின் உறை
Nerve impulse	நரம்புத் தூண்டல்
Axon hillock	ஆக்ஸான் மேடு
Synapsis	நரம்பு செல் சந்திப்பு
Synaptic knob	நரம்பு செல் சந்திப்பு முடிச்சு
Synaptic vesicles	நரம்பு செல் சந்திப்பு பகுதி நுண்பைகள்
Neurotransmitters	நரம்புணர்வு கடத்திகள்
Extra cellular fluid	செல்வெளித் திரவம்
Intra cellular fluid	செல்உள் திரவம்
Resting membrane potential	ஓய்வுநிலை சவ்வின் மின் அழுத்த அளவு
Action potential	செயல்நிலை மின் அழுத்தம்
Polarization	முனைப்பியக்கம்
Sodium-potassium pump	சோடியம்–பொட்டாசியம் உந்திக் கடத்தல்
Depolarization	முனைப்பியக்க நீக்கம்
Threshold stimulus	அவசியமான குறைந்தபட்ச தூண்டல்
Repolarization	முனைப்பியக்க மீட்சி
Spike potential	கூர்முனை மின் அழுத்த அளவு
Hyper polarization	மிகை முனைப்பியக்கம்
Synaptic cleft	நரம்பு செல் சந்திப்பு இடைவெளி
Exocytosis	செல்வெடித்தல்
All or none principle	உண்டு – இல்லை கோட்பாடு
Cranial nerves	மூளை நரம்புகள்
Olfactory nerve	நுகர்ச்சி நரம்பு
Optic nerve	பார்வை நரம்பு
Trigeminal nerve	முக்கிளை நரம்பு
Facial nerve	முக நரம்பு
Hypoglossal nerve	நாவடி நரம்பு

Sympathetic nervous system	பரிவு நரம்பு மண்டலம்
Para sympathetic nervous system	இணைப் பரிவு நரம்பு மண்டலம்
Mechanoreceptors	தொடு உணர்விகள்
Myopia	கிட்டப் பார்வை
Hyper metropia	தூரப் பார்வை
Cataract	கண்புரை
Proprioception	அசைவுகளை உணரும் உணர்வு
பாடம் 11 வேதி ஒருங்கிணைப்பு Chemical co- ordination and integration	
Goose bumps	ரோமங்கள்சிலிர்த்த நிலை
Hormones	ஹார்மோன்கள்
Homeostasis	உடல்சமநிலைப் பேணுதல்
Exclusive endocrinme glands	முழுமையான நாளமில்லாச் சுரப்பிகள்
Neuroendocrine glands	நரம்புசார் நாளமில்லாச் சுரப்பிகள்
Partial endocrine glands	பகுதி நாளமில்லாச் சுரப்பிகள்
Neuro secretory cells	நரம்பு சுரப்பு செல்கள்
Releasing hormone	விடுவிக்கும்ஹார்மோன்
Inhibiitory homone	மட்டுப்படுத்தும் ஹார்மோன்
Hypothalamic hypophyseal portal blood vessel	ஹைபோதலாமிக் ஹைபோ:பைசியல் போர்ட்டல் இரத்தக் குழல்
Hypothalamic hypophyseal axis	ஹைபோதலாமிக் ஹைபோ:பைசியஸ்அச்சு
Limbic system	உணர்வுச் செயலித் தொகுப்பு
Sella turlica	செல்ல டர்சிகா
Infundibulam	இன்:பன்டிபுலம்
Anterior lobe	முன் கதுப்பு
Tropic hormone	தூண்டும் ஹார்மோன்
Feed back	பின்னூட்டம்
பாடம் 12 : அடிப்படை மருத்துவக் கருவிகள் மற்றும் தொழில் நுட்பங்கள் Basic medical instrument ad techniques	
Diagnostic and monitoring Instruments	பரிசோதனை மற்றும் கண்காணிப்புக் கருவிகள்
Imaging Instruments	நிழலுரு கருவிகள்
Therapeutic Instruments	சிகிச்சை கருவிகள்
Biomedical Techniques	உயிரி – மருத்துவ தொழில் நுட்பம்
Stethoscope	ஸ்டெத்தஸ்போப்
Sphygmomanometer	ஸ்பிக்மோமானோமீட்டர் (இரத்த அழுத்தமானி)
Autoanalyser	ஆட்டோ அனலைசர் (தானியங்கி பகுப்பய்வி)
ECG	எலக்ட்ரோகார்டியோகிராம் (இதய துடிப்புமின் வரைவி)
EEG	எலக்ட்ரோ என்செ:பாலோகிராம்
Ultra ound scanner	அல்ட்ராசவுண்ட் ஸ்கேனர்
CT Scanner	கம்ப்யூட்டட் டோமோகிராபி ஸ்கேனர்
Prognosis	முன் கணிப்பு
பாடம் 13 வணிக விலங்கியலின் போக்குகள் Trends in Economic zoology	
Apiculture	தேனீவளர்ப்பு
Drone	ஆண் தேனீ
Nuptial flight	புணரும் பறத்தல்
Pheromone	:பிரோமோன்
Fertilization	கருவுறுதல்
Sterile	மலட்டுத்தன்மை

Hive	தேன்கூடு/தேனடை
Necter	பூந்தேன்
Propolis	புரோபோலிஸ்/ தேன் பிசின்
Swarming	கூட்டமாகசெல்லுதல்/கூட்டமாகபறத்தல்
Inoculation	நோய்தடுப்பு ஊசிமருந்து
Predators	கொன்றுண்ணிகள்
Queen Excluder	இராணித்தேனீ தடுப்பான்
Comb foundation	தேன்கூட்டு அடித்தளம்
Bee glove	தேனீக்கையுறை
Bee veil	முகத்திரை/ தேன் எடுக்க உதவும் முகத்திரை
Hive Tool	தேன்கூட்டு சாதனம்
Honey extractor	தேன்பிழி சாதனம்
Hive entrance guard	தேன் கூடு முகப்பு தடுப்பு
Antseptic	நச்சுத்தடை
Laxative	மலமிளக்கி
Sedative	மயக்கமூட்டி
Masticated	மெல்லுதல்
Hyper parasitism	ஒட்டுண்ணி மேல் ஒட்டுண்ணி வாழ்க்கை
Aquaponics	நீர் உயிரி பயிர் வளர்ப்பு
Deep water culture	ஆழ் நீர் வளர்ப்பு
Media based culture	ஊடக அடிப்படை வளர்ப்பு
Nutrieut film technique	ஊட்டப் பொருள் படல (தொழில் நுட்ப முறை) வளர்ப்பு முறை
Aqua vertica	செங்குத்து முறை
Polyculture	கலப்பின மீன் வளர்ப்பு
Zooplankton	விலங்கு மிதவை உயிரிகள்
Phytoplankton	தாவர மிதவை உயிரிகள்
Isinglass	இஸ்ஸிங்கிளாஸ்
Milch breed	கறவை இனம்
Drought breed	இழுவை இனம்
Duel purpose breed	இரு உபயோக இனம்
Incubator	அடைகாப்பு சாதனம்
Brooding	பேணிக்காத்தல்
Drilospheres	மண்புழு ஏற்படுத்திய குழி
Reeling	பின்னுதல்
Spinning	நூற்றல்
Moricultere	மல்பெரி தாவர வளர்ப்பு
Moulting	தோலுரித்தல்
Diapause type of egg	விரைவில் பொரிக்கும் முட்டைகள்
Non – diapause type of egg	மெதுவாகப் பொரிக்கம் முட்டைகள்
Stifling	புழுக்கூட்டை கொன்று பதப்படுத்துதல்
Brood cells	இளம்தேனீ வளர் அறை
Smoker	புகையூட்டி
Hive tool	தேன்கூட்டுக்கருவி

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