TEST EDITION

THE TEXTBOOK OF

BIOLOGY

For Class XII

SINDH TEXTBOOK BOARD JAMSHORO

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PREFACE

The era we are living in, is the era of science and technology wherein Biology along with its connected disciplines play a pivotal role for the development of society in general and technology in particular, in order to guarantee continuous progress of humankind.

To keep the students abreast of the fundamental knowledge of Biology in a very enlightened manner, this latest edition of The Textbook of Biology for XII is being unveiled and is expected to serve for the cause.

This Text Book is the result of countless endeavors put in by the authors that fundamentally emphasizes on improving the learning skills of students. The book is designed according to the national curriculum and precisely focuses on the concepts of Biology in a student-friendly language and a well-organized manner.

At the beginning of each chapter, students and teachers both will found the objectives of learning about all concepts discussed in the chapter. The text is presented with numerous illustrations and information tables. Also, at the end of each chapter there are several multiple choice and reasoning questions provided to test the learned concepts.

The study material presented in this book covers the subject in accordance with the revised curriculum prepared by the Ministry of Education, Govt of Pakistan, Islamabad and is reviewed by independent team of Bureau of Curriculum, Jamshoro Sindh. Every topic is covered in the same level of detail that is considered prerequisites for the professional studies at undergraduate level.

Last but not the least, I am grateful to the learned authors, reviewers and editors of this text book especially Prof. Dr. Nasiruddin shaikh (First V.C of GCU Hyd.) who played major role as author, reviewer and editor to give this shape of book by his untiring efforts. I also admire Director (ART) and Subject Specialist (Biology) of Sindh Textbook Board for their day and night effort for the nation cause to develop future nation.

Chairman
Sindh Textbook Board

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HOMEOSTASIS

Chapter 15

Major Concept

In this Unit you will learn:

- Homeostasis
- Osmoregulation
- Excretion
- Urinary system of Man
- Disorders of Urinary Tract
- Thermoregulation

HOMEOSTASIS

The term homeostasis was introduced by Walter B. Cannon (1871–1945). He described it as a self-regulating process by which biological systems maintain stability while adjusting to the changing conditions. Homeostasis is essential for the continuity of life as it is responsible for the stability of body functions according to the environment.

Organisms live in terrestrial and aquatic environments. These environments have variable conditions, i.e., moderate to extreme conditions which influence upon the organisms and they tend to develop physical and physiological changes in their body accordingly. In view of the environmental changes, organisms need to maintain their internal body environment up to suitable limits. The body environment comprises of different components including body fluids, tissues, organs, systems etc. These components are physiologically well integrated and efficiently controlled and coordinated by endocrine as well as nervous systems. These systems ensure the proper performance of the homeostatic regulatory functions like **osmoregulation**, **excretion** and **thermoregulation**, in the body and adjust to maintain the balance between the external and internal body environment.

15.1 ELEMENTS OF HOMEOSTASIS

Homeostatic surveillance is based upon necessary physiological check and balance mechanism of the body functions that maintain its normal state called **feedback system**. Feedback mechanism develops through some integrated components **i.e., receptors, control center and effectors.** Receptors are the sensory organs that are neurologically connected with the nervous system, detect any external or internal environmental changes and send messages to the central nervous system (CNS). CNS act as control center and respond by concerned effector organs to bring back the normal state of the body.

15.1.1 Feedback systems

Feedback, in biology, a response within a system (molecule, cell, organism, or population) that influences the continued activity or productivity of that system. There are two types of feedback

mechanisms that counter act upon each other called positive and negative feedback.

The **positive feedback** is concerned with the increase or initiate the change of output for any biological process, e.g. if body is injured and bleeds positive feedback begins by the action of platelets. Platelets reached at the site of injury through circulating blood, recognize the damaged area and begin to stick together to stop the loss of blood and patch up the tear in the wall. Eventually blood clot is formed, the loss of blood is kept to a minimum, and the positive feedback ends. Positive feedback does not maintain a stable, homeostatic condition rather it intensifies the change that is happening to the body.

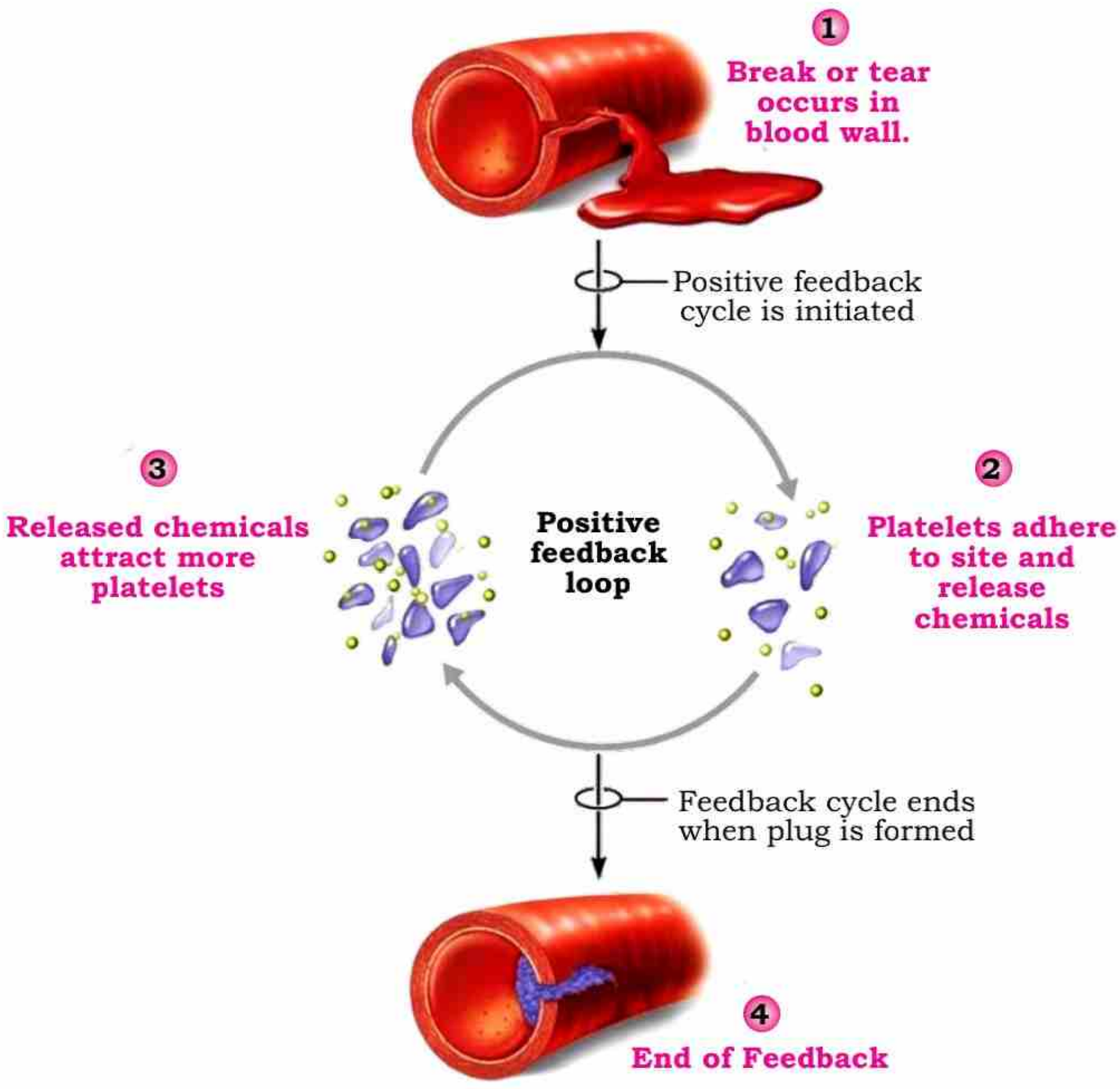


Fig.15.1 Positive feedback mechanism

The **Negative feedback** suppresses the normal physiological activities to bring body back to normal state e.g. when it is cold out,

and body temperature decreases below the set point range. A **set point** is the physiological value around which the normal range fluctuates. A **normal range** is the restricted set of values that is optimally healthful and stable. The negative feedback loop will cause the body to shiver producing heat and ultimate body temperature will return within the set point.

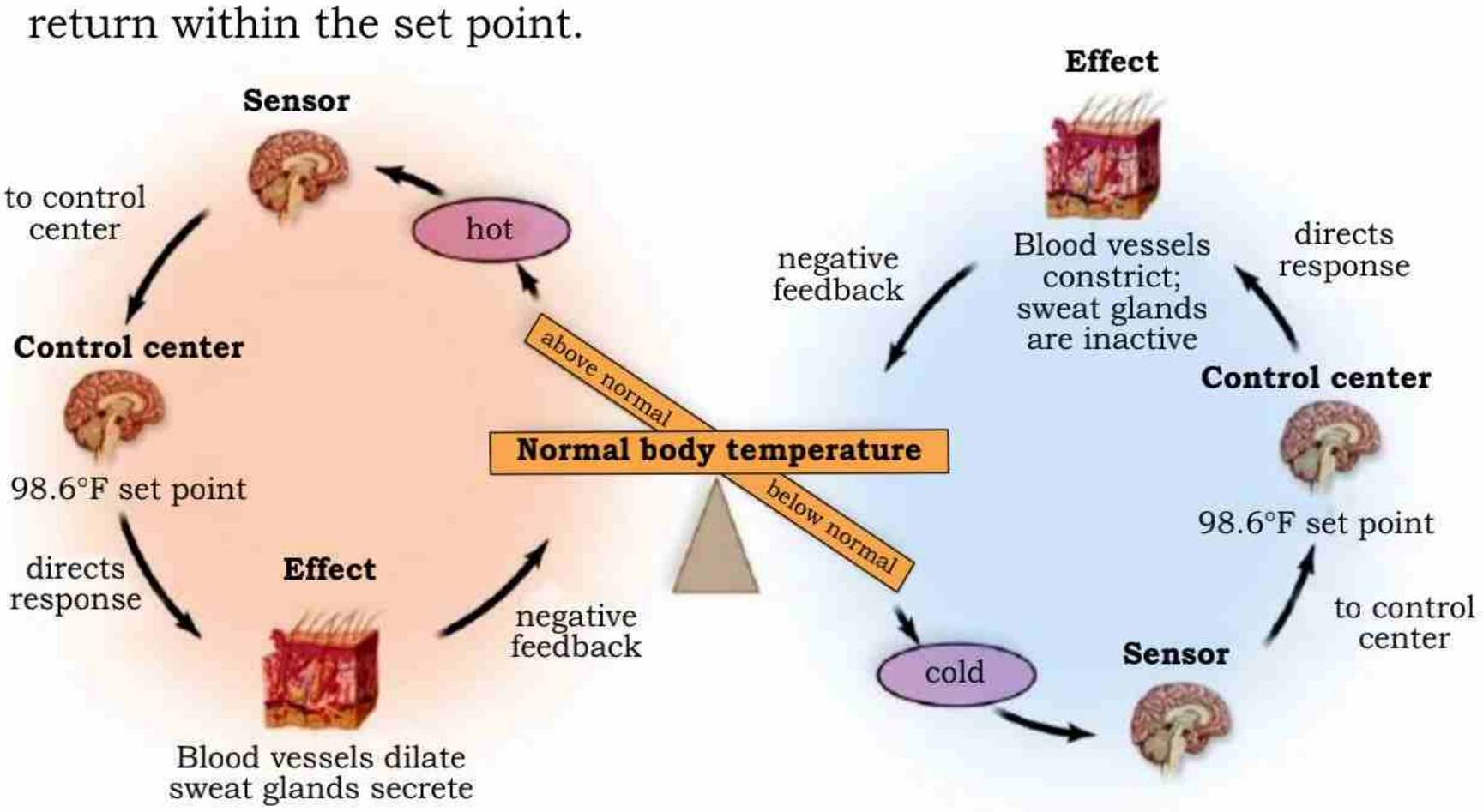


Fig.15.2 Negative feedback mechanism

15.2. OSMOREGULATION

Organisms must need appropriate amount of water and minerals in their body to perform many vital functions.

Extra Reading Material

Osmoconformers are another group. This does not mean that they have the similar solutes in their body as present outside instead they contain urea and trimethylamine oxide (TMAO) in their blood to adjust osmotic balance. TMAO accumulates in the tissue and protects against the protein-destabilizing effects of urea, for examples shark and most of the marine invertebrates like echinoderms (such as starfish), mussels, marine crabs, lobsters, jellyfish, ascidians are osmoconformers.

15.2.1 Osmoconformers and Osmoregulators

Osmoconformers	Osmoregulators
Organisms that have internal body solute composition equals or isotonic to the external environment	Organisms maintain a constant internal osmotic environment in spite of changes in their external environment
These are marine organisms.	They live in marine, fresh water and terrestrial environments.
Can survive in wide range of salinities	Can survive in a narrow range of salinities

15.2.2. Problems faced by Osmoregulators

Fresh water animals have an external hypotonic environment while they retain salts in their body, they have hypertonic internal body environment. In this case water enters the body by endosmosis through their organs like skin and gills and disturbs the internal osmotic balance. This problem is resolved by different adaptations to remove excessive water from the body.

Marine animals have hypertonic external environment and they face the problem of severe dehydration. Therefore, they need to intake or drink water but in this case another problem develops which is about the retaining salts that enters with water which also imbalance the osmoregulatory components of the body.

Terrestrial organisms retain water in their body, while bearing external hot environment they perspire and not only dehydrates but also lose essential salts which disturbs the osmotic balance of the body.

15.2.3 Methods for osmoregulation in fresh water, marine and terrestrial habitat

Osmoregulation in fresh water Habitat

Fresh water animals have internal hypertonic and external hypotonic environment. Fresh water fishes face the problem of osmotic incursion of water from gills and skin and minimize the loss of salt by urine and by diffusion across the gills. The water influx and salt removal are balanced from the kidney by producing dilute urine. The filtration rate in kidney is high and they are specialized to actively

reabsorb salts and send back into the blood. Fresh water organisms also have specialized cells located in their gills and in skin called **ionocytes** which actively extract Na^+, Cl^- and Ca^{++} from external medium and excrete (H^+) or basic (HCO_3^-) for acid base balance in the body fluids.

Osmoregulation in marine water Habitat

Marine animals also need to retain water in their body for their metabolic requirements. They have higher concentration of water in their blood than their surrounding environment. They don't gain water like fresh water organisms due to their external hypertonic environment, therefore they intend to drink lot of water and also digest its salts which are harder than fresh water salts. In marine bony fishes, the gills, kidney and digestive tract are involved in maintenance of body fluid balance, as the main osmoregulatory organs. These fishes are capable of digesting marine salts which are added in their blood along with water, excessive salts are extracted and remove by specialized rectal glands in intestine and salt glands located in gills. These fishes reabsorb water some salts and excrete very small amount of urine with excessive salts mainly divalent ions, mainly Mg^{++}, SO_4^{--}, Na^+, Cl^-, Ca^{++} from the kidney.

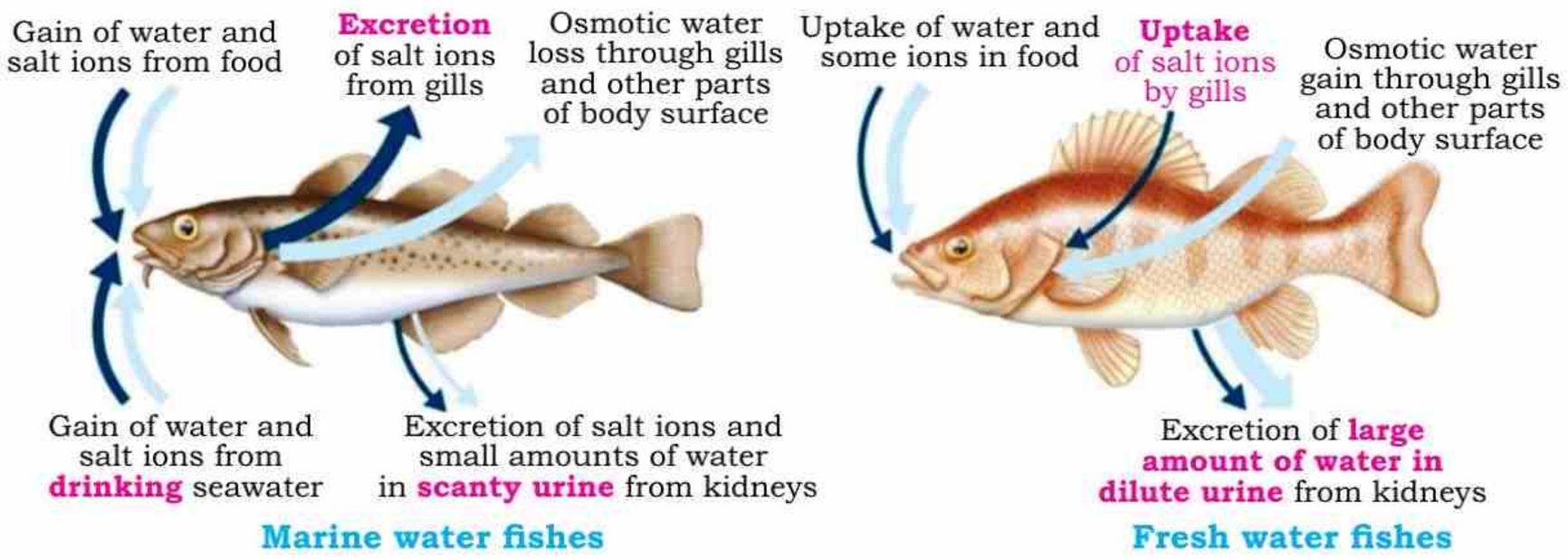


Fig.15.3 Osmoregulation in marine and freshwater fishes

Osmoregulation in terrestrial Habitat

Terrestrial animals live in moderate to extreme environmental conditions on land. Some are immensely exposed to scorching sun and

temperature and face the severe problem of dehydration like in desert while others live in moderate environment but all of them need to conserve water and essential solutes in their body. These organisms can lose water from integument, excretion and exhaling during breathing, therefore they have evolved many adaptations in response to environmental stresses. These adaptations are related with preventing removal of water from skin or body covering, not losing much water by excretion and maintaining osmotic balance of the body fluid by metabolic activities within the body. To prevent water loss from the skin they develop water proof external covering as exoskeleton made up of keratin, chitin and $CaCO_3$ found in various arthropods and other organisms. Animals produce excretory waste which require less amount of water like uric acid and conserve water through efficient reabsorption in kidney and intestine. Some animals like camel, kangaroo-rat, etc., in the absence of environmental water get it through metabolic water by breakdown of fats and other compounds during cellular oxidation reactions as a byproduct.

Extra Reading Material

The major cause of water loss in terrestrial insects is due to its tracheal system. Certain terrestrial arthropods have the ability to extract water vapor directly from air.

15.3.1. EXCRETION

Excretion is a process of removal of metabolic waste produced during biochemical reactions in the body. It is an important homeostatic activity as in broader sense it involves controlling the osmotic pressure, the balance between inorganic ions and water and maintaining acid base balance of the body. Though the waste includes variety of compounds like CO_2, nitrogenous waste including ammonia, urea and uric acid, in a restricted sense, we are going to discuss the removal of nitrogenous wastes only.

15.3.2. Excretory products in relation to habitat:

Animals produce different types of nitrogenous excretory waste. The major types of nitrogenous wastes are **ammonia, urea, uric acid, and creatinine**. Both wastes and their removal depend upon firstly, the nature of food like herbivores do not excrete as much urea as

carnivores because carnivores eat more protein, and therefor excrete more nitrogen, secondly, availability of water and third the animal's habitat. Nitrogenous waste produced as a byproduct due to the breakdown of protein and nucleic acids.

Extra Reading Material

Animals live in aquatic places generate large amount of ammonia are called ammonotelic because they need lot of water to dissolved ammonia in it. Terrestrial animals excrete urea are called ureotelic and for producing uric acid called uricotelic later two products require comparatively less amount of water to dissolved then ammonia as land animals occasionally face shortage of water in their habitat.

Ammonia:

Ammonia is an immediate and highly toxic gaseous waste initially produced by the breakdown of nitrogenous compounds in the body. It is exceedingly soluble in fresh water and body fluids and raises the pH therefore should be present in low concentration in the body. Ammonia reduces its toxicity in water and requires lot of fresh water to dissolved and generate non-toxic ammonium (NH_4^+) ions, therefore produced in aquatic animals in gaseous form and mostly diffused out from the body while some amount also excreted through urine as urea. Ammonia is also produced in terrestrial animals and converted in to another nitrogenous product i.e., urea and excreted through urine from the body. Chemically it is alkaline, corrosive and 100,000 times more toxic than urea. Animals that excrete ammonia are said to be **ammonotelic.**

Urea:

Urea $CO(NH_2)_2$ is the nitrogen containing liquid waste product produced by the breakdown of protein in mammals, amphibians, in some fishes and excreted in urine. It is also called carbamide, neither acidic nor alkaline and highly soluble in water. Liver combines ammonia with CO_2 molecule to form some intermediate compounds and then produces urea in the urea cycle or ornithine cycle. Animals produce urea are called **ureotelic.** Urea is not only a waste product in the body but also plays important role in the absorption of important ions and water in kidneys.

Extra Reading Material

Urea is beneficial as a raw material source of nitrogen for making fertilizers in chemical industry. In humans blood nitrogen test (BUN) is performed to check the renal function for the removal of urea and other nitrogenous waste.

Uric acid:

Uric acid is another nitrogenous compound and oxidative metabolic product of purines present in nucleic acids. It is also structurally resembled with purines, weak acidic and less soluble in water than ammonia and urea. It is about 10,000 times less toxic than ammonia. Animals that produce and excrete uric acid are called **uricotelic** which include reptiles, birds and numerous arthropods like insects etc. Uric acid can be stored in the body tissues without any toxic effect or harm. Excretory wastes contain uric acid appears thick paste like and needs less amount of water and animals get the advantage to conserve water in their bodies. In humans 75% uric acid is excreted by kidneys and 25% is excreted by intestine.

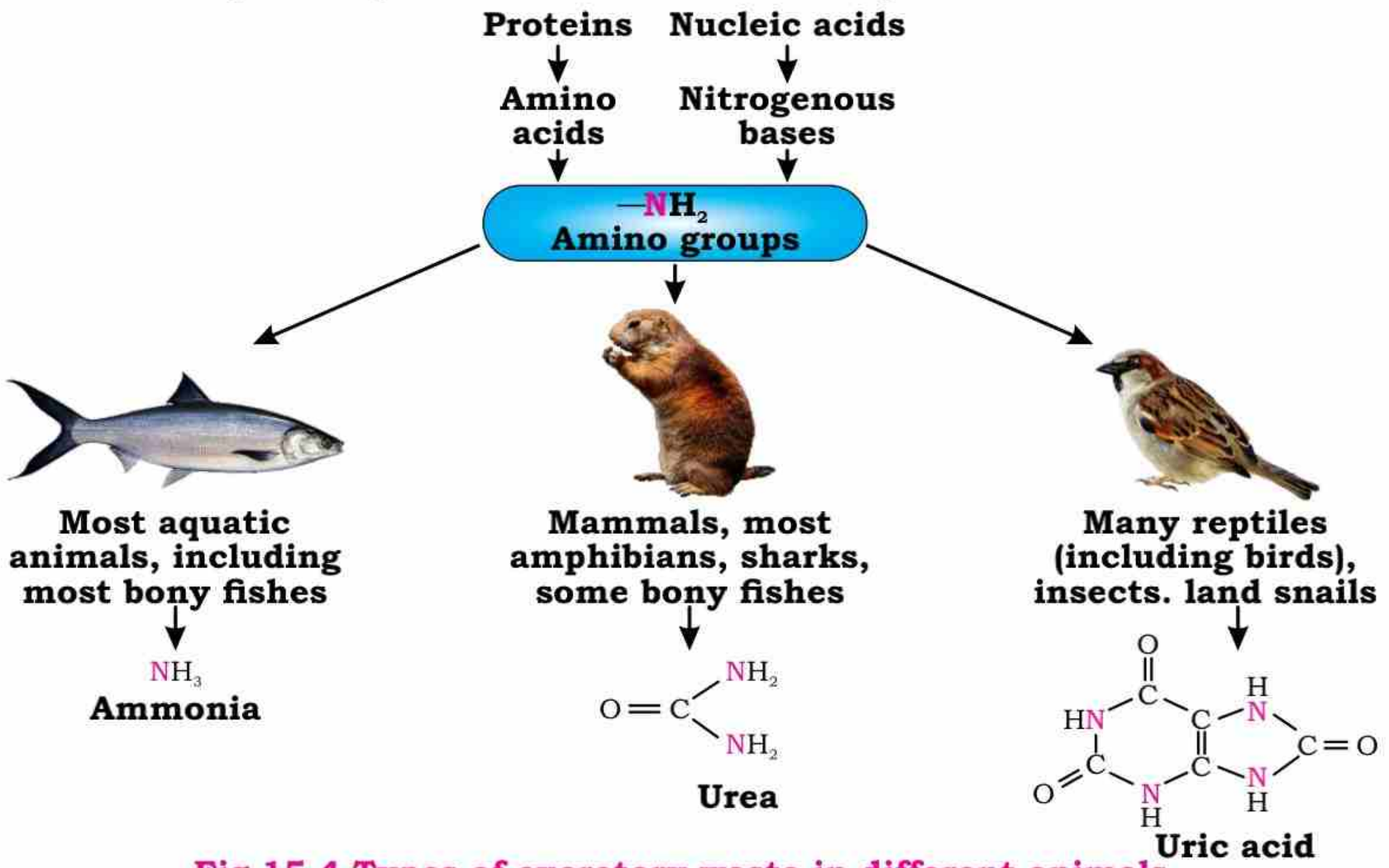


Fig.15.4 Types of excretory waste in different animals

15.4.1 Urinary System of Man

The **urinary system** or renal system is a system for removing waste from the body. This system not only removes the toxins but also maintain the body's homeostasis regulating the body acid base balance by controlling the electrolytes and metabolites, blood pressure and blood pH. The organs associated in urinary system are a pair of kidneys, ureters, a bladder and urethra.

Extra Reading Material

In humans the normal range of ammonia in blood is 15 to 45 µmol /L (11 to 32 µmol/L) while 100 µmol /L can lead to disturbance of consciousness. A blood ammonium concentration of 200 µmol /L is associated with coma and convulsions.

Kidneys are the blood purifier. These are paired, bean shaped structures located in abdominal cavity. Blood enters in to the kidney by renal arteries, both kidneys filter and remove waste substances from the blood and form filtrate. That filtrate ultimately becomes urine which flows down through the ureter. **Ureters** are 25 to 30 cm long tubes connected anteriorly with kidneys by wide opening called **renal pelvis** posteriorly they become narrow and extended downward to join urinary bladder. Ureters drain urine in to the **urinary bladder** where it is temporarily stored. The wall of the bladder is thick muscular and strong enough to hold half liter of urine in adults for some time then it is excreted out from the body by a connected muscular thin tube called urethra.

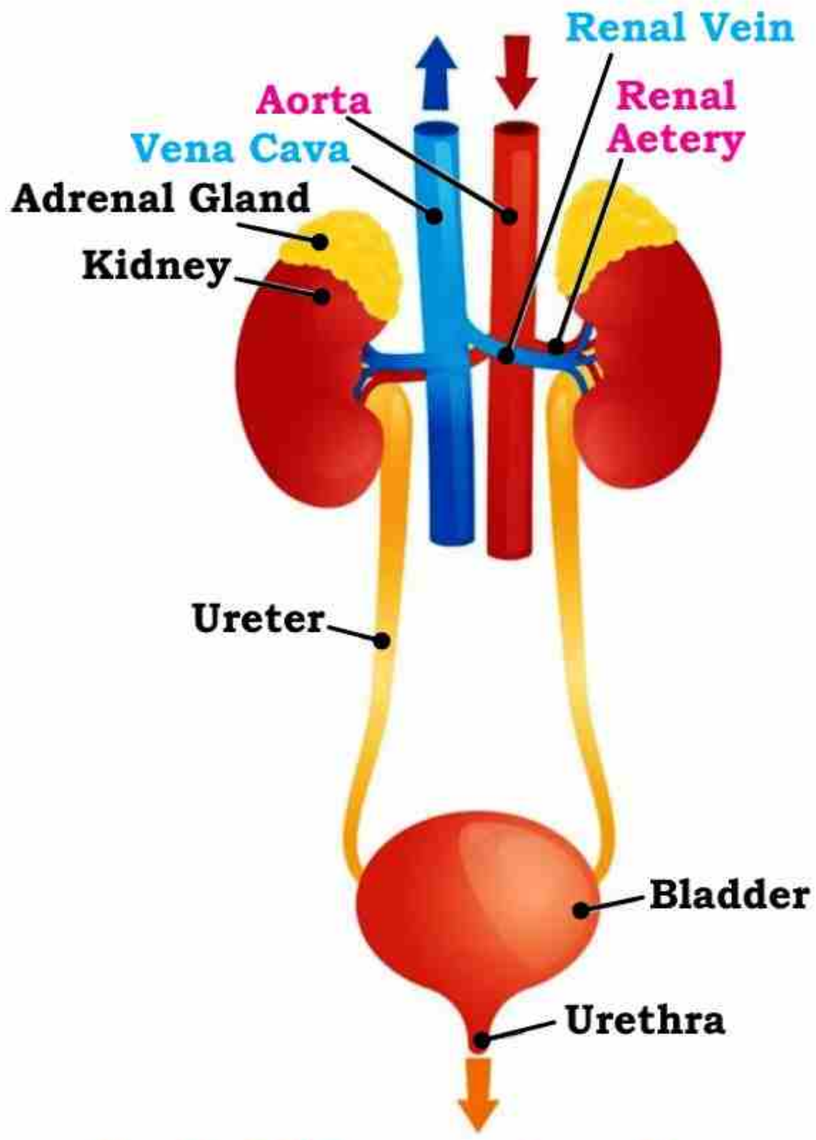


Fig.15.5 Urinary system of man

Urethra has valves called sphincters that control the flow of urine. The internal urethral sphincter regulates involuntary control of urine flow from the bladder to the urethra, and the external urethral sphincter provides voluntary control of urine flow from the bladder to the urethra.

15.4.1. Structure and Function of Kidney

Kidneys are symmetrical, bean shaped reddish brown structures located just below the rib cage, one on each side of the vertebral column between the 12th thoracic and 3rd lumber vertebrae. Kidneys positioned retroperitoneal in the abdominal cavity. These are 4 to 5 inches long almost size of the fist. The right kidney is located slightly below the left kidney providing space to adjust liver. Left kidney is slightly larger and closer to the heart.

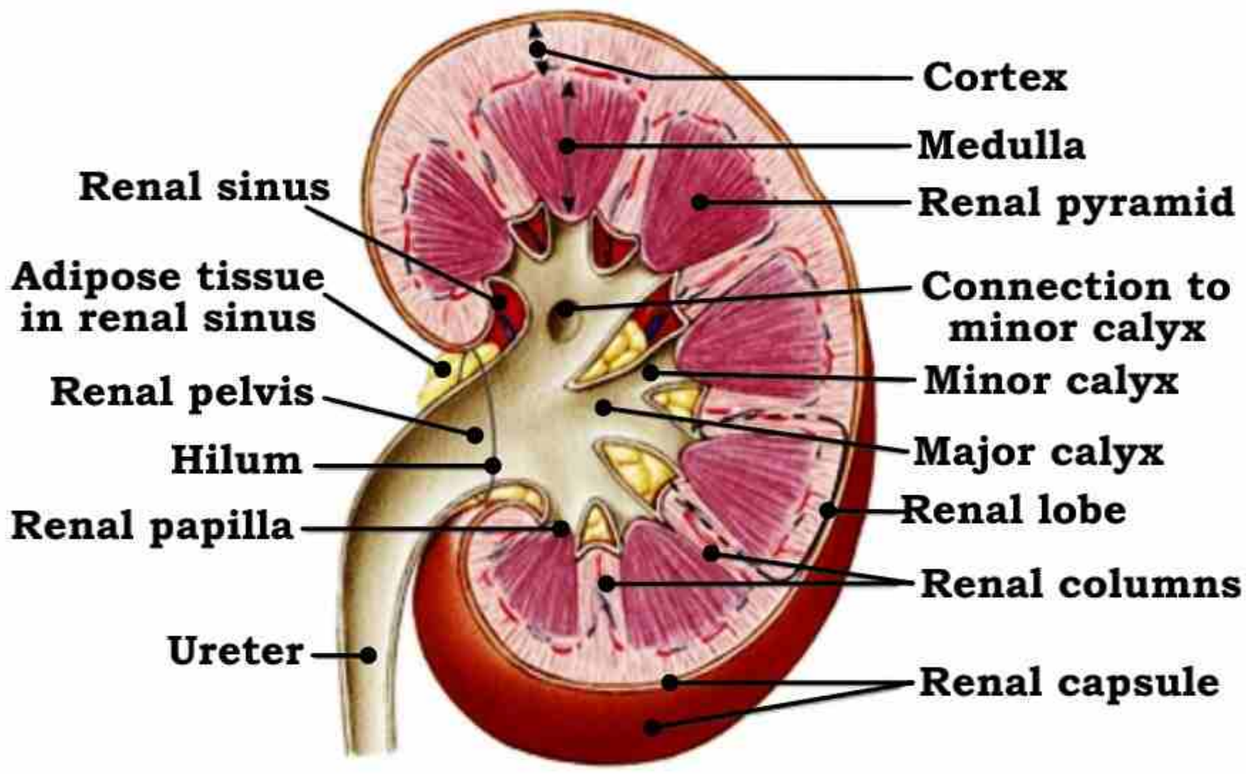


Fig.15.6 L.S of Human kidney

Externally kidneys are surrounded by a layer tough connective tissue called **renal fascia** behind that another fatty layer is present and the inner most layer covers the kidneys called **renal capsule**. Kidneys are laterally convex laterally and the medial side is deeply concave this medial depression hollow from inside called **renal sinus**. In the medial depression a small convex region is called hilum is present which has hollow sinus inside and serve as an important location for the entrance of blood vessels, nerves, lymphatic vessels and the ureter into the kidney.

Kidneys have two distinct regions internally: an outer cortex and inner **medulla**. Renal **cortex** is surrounded by renal capsule which provides shape to the kidney. Renal cortex contains arteriole and venule and the cells called **nephron**. This is outer thin region then the medulla and produces an important hormone **erythropoietin** necessary for the synthesis of RBC's.

Renal medulla is composed of compact seven to eighteen conical shaped masses of tissues called renal pyramids. The spaces in between pyramids are called renal columns. Medulla regions mostly contain the loop of Henle part of nephron and the collecting ducts. Urine enters the collecting duct and then flow towards the hilum and then collected by pelvis and ureter to remove from the body.

15.3.2. STRUCTURE OF NEPHRON

Both kidneys are consisted of millions of functional units called nephrons. These nephrons are about one million in each kidney and mainly perform filtration of blood. There are two types of nephrons present in the kidneys. The juxta medullary nephrons have longer loop of Henle penetrates deep inside the medulla and cortical nephrons with shorter loop of Henle restricts only in cortex region. Juxta medullary nephron consists of a **renal corpuscle** and a **renal tubule**.

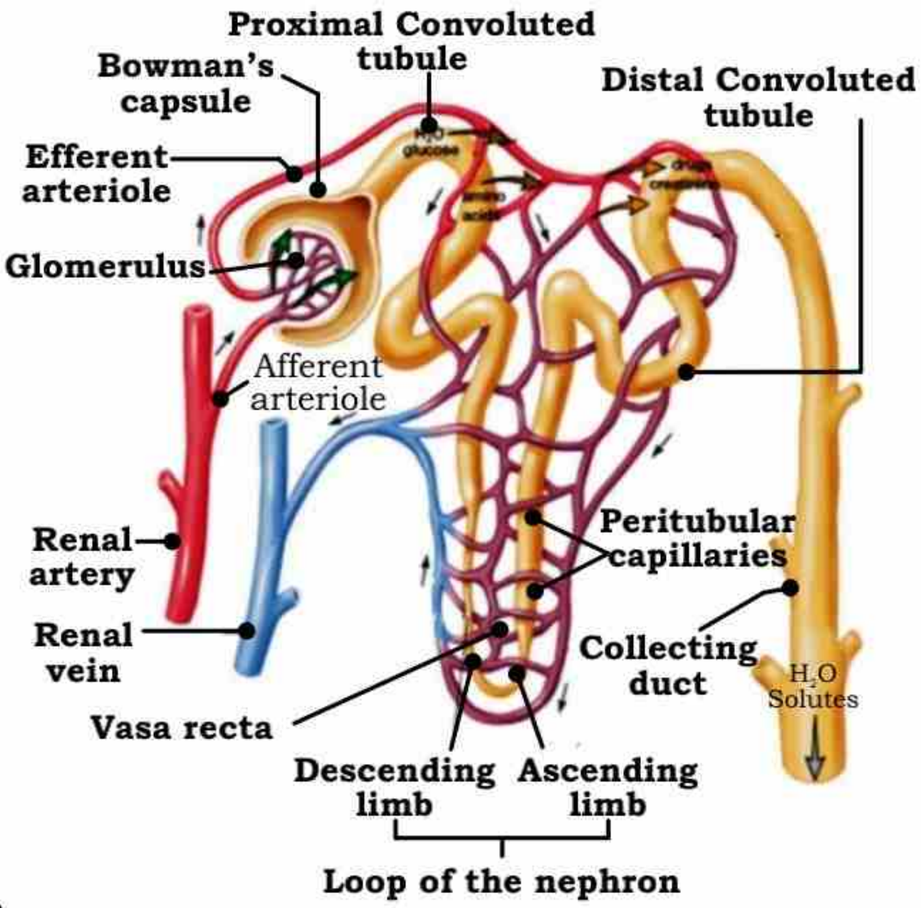


Fig. 15.7 Structure of Nephron

Renal corpuscle consists of a dense cluster of blood capillaries network called **glomerulus** surrounded by thin-walled covering called **Bowman's capsule** or glomerular capsule and both are collectively called **malpighian body**. Glomerulus is the ball like structure which arises from afferent arterioles. High volume and pressure of blood facilitates the ultra-filtration in this region. Glomerular capillaries have pores of about 70 nm in diameter which prevents the large molecules and blood cells to

pass through it. Glomerulus have specialized **Podocyte cells** that are wrapped around blood capillaries. These cells have small slits like opening that play an active role in preventing plasma proteins from entering the urinary ultrafiltrate. All the glomerulus capillaries fuse to form efferent arteriole, which exit the malpighian body.

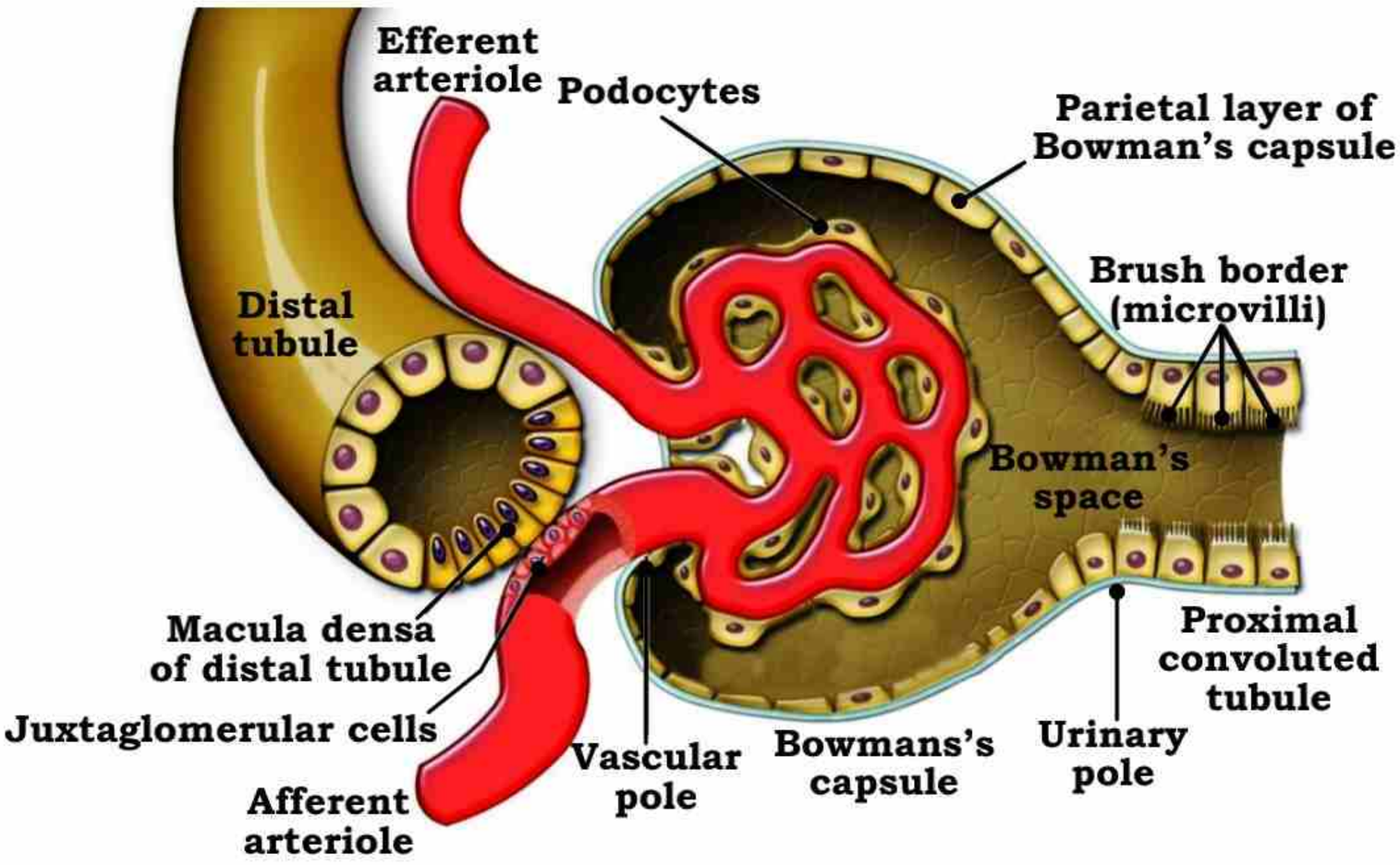


Fig.15.8 Nephron Glomerulus and Podocytes

Bowman's capsule further extended and form **renal tubule** which becomes highly coiled. This coiled region is called **proximal convoluted tubule (PCT)**, most of the essential compounds like glucose, amino acids, electrolytes and water is reabsorbed in this region. The PCT runs down towards the renal pyramids of medulla to become descending limb of loop of Henle. The tubule then turns back towards the bowman's corpuscle making an ascending limb and then coiled again and is called **distal convoluted tubule (DCT)**. Several DCT joins the common duct called **collecting duct**. Which carry urine to the renal pelvis to exit from the kidney.

Blood supply to the nephron

Renal artery enters in kidney at hilus, which further divides into numerous smaller arterioles. One of the arterioles such as afferent arteriole forms the dense network as glomerulus and leaves it as efferent arteriole. The diameter of afferent arteriole is larger than

efferent arterioles, due to difference in diameter between these arterioles, high pressure in glomerulus than other capillaries elsewhere.

The efferent arterioles extended down and forming a network of capillaries called **peritubular capillaries** that surround the both PCT and DCT. It provides nutrients and oxygen to the renal cortex. It moves downward along with loop of henle give branches which are laterally connected with the capillaries of renal vein or venule in the region of medulla. This complex network capillaries over the loop of henle called **vasa recta**. After passing through the vasa recta blood flow through peritubular capillaries system and enters in to the renal vein to join venous circulation and leaves the kidney.

15.3.3. Functions of the kidney

Kidneys are very important homeostatic organs. It filters our blood and excretes waste and extra fluid from our body by urine. Kidneys also work as an endocrine organ and secrete some vital hormones like **renin** and **erythropoietin**. Renin maintains the blood pressure while erythropoietin is involved in red blood cells production. Kidney produces an active form of vitamin D3 which helps to absorb calcium and phosphorus in our bones. These important minerals keep bones strong. Kidneys balance the pH of our body by making changes and adjusting amount of bicarbonate HCO^{3-} from the urine back to the blood and by secretion of H^+ ions into the urine. Kidney regulates the water balance by producing dilute and concentrated urine according to the external environmental changes. The process of producing urine occurs in three stages glomerular filtration, selective reabsorption, and tubular secretion.

Table 15.1
Composition of plasma and urine

Substance	% in plasma	% in urine
Water	90	95
Protein	8	0
Glucose	0.1	0
Urea	0.03	2
Uric acid	0.004	0.05
Ammonia	0.0001	0.04
Creatinine	0.001	0.075
Na^+	0.32	0.35
K^+	0.02	0.15
Cl^-	0.37	0.60
PO_4^{-3}	0.009	0.27
SO_4^{-3}	0.002	0.18

a) Glomerular filtration

Urine is the ultimate kidney product and based upon waste removed from the blood with addition of some other fluids and ions. This process is initiated in the glomerulus when blood is filtered out under hydrostatic pressure leaving the small molecules of waste and other compounds as **glomerular filtrate** this process is called **ultra-filtration**. Filtrate primarily includes water, electrolytes, some amino acids, bicarbonates and nitrogenous wastes like urea, uric acid and creatinine. Glomerular filtration rate (GFR) is directly proportional to the hydrostatic pressure exerted in its wall. This pressure is increased due to the difference in diameter of both afferent and efferent arterioles as mention earlier. Kidney receives 180 liters of blood by circulation in 24 hours and after filtration it produces 2.5 liters urine in normal climatic conditions. GFR usually remains constant by autoregulation however it may change depending upon the fluid intake or its variable amount in the body.

b) Selective reabsorption

The composition of glomerular filtrate and the urine is different it means that the fluid contents become change while passing through the renal tubules including PCT, loop of henle and DCT in nephron. For example, glucose if present in the filtrate but absent in the urine of a healthy person. The amount of urea and uric acid present more in urine than the filtrate. These changes are the outcome of selective reabsorption and the tubular secretion. **Selective reabsorption** is the process whereby certain molecules after being filtered out of the capillaries along with nitrogenous waste products (i.e., urea) and water in the glomerulus, are reabsorbed from the filtrate as they pass through the nephron and return back to the blood circulation. Most of the selective reabsorption of molecules takes place in proximal convoluted tubule (PCT). Water (about 67%), Na^+ and K^+, variable quantities of Cl^- (about 50%), Ca^{2+}, Mg^{2+}, and HPO_4^{2-} ions, important nutrients like glucose (100%), amino acids, vitamins and other organic substances are reabsorbed in PCT and given back to the blood circulation. Water is absorbed passively while glucose and sodium are absorbed actively. Na^+ drags the other negatively charged ions due to opposite charge interaction. Hormone aldosterone facilitates the sodium and ADH facilitates the water reabsorption.

c) Tubular secretion

In this process certain substances moves in to the filtrate of PCT and DCT from blood plasma. This includes waste that escape during ultra-filtration and remained in the blood. These substances are absorbed actively and include urea, creatinine, hydrogen ions, potassium ions, some hormones and drugs if present. Tubular secretion mostly performed by proximal convoluted tubule (PCT) but some of the K^+ are also secreted from DCT and collecting duct due to reciprocal exchange of Na^+ with K^+. it adjust the pH of urine.

d) Counter current mechanism

The counter current mechanism is biological processes intend to allow maximum exchange of molecules between two fluids of different concentration which are moving in opposite directions. This mechanism involves loop of henle and the environment of medulla. In medulla region of the kidney, the **ascending limb of loop of henle** is permeable to Na^+, K^+ and Cl^- ions while impermeable to water. The **descending limb of loop of henle** is permeable to water.

Ascending limb cells have specialized ionic co-transporter protein, each allow one Na^+ with one K^+ and two Cl^- hence allow lot of ions to move out from the entire limb. when these ions are actively reabsorbed from the ascending limb and accumulated in medulla, it makes medulla environment hypertonic. This movement of ions is also facilitated by a steroid-based hormone called **aldosterone** secreted from the cortex region of adrenal gland. Movement of water molecules is facilitated by **anti-diuretic hormone (ADH)** secreted from posterior lobe of pituitary gland. Another compound that increases the osmotic gradient in inner medulla is the **Urea,** it enters in the medulla from the collecting duct and along with other ions, helps the reabsorption of water. This process is called **counter current multiplier**. Now there is another counter current mechanism performed in between nephron loop of Henle and the peritubular capillaries or vasa recta.

The loop of Henle is surrounded by peritubular capillaries containing blood. These capillaries are permeable to both water and ions so due to high ionic concentration in the interstitium, water is diffusing out and solutes diffuse inside the capillaries that travel

alongside the descending limb, if this blood is carried away it destroy the medullary concentration gradients. Therefore, to counter act this effect the peritubular capillaries alongside of **ascending limb** releases the extra solutes which diffuse back in to the medulla hence maintaining the concentration gradient inside medulla and making blood more dilute. This process of exchange of gradient in vasa recta or peritubular capillaries is called **counter current exchange.** So, the water is secreted then reabsorbed in to the system. Solutes are reabsorbed then secreted in to the medulla. Normally the blood flow is slower in peritubular capillaries or vasa recta to allow time for passive diffusion.

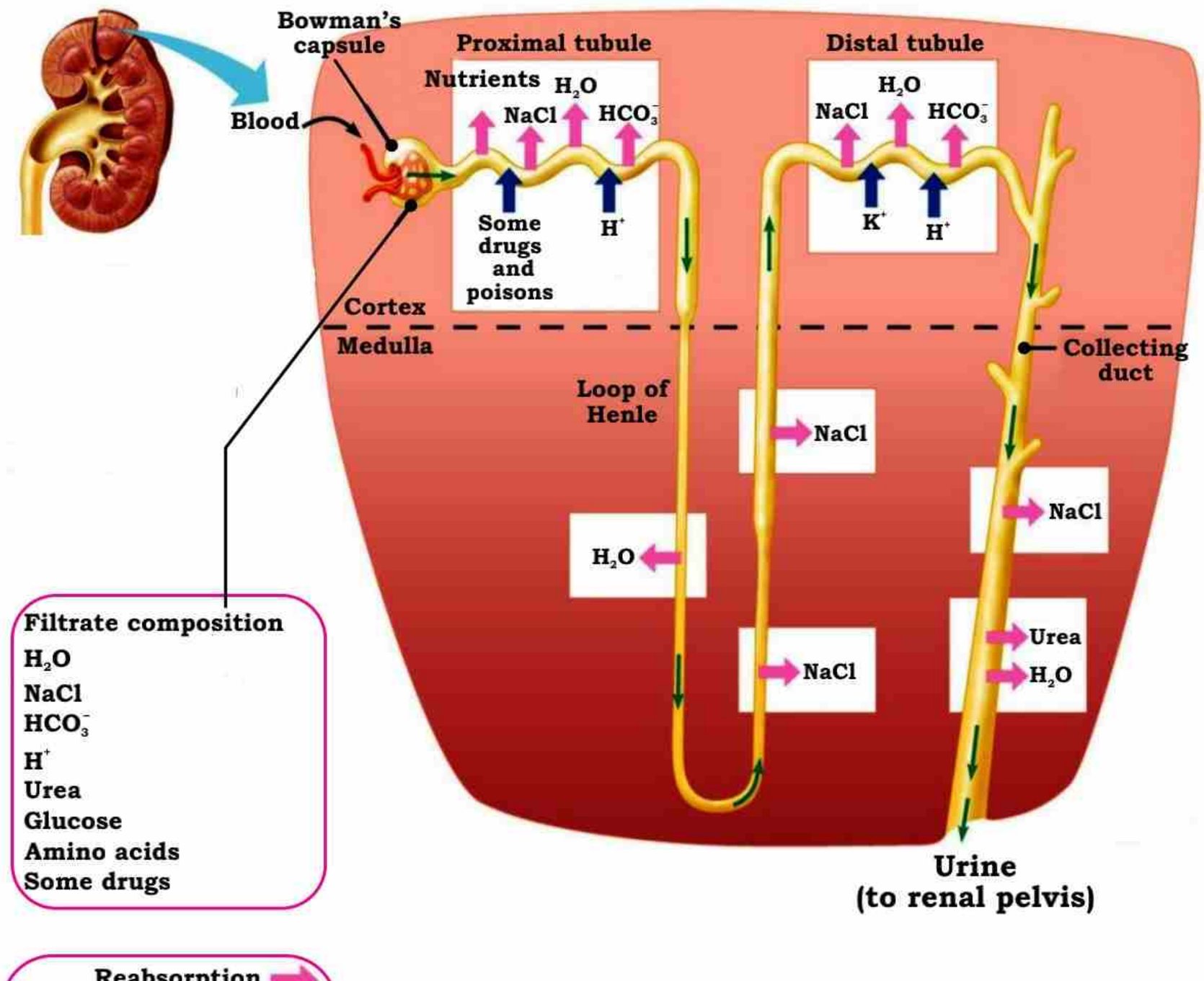


Fig.15.9 Urine formation

15.4. DISORDERS OF URINARY TRACT

Urinary tract infections are the infections in organs associated with urinary system. These infections are usually caused by bacteria and viruses that invade or enter through anus or urethral opening or by other means. The site of infections could be any part of the urinary system like kidneys, bladder ureters and urethra

The most common urinary tract infections among others are **Pyelonephritis, Cystitis and Urethritis.**

Name of the disease	Cause	Symptoms
Pyelonephritis	E. coli	if bacterium reaches in the kidneys it brings nausea, vomiting, back pain, high fever with cold
Urethritis	E. coli, Chlamydia, Neisseria gonorrhea	Feeling the frequent or urgent need to urinate, Difficulty starting urination, Pain during sex, Discharge from the urethral opening or vagina
Cystitis	E. coli	A strong urge to urinate, Pain or a burning feeling when urinating, Passing frequent, small amounts of urine, Blood in the urine, Passing cloudy or strong-smelling frequent urine, Pelvic discomfort, A feeling of pressure in the area below your belly button (abdomen), Low-grade fever.

15.5.2 Kidney Stones

Urine contains many dissolved mineral and salts that form different compounds. The components of these compounds include calcium, sodium, potassium, oxalates, uric acid and phosphate. Increased level of calcium in urine is called **hypercalciuria** and high level of oxalates in urine is called **hyperoxaluria**. When these components in the urine get too high or urine becomes too acidic or basic, they combine to form crystals. The crystals progressively grow and become detectable stones in months or a year. This presence of stones in the kidney is called **Nephrolithiasis** or **Urolithiasis** and the

inflammation in kidneys due to irritation of kidney stones is called **Lithonephritis.** Kidney stones hinder the flow of urine and cause severe pain in the back. **Calcium oxalate** is the most common type of crystals to form 80 % of kidney stones. Other 5 to 10% of less common type of kidney formed by **calcium phosphate or uric acid**. Some stones are formed by **magnesium ammonium phosphate** (struvite) in alkaline urine due to bacterial activity. These stones are about 10 percent and called struvite or infectious stones. Less than 1 percent of urines stones are formed by an amino acid cystine. **Cystine** stones are usually formed in childhood.

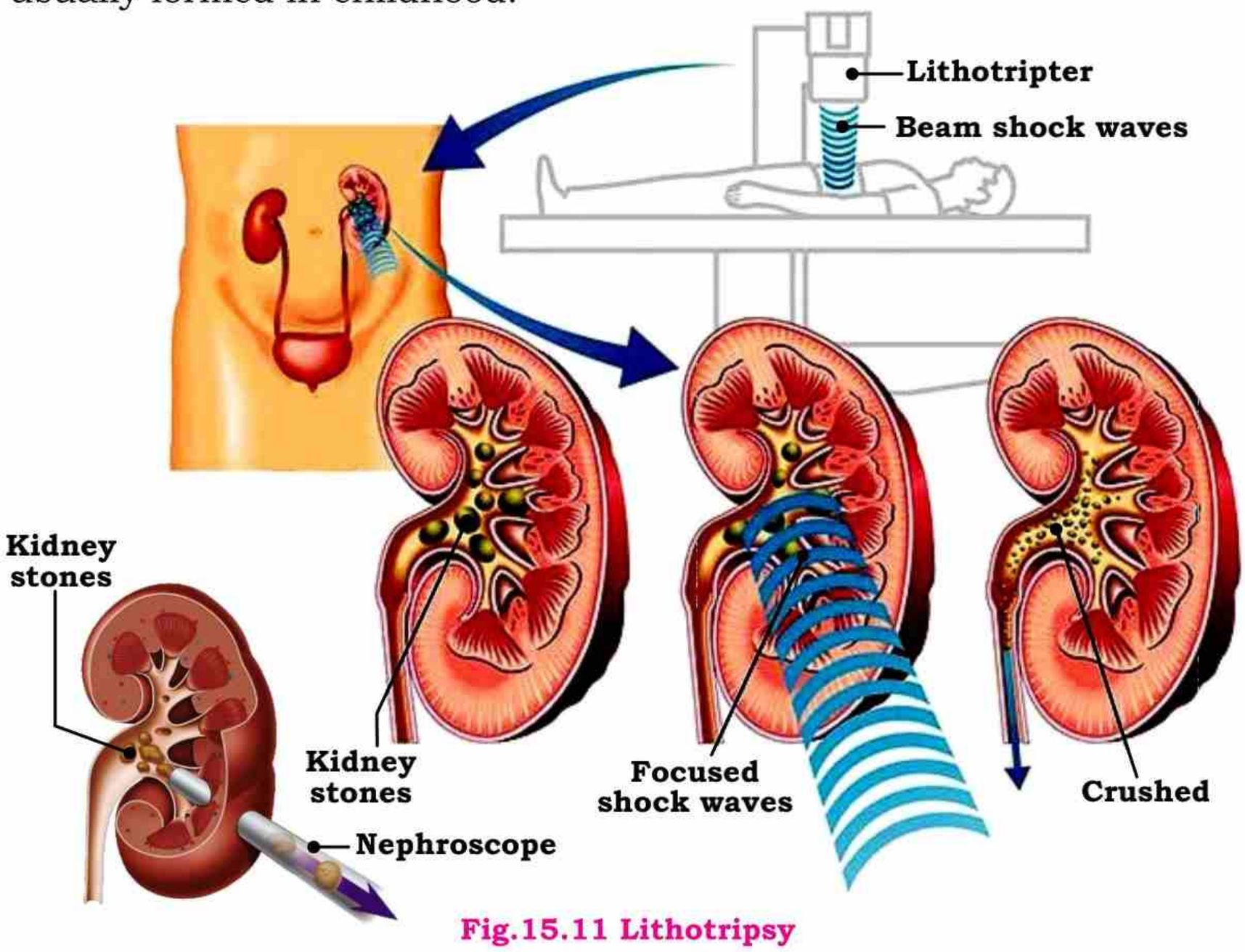


Fig.15.11 Lithotripsy

Kidney stones can be treated from outside the body by shock waves. This treatment is called **extracorporeal (outside the body) shock wave lithotripsy (ESWL).** Another treatment for kidney stone is **percutaneous nephrolithotomy (PCNL)**. This procedure is used to remove kidney stones when they can't pass on their own. This is made under the general anesthesia in which patient will be a sleep. During

this procedure one catheter is placed in the bladder to drain urine out of the body then another catheter is inserted into the ureter to track down the stone by attached visual device. Once the stone is detected it is crushed and nephroscope grasper is used to pull out the pieces of stone from the kidney. If the stones are too many or large then **laparoscopic pyelolithotomy** procedure is used in which kidneys are cut open to remove stones physically.

15.4.2 Kidney Failure

Kidney failure is the condition in which kidneys fail to extract nitrogenous waste products and perform osmoregulatory activity in the body. In this medical condition more than 85% of the both kidneys are affected. Kidney failure is classified as acute and chronic.

Acute kidney failure is concerned with the suddenly loss of filtering abilities of the kidney. This condition develops in a few days particularly in those who are already having renal abnormalities and hospitalized. The diseases that could cause the kidney failure are blood loss due to injury, heart attack, liver failure, severe allergic condition, and sudden dehydration due to sweating or excessive urination, urinary tract obstruction due to stones or any infection.

Chronic kidney disease involves a gradual loss of kidney function. Initially this disease shows no symptoms in the body but periodic blood or urine test indicate the problem. Its symptom includes fatigue, short breath, swollen hands or feet, blood in urine. The causes are hypertension, hyperglycemia, high cholesterol, cyst develop inside the kidney, kidney stones and inflammation.

15.4.3. Dialysis

Dialysis is a medical procedure to separate unwanted and toxic substances from the blood by artificial means. It is performed when kidneys are failed to remove waste from the blood body feels unrest particularly in breathing and later on non-adjusted biochemical components cause serious damages to the body like dementia or heart failure. There are different types of dialysis applied on patient depending upon the need and intensity of disorder, these are **hemodialysis**, **continuous renal replacement therapy (CRRT)** and **peritoneal dialysis.**

The **hemodialysis** is performed by a machine regarded as artificial kidney. This artificial kidney contains a number of tubules with a semipermeable lining suspended in a tank filled with a dialyzing fluid. This fluid has the same osmotic pressure as blood except it lacks nitrogenous waste.

To begin the procedure a surgeon, make a small incision to connect artery with a vein by a graft i.e., a small plastic tube that connect the both artery and vein also called a **fistula**. When the circuit is completed two needles are inserted in to the AV fistula. The one needle is connected to the artery and at the other end it is connected to the dialysis device where blood is collected from patient for filtration. During this process the waste product from the blood passing into the dialyzing fluid by diffusion. The purified blood is pumped back into the vein of the patient which is connected to other end of the dialysis device.

This is similar to the function of the kidney but it is different since there is no reabsorption involved. Hemodialysis is normally performed as 4-hour treatment, 3 times a week. The complications in this process may include the risks of blood infection, thrombosis and internal bleeding due to the added anticoagulant.

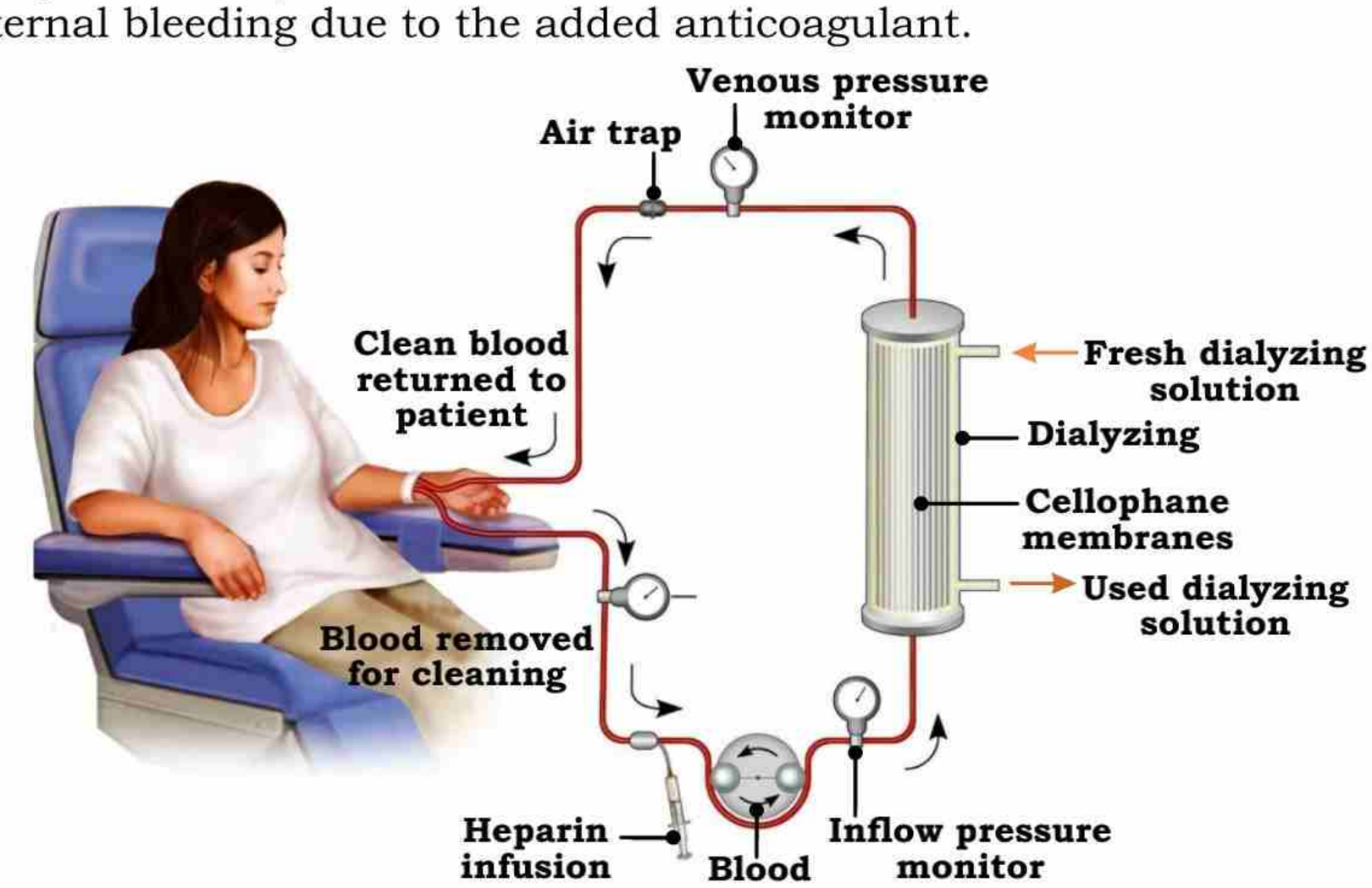


Fig.15.12 Haemodialysis

Continuous renal replacement therapy (CRRT) is the same class as hemodialysis. It is used for the patients who are in critical condition and it is design for the patients who are unable to tolerate the repeated procedures of hemo. or peritoneal dialysis. This procedure is running continuously 24 hours a day once started.

In **peritoneal** dialysis, abdominal cavity is used to filter blood. This procedure starts when doctor makes an incision at the lower abdominal cavity to implant or pass catheter. Which is soft tube that allows dialysate to pour in to and out of the abdominal cavity. Abdominal cavity is internally lined with the peritoneum which serves as the natural filtering membrane. When the dialysate is poured inside the abdominal cavity it pulls toxins from the blood that pass-through peritoneum membrane from its high concentration to the low concentration. The fluid remains in the body of several hours allowing exchange and equilibrium of ionic components with the blood running in the underlying vessels before being discarded. The dialysate is removed when it appears saturated and this process is repeated again if needed. Peritoneal dialysis can be repeated 4 to 5 times a day. It is less effective than hemodialysis but because it can be performed for longer periods of time. Peritoneal dialysis offers more flexibility, is better tolerated by patient, and less expensive but it is more often complicated with abdominal infections.

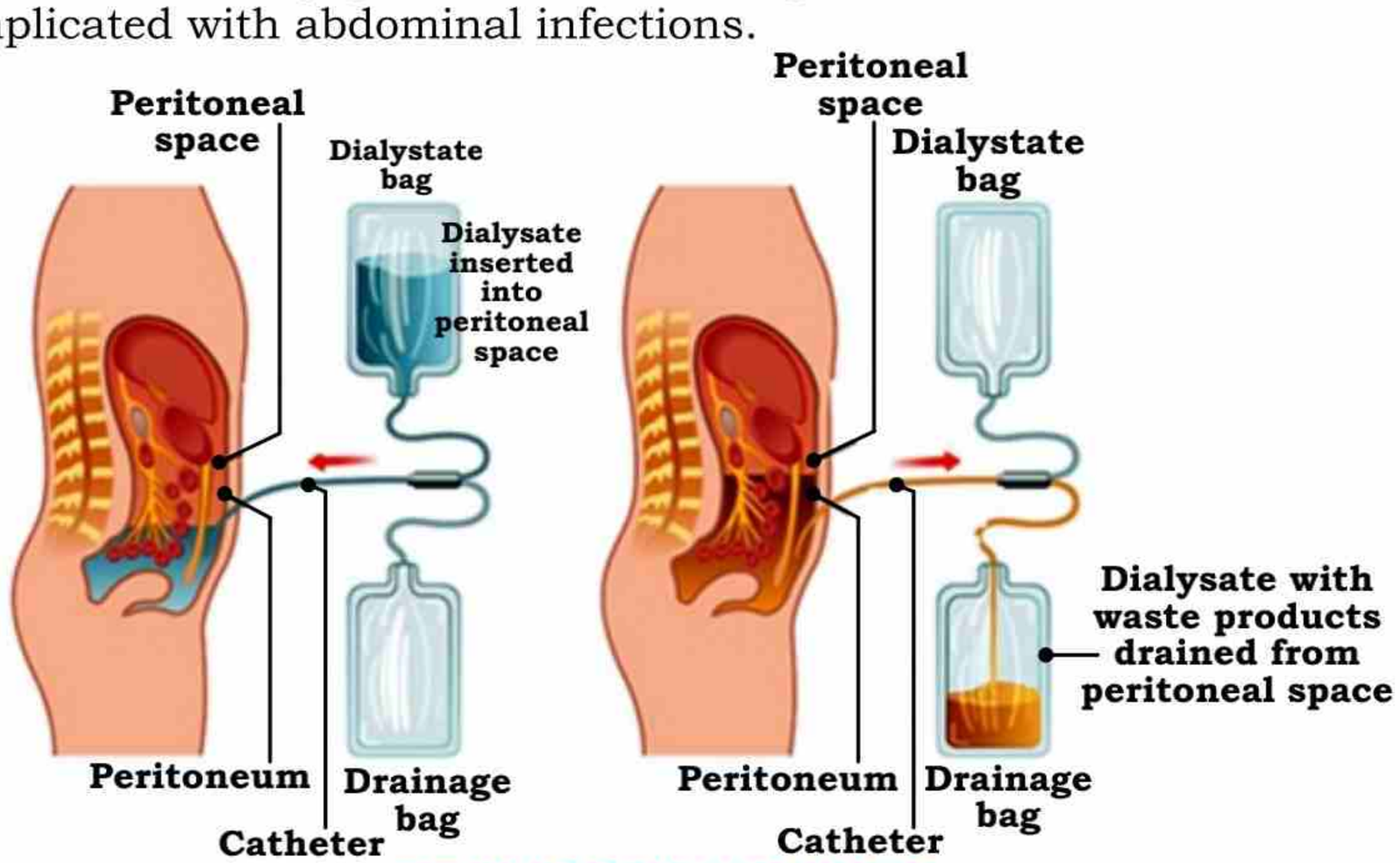


Fig.15.13 Peritoneal dialysis

15.4.4. Kidney Transplant

Kidney transplant is the major surgical treatment of kidney failure disorder. In this procedure, a healthy kidney from a living or deceased donor is acquired and is placed in the lower belly on the front side of the body. The diseased kidneys are usually left in place. Kidney transplant is done when the kidneys have lost about 90% of their ability to function normally due to some serious disorders like high blood sugar level and uncontrolled high blood pressure, kidney stones and polycystic kidney disease etc.

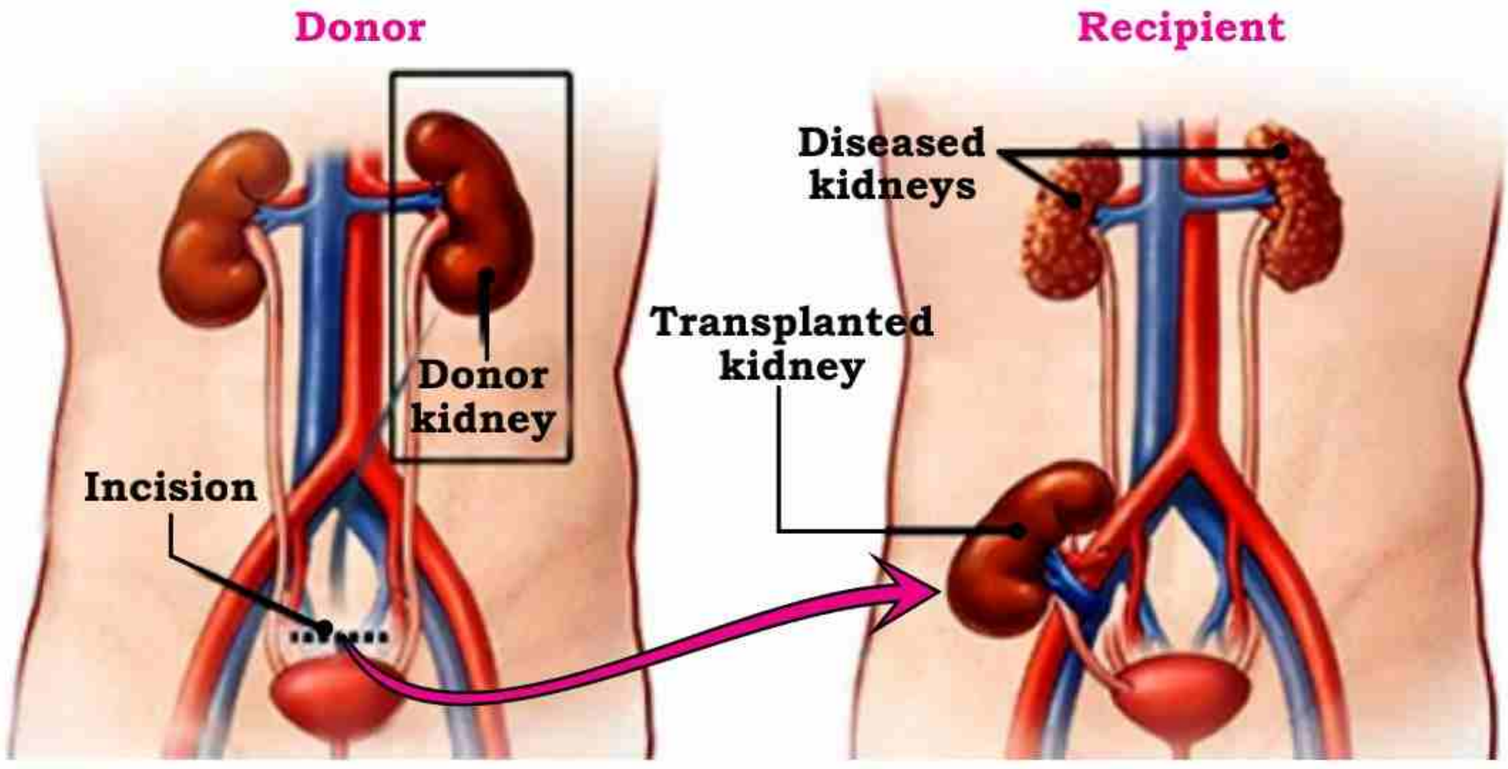


Fig.15.14 Kidney Transplant

Principles of kidney transplant

Kidney transplant requires the same matching blood group and biochemical components with the kidney donor and recipient. The compatibility is necessary without it, transplant cannot be done. The resistance against the implanted kidney by the immune system particularly from human leucocytes antigen system (HLA) should be minimize at the level that body accept new kidneys.

Problems associated with kidney transplant

After transplants the Immunosuppressant drugs like Cyclosporine are administered. This would be the risk factor along with treatment because at first it must be given to stop the body from rejecting the new kidney and minimize the side effects but at the other end it may invite some other opportunistic infections to enter the body

due to suppressed immune system. Kidney transplant surgery involves substantial complications like blood clots and bleeding, leaking from or blockage of the tube that links the kidney to the bladder (ureter), different bacterial Infection, those infections or cancer that can be passed on from the donated kidney, Death, heart attack and stroke. Besides all complications studies reveal that people who have done their kidney transplant live better and longer than those who keep on dialysis.

15.6. THERMOREGULATION

Thermoregulation is a homeostatic mechanism that keeps the body temperature of an organism up to suitable limits independent of external environmental temperature. It is all about keeping the stability of thermal energy expense in the body. This stability of temperature is necessary because if a person suffers with loss the body heat (i.e., hypothermia) in a very low external temperature then this condition may lead to low metabolic activities, cardiac arrest, brain damage and even death. Likewise, if the body temperature raises from 37^0C to 42^0C (i.e., hyperthermia) a person also suffers with many complications like fever, osmoregulatory imbalance, stroke or even death in rare cases. Temperature is the limiting factor for enzyme activities. Body metabolism depends upon the enzymes and change in temperature affect the working of enzymes which disturbs the metabolic activities.

15.6.1. Animals Classification on the Basis of Thermoregulation

Animals are classified on the basis of their capability to maintain body by utilizing different heat sources. Those animals who derives temperature to warm their bodies from external sources are called **ectotherms or poikilotherms.** Since ectotherms rely on environmental heat sources, they can operate at economical metabolic rates. Ectotherms live in environment where in which temperatures are constant such as tropics or ocean therefore, they would rather prefer to get heat by behavioral means rather than the physiological activities. These animals include invertebrates, fishes, amphibians and reptiles.

Animals who maintain a constant internal body temperature, usually within a narrow range of temperature are called **endotherms**

or homeotherms. These animals regulate their own body temperature through internal metabolic processes. When external environment becomes cold or hot, they autonomically monitor these changes and maintain the body temperature up to normal range through physiological and behavioral strategies. These animals include birds and mammals.

Some animals are called **heterothermic animals**. These animals can switch between homeotherms and endotherms. These changes in strategies typically occur on a daily basis or on an annual basis. These animals regulate body temperature usually as constant, but allows body temperature to fluctuate with the environment when inactive. Bats and hummingbirds go into what is known as torpor and bears hibernate. Both are examples of heterothermy; where the internal temperature of the animal drops during specific periods of time, usually when food is scarce

15.5.2. Thermoregulation in Humans

Humans maintain their body temperature at suitable limit that is 37^0C. We are adapted some behavioral and physiological strategies to adjust thermogenesis in cold and hot environment. Thermoregulation is controlled by an important part of our brain called hypothalamus which is considered as the thermostat or set point for temperature. Hypothalamus detects changes of the body temperature by receptors located in different parts of the body and responds accordingly.

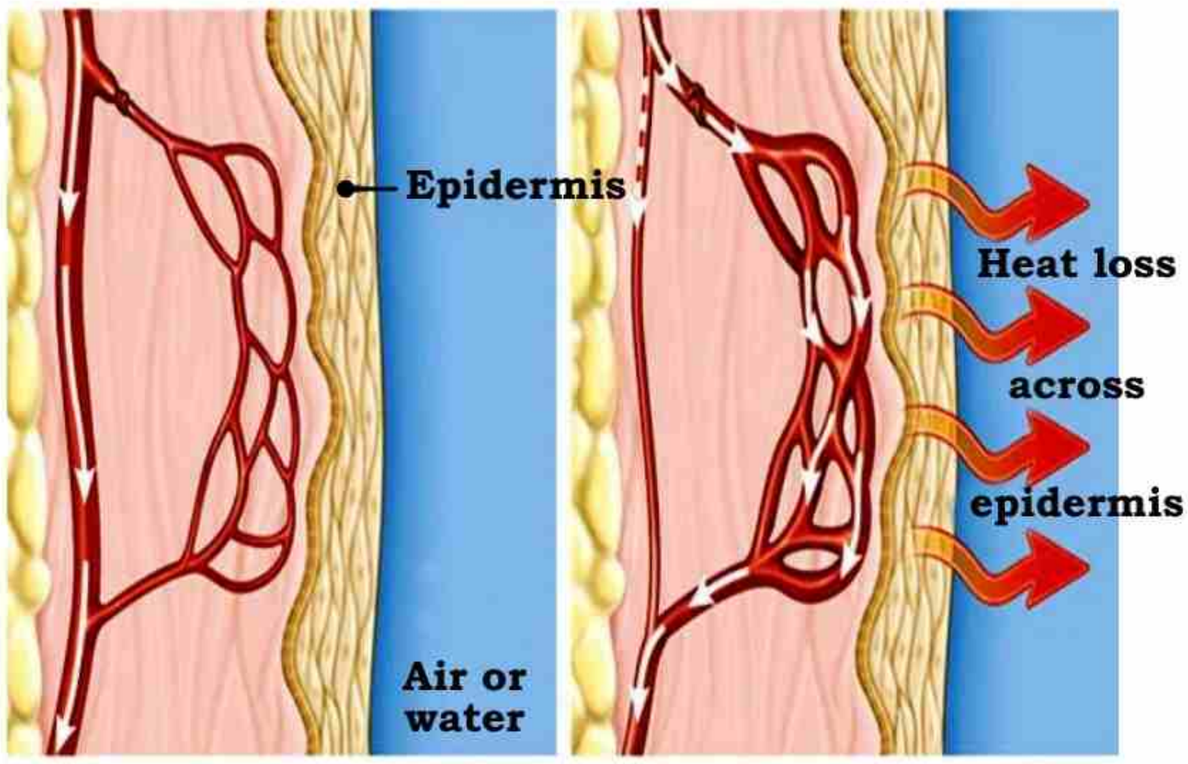


Fig.15.15 Vasoconstriction and Vasodilation

For example, if the surrounding environment becomes hot or a person do strenuous physical activity, the heat produced inside the body and raises body temperature above suitable limit this condition is called **hyperthermia**. That heat is transported to the blood which carries it near to the skin. When this elevated body temperature is detected by hypothalamus it neurologically activates the sweat glands to start secretion. As the skin perspires, the **evaporating sweat** take away the body heat from the blood into the surrounding environment. This cooled blood is then transported back through the body to prevent the body temperature from becoming too high. The blood vessels near to skin dilate in hot condition and facilitate the maximum transfer of heat away from inside the body. This dilation of blood vessels is called **vasodilation.** Thinning of hypodermis lowers the perspiration and this condition may lead to heat stroke and exhaustion. Humans can also transfer heat by conduction and **convection** as well. **Conduction** means heat transfer through some physical interaction for example prickly heat powder or ice pack makes a cooling effect on skin. Convection means transfer of body heat by movement of air or water molecules across the skin.

When the body experiences cold environment and body temperature tends to decrease this condition is called **hypothermia**. To conserve body heat in hypothermia, perspiration reduces and blood vessels become narrow and carrying blood down to skin. This condition of blood vessels is called **vasoconstriction**. The subcutaneous fats become thick and become an insulating layer to conserve heat in the body. In hypothermia sometimes body shivers and this involuntary action of muscles generate heat to warm the body. The vasoconstriction caused by hypothermia induces renal dysfunction and cold diuresis due to the decreased levels of ADH. These decreased levels of antidiuretic hormone result in dilute urine.

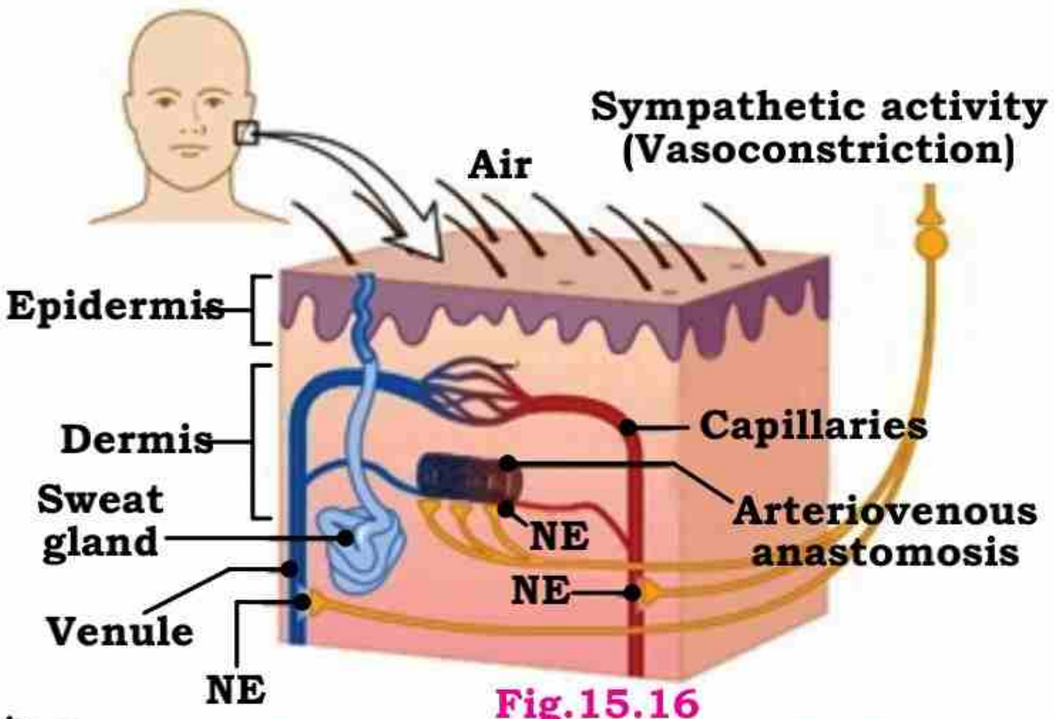


Fig.15.16
Thermoregulation through skin

SUMMARY

- Homeostasis is process by which biological systems maintain stability while adjusting to the changing conditions.
- Feedback, in biology, a response within a system. There are two types of feedback mechanisms that counter act upon each other called positive and negative feedback.
- Fresh water and marine water animals adjust their osmotic internal environment according to the changing external environment primarily by excretion.
- Animals produce different types of excretory waste to regulate their internal homeostatic environment.
- Urinary system is not only used for removing waste from the body, but also maintains the acid base balance of the body.
- Urinary system formed by mainly a pair of kidneys and associated organs.
- Kidney performs different functions including ultra filtration, selective reabsorption and counter current mechanism.
- Diseases of urinary tract are caused by bacteria and viruses that invade or enters through anus or urethral opening and by other means.
- Urine contains many dissolved mineral and salts that form different compounds.
- Kidney failure is treated by are hemodialysis, continuous renal replacement therapy (CRRT), peritoneal dialysis and in severe case kidney transplant.
- Thermoregulation is a homeostatic mechanism that keeps the body temperature of an organism up to suitable limits independent of external environmental temperature. It is all about keeping the stability of thermal energy expense in the body.
- Humans are endotherms means they maintain their body temperature at suitable limit that is 37^0C. Humans have adapted some behavioral and physiological strategies to adjust thermogenesis in cold and hot environment.

EXERCISE

1. Encircle the correct choice

i) A self-regulating process by which biological systems maintain stability while adjusting to the changing conditions called
(a) Homeostasis (b) Osmoregulation
(c) Excretion (d) Biological rhythms

ii) Which does not maintain a stable, homeostatic condition rather it intensifies the change that is happening to the body.
(a) Negative feedback (b) Positive feedback
(c) Feed back system (d) Excretion

iii) Fresh water organisms also have specialized cells located in their gills and in skin which actively extract Na^+, Cl^- and Ca^+ from external medium and excrete (H^+) or basic (HCO_3-) for acid base balance in the body fluids are called
(a) Granulocyte (b) Lymphocyte
(c) Ionocytes (d) podocyte

iv) Renal cortex produces an important hormone necessary for the synthesis of RBC's
(a) Erythropoietin (b) Leukopoietin
(c) Thrombopoietin (d) Renin

v) Glomerulus have specialized cells that are wrapped around blood capillaries that play an active role in preventing plasma proteins from entering the urinary ultrafiltrate called
(a) Epithelial cells (b) Podocyte cells
(c) Endothelial cells (d) None of them

vi) Tubules secretes ions such as hydrogen, potassium, and NH_3 into the filtrate while reabsorbing the HCO^{3-} from the filtrate are called
(a) Distal convoluted tubule (b) Proximal convoluted tubule
(c) Collecting duct (d) Loop of Henle

vii) Glomerular filtration rate (GFR) is in which proportional to the hydrostatic pressure exerted in glomerulus wall
(a) Indirectly proportional (b) Directly proportional
(c) Same proportional (d) High proportional

viii) Another compound that increases the osmotic gradient in inner medulla is the
(a) Urea (b) Water
(c) Sulphates (d) Phosphates

ix) The inflammation in kidneys due to irritation of kidney stones is called
(a) Lithonephritis (b) Edema
(c) Sarcoma (d) Encephalitis

x) If the surrounding environment becomes hot or a person do strenuous physical activity the heat produced inside the body and raises body temperature above suitable limit this condition is called
(a) Exothermia (b) Hyperthermia
(c) Hypothermia (d) Endothermia

2. Write short answers of the following questions:

i) Why the physiological integration of internal body environment is important for living organisms?
ii) Why it is important that positive and negative feedback mechanisms counter act upon each other?
iii) How the aquatic Osmoregulators overcome the osmoregulatory problems?
iv) Why animals excrete different types of excretory waste?
v) What is the use of counter current mechanism in kidney?
vi) What is the role of kidney as an endocrine organ?
vii) How kidney stones are formed?
viii) What is the impact over the human body if kidneys suddenly or gradually loss the filtering abilities?
ix) What are the problems associated with kidney transplant?
x) What is hypothermia? How body overcome this condition?

3. Write detailed answers of the following questions:

i) Explain the detailed structure of nephron with labelled diagram
ii) Explain the functions of kidney
iii) Explain the causes of kidney failure and its treatment

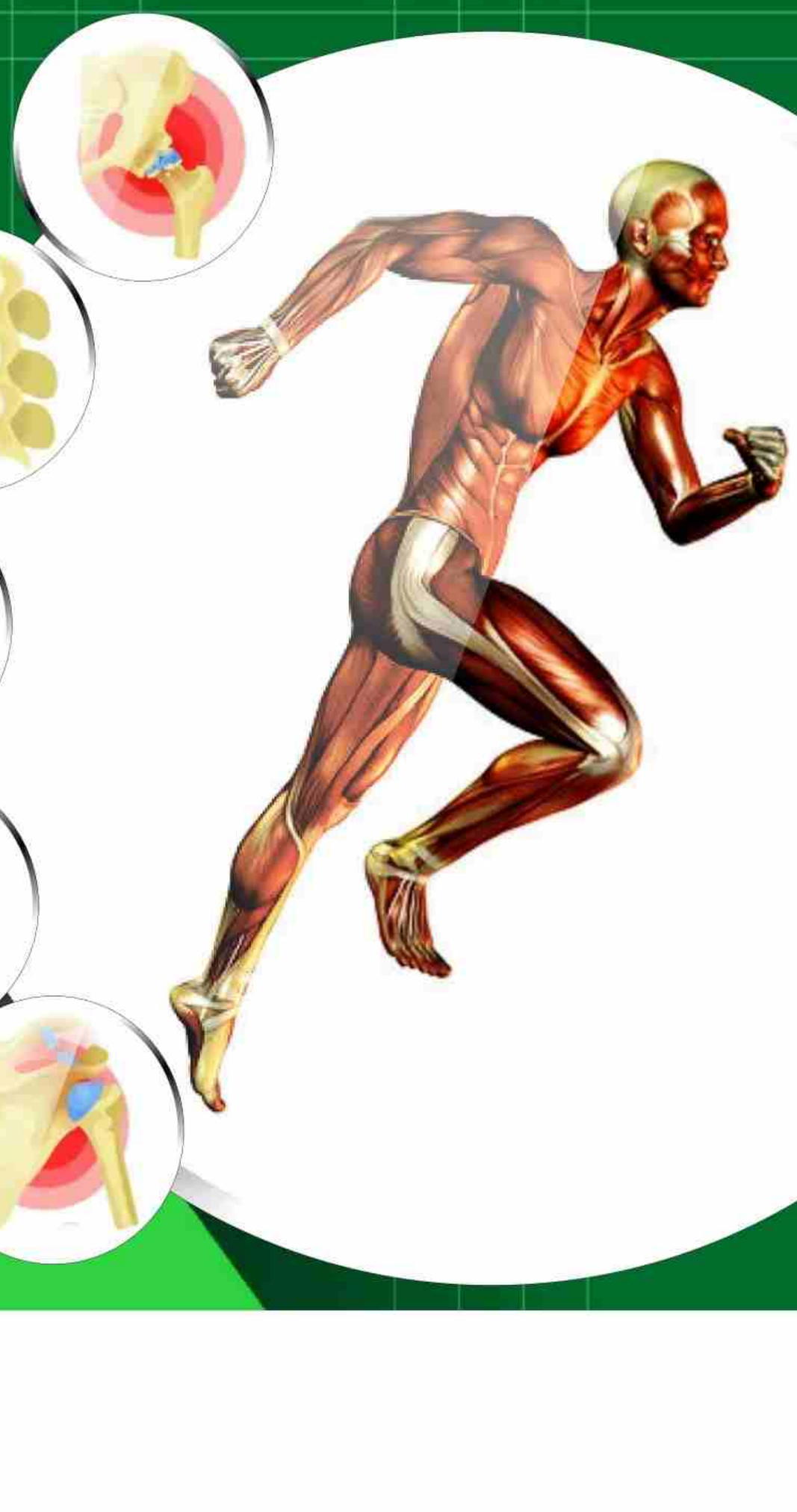
SUPPORT AND MOVEMENT

Chapter 16

Major Concept

In this Unit you will learn:

- Human skeleton
- Disorders of skeleton
- Muscles



Animals live in different habitats on earth. They need to develop appropriate physical adaptations to obtain resources in variable environmental conditions for existence. These adaptations help them to acquire food, shelter, and protection in their competitive surroundings. The adapted physical changes develop strong muscular and skeletal support system of the body that helps in movement and locomotion. Biologically, there is a difference between movement and locomotion. Movement is the changing position of an animal while locomotion is the type of movement of an organism in search of food and other needs over a long or short distance.

16.1. HUMAN SKELETON

The human skeleton acts as a framework of the body. Since it lies inside the body therefore called **endoskeleton**. Human endoskeleton comprises of **bones** and **cartilage** which provides shape of the body, makes blood cells through their red bone marrow, protection of internal organs and stores minerals. The branch of science deals with the study of human bones is called **osteology**. Bones and muscles are attached to form a well-coordinated musculoskeletal system. Humans have around 300 bones at birth but due to fusion of some bones it becomes 206 in adults.

16.1.1. Structure of bone

Bones are the toughest living structure, composed of different cells. Bones of the skeletal system differ in size and shape, but they are similar in their structure, development, and function. The major proportion of the bone is formed by collagen fibers and different types of cells while other components include minerals and 10 to 20% water. Collagen is the fibrous protein strengthening bone with calcium upon **calcification** or **ossification**.

A long bone has three distinct regions. The terminal regions are called **epiphysis**, middle region is called **diaphysis** and in between middle and terminal region is the **metaphysis** at both ends. The **epiphysis** is **a cancellous** or **spongy** part of the bone. It has small weight bearing cross linked regions called **trabeculae**. Epiphysis is filled with red bone marrow, which produces 20% blood cells that forms about 20% of the total mass of the skeleton.

The external part of the diaphysis is called **cortical bone**. Cortical bone forms almost 80 percent of the skeletal structure and consists of many small cylinders known as **osteons.** Each osteon is made of many lamellae, which are the concentric layers made of an organic part collagen and an inorganic part called hydroxyapatite, which is mostly calcium phosphate. In the center of every **osteon** is a haversian canal, which contains the blood supply and innervations of the bone cells. In the center of the bone is the **medullary canal,** a hollow space lined by a honeycomb like structure called the spongy or **cancellous bone**. The medullary canals contain the bone marrow which is the site of blood cell production.

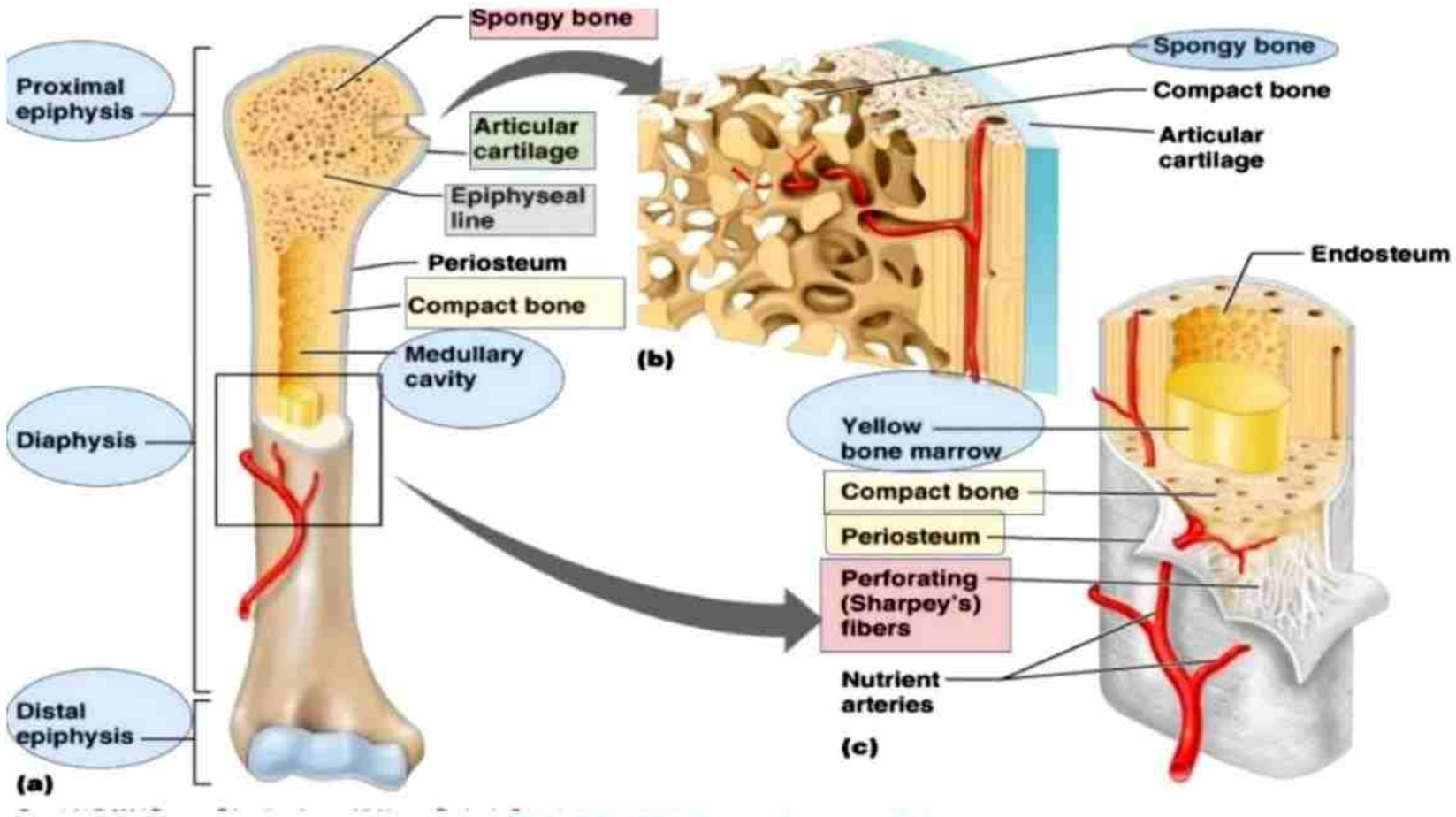


Fig 16.1 Structure of bone

The overall outer covering of the bone is called **periosteum** and the inner layer is called endosteum. Periosteum allows for attachment of muscle connective tissue (tendons) to the bone and provides pathways for blood and lymphatic vessels. **Endosteum** is a soft, thin layer that lines the inner cavity of long bones. It has progenitor stem cells. These **osteogenic progenitor cells** develop into **osteoblast** which secretes the bone matrix, and **chondroblast** which secrete cartilage. It plays a key role in the healing of fractures by creating new cells necessary for the bone to fuse.

There are three types of cells present in bone namely osteoblasts, osteocytes, and osteoclasts. **Osteoblasts** are the progenitor that secrete matrix around themselves to form spongy bone which later become compact bone. When osteoblast is isolated by surrounded matrix in the spaces called **lacunae**, they become **osteocytes**. Osteocytes are the mature cells that form the bones. The osteocytes direct osteoblasts to the site of the damage, hastening (fast) healing. **Osteoclasts** perform the job of breaking down the composite material in bones. Osteocytes also phagocytize the bony matrix. Once the matrix is removed osteoblast reforms a new bone material. It helps in demineralization and repair of bone.

16.1.2. Structure of cartilage

Cartilage is a soft flexible form of connective tissue surrounded by a layer called **perichondrium.** It is present in human skeleton and regarded as a precursor to bone in developing embryo. Cartilage is present in joints to provide cushion, reduce friction between bones, give them protection from compressive forces and weight bearing stresses during movement. Cartilage gets nutrition from their surrounding tissues by diffusion. Since they lack blood vessels therefore, they grow and repair slower than other tissues. Formation of cartilage is initiated by chondroblast cells located in outer covering of developing bone and divide to form **chondrocyte cells**. They are concentrated in lacunae in the cartilage and produce firm matrix that contain collagen protein, proteoglycan (formed by chondroitin sulphate and protein) and some other non-collagenous proteins to develop cartilage. There are three types of cartilage associated with skeleton which are different in their structure and function. **Hyaline cartilage** is present in between ribs and sternum, nose and at the bone surface in many joints. It has a smooth surface that allows tissues to slide easily. **Fibrocartilage** is the hardest among other cartilages. It is present as intervertebral disc, in knee joint and in pectoral girdle. **Elastic cartilage** is the most flexible and strong cartilage. It is located in the pinna of the ear, external and internal auditory tubes, epiglottis, and larynx.

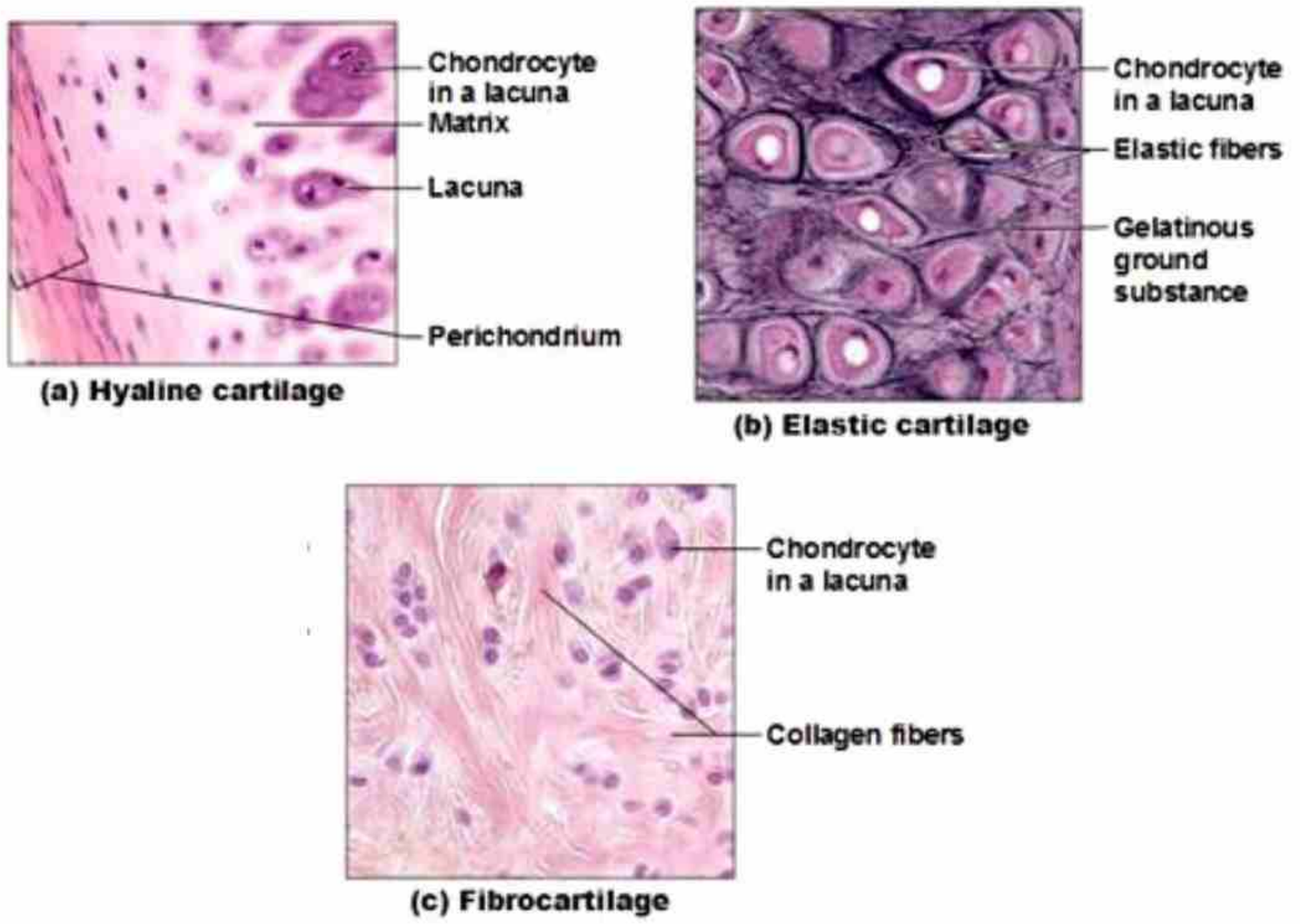


Fig. 16.2 Types of catilage in skeleton

Table 16.1 DIFFERENCE BETWEEN BONE AND CARTILAGE

CHRACTERISTICS	BONE	CARTILAGE
Strength	Hard	Soft
Formation	Formed by osteocytes	Formed by chondrocytes
Calcification	Bones are calcified i.e.; calcium and minerals are deposited	Not calcified
Covering	Covered by periosteum	Covered by perichondrium
Protection	Provide protection and support to the body	Protect joints
Water	10-20% water present in bones	80% water present in cartilage
Blood cells	Forms blood cells	Does not form blood cells

16.1.3. Division Human skeleton

Human skeleton is subdivided into two major divisions called the axial skeleton and the appendicular skeleton.

The Axial skeleton

The axial skeleton is on the central axis of the body and comprises the skull, vertebral column and thoracic cage including ribs and sternum. It has eighty (80) bones, including twenty-eight bones in the skull, one hyoid bone, twenty-six bones in the vertebral column, twenty-four ribs and one sternum.

The **skull bones** are further divided into cranial bones, facial bones, and auditory ossicles. The **cranial** bones protect brain and provide attachment for the essential receptor organs. Cranial bones are eight which include two **parietal**, two **temporal**, one **frontal**, one **occipital**, one **ethmoid** and one **sphenoid** bone. The **facial** bones protect soft tissues of the face, help in breathing, eating, facial expressions, speech, and structure.

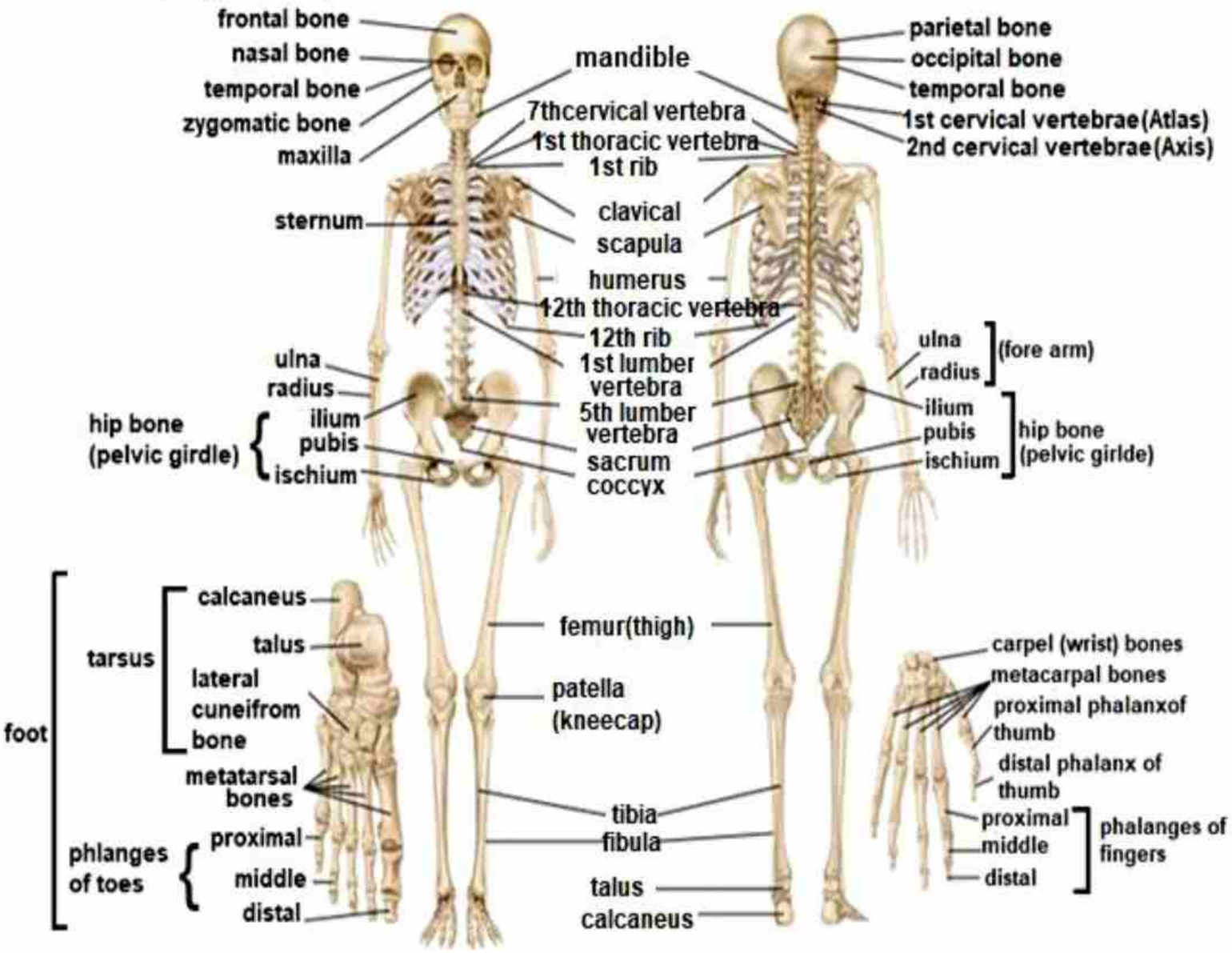


Fig. 16.3 Human skeleton

The **auditory ossicles** help in transmission of sound waves from external environment to the inner ear. They are six including two **malleus**, two **stapes** and two **incus**. A bone lies in between skull and postcranial skeleton called the **hyoid bone.** It is "U" shaped and provides attachment for the tongue and muscles of the oral cavity.

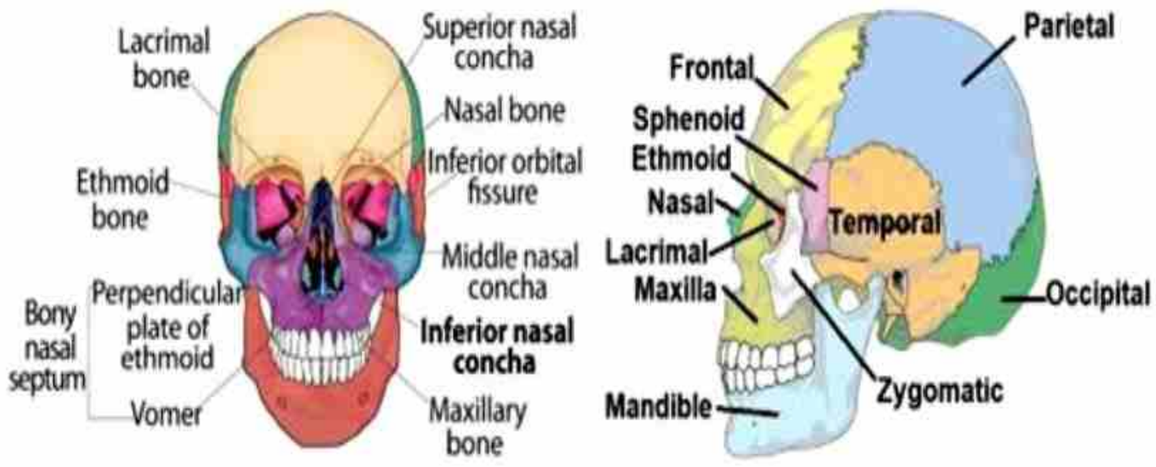


Fig. 16.4 Bones of human skull

The **vertebral column** protects spinal cord and serves as the site for blood cells production. Vertebral column consists of seven **cervical**, twelve **thoracic**, five **lumber**, one **sacrum** and one **coccyx** vertebrae. These vertebrae are fixed in different regions of the body, cervical in neck, thoracic in chest and anteriorly attached with the ribs, lumber in abdominal region behind the chest, sacral (formed by the fusion of five vertebrae) and at the last coccyx (formed by the fusion of four vertebrae).

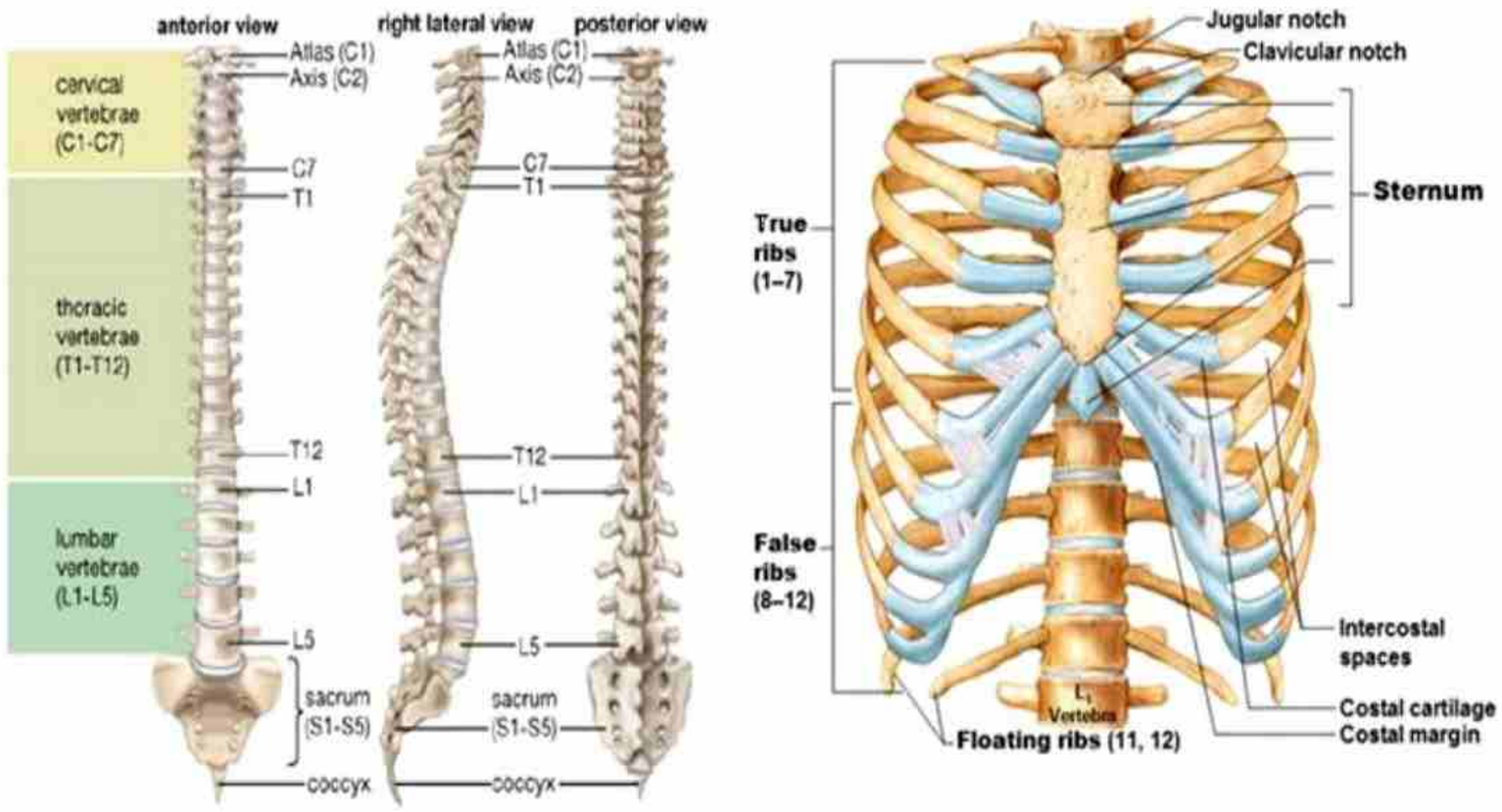


Fig. 16.5 Human Ribs and Vertebral column

The **rib cage** is formed by ribs and sternum. Each rib is flat and curved, supports the thorax wall and provides space for thoracic visceral organs. Ribs are twelve pairs, out of them first seven pairs are directly attached with sternum by cartilage and are called true ribs. The remaining five pairs are called false ribs due to their attachment to the sternum. Among the five pairs there are the last two pairs are called floating ribs because these are not associated by means of common costal cartilage sternum and even other pairs of ribs.

Appendicular skeleton

The appendicular skeleton consists of 126 bones. This division of skeleton is further divided into pelvic and pectoral girdle with associated bones.

Pectoral girdle and Fore limb bones

The **pectoral girdle** provides structural support to the upper region of the body. The total number of bones associated with pectoral girdle are **sixty-four** (both sides) which include two clavicle and two **scapula** (both side) in pectoral gridle while the anterior limb (arm) bones associated with girdle are two **humerus**, two **radius**, two **ulna**, sixteen **carpals**, ten **metacarpals** and twenty-eight **phalanges** in both limbs.

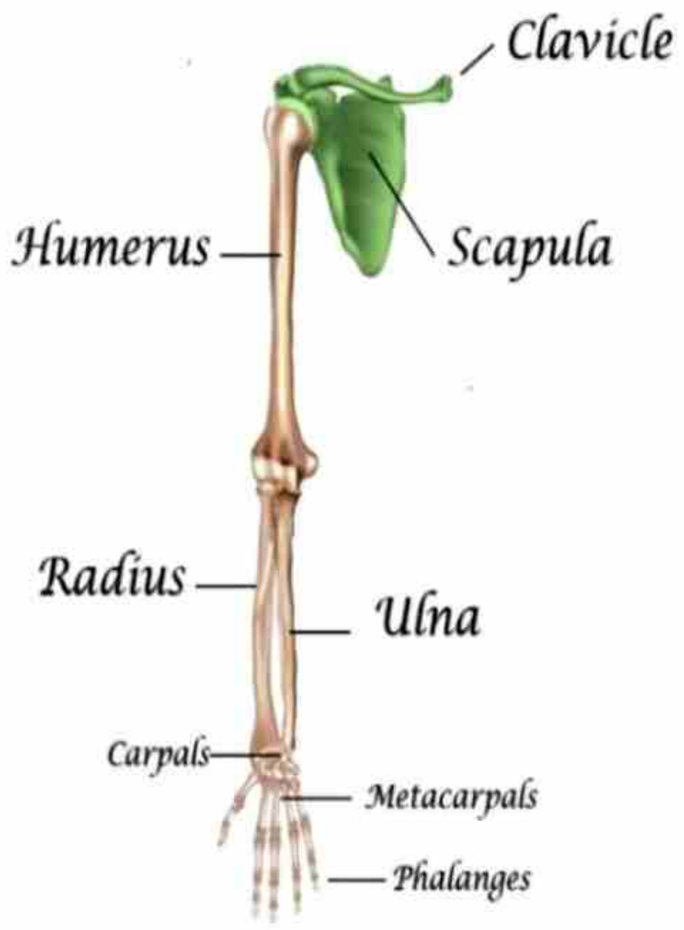


Fig. 16.6 Bones of Forelimb

Pelvic girdle and Hind limb bones

The pelvic girdle supports the body weight, helps in movement, and protects pelvic viscera including parts of urinary system and reproductive organs. The total number of bones in pelvic girdle and associated lower limb bones are **sixty-two**. The pelvic girdle is formed by two ilium, two pubis and two ischium bones. All these bones are fused to form **innominate**, hip, or curved **coxal** bones in two halves.

The two coxal bones form bowel shape pelvises that keep the female reproductive organs. The ring-like shape of the girdle is due to the joining of coxal bone with the sacrum of vertebral column at anterior side and below by a joint in between pubic part called **pubic symphysis**. The posterior limbs include two **femur**, two **tibia**, two **fibula**, two **patella**, fourteen **tarsals**, ten **metatarsals** and twenty- eight **phalanges**.

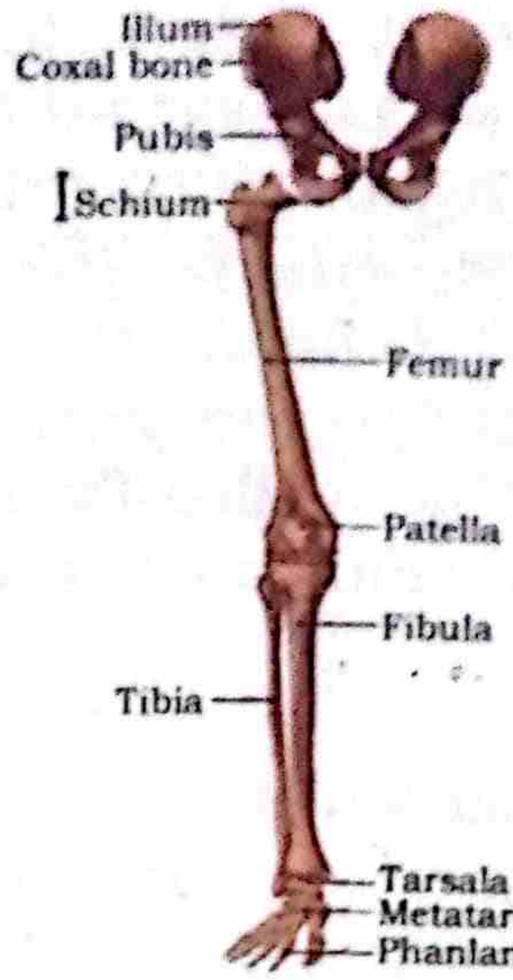


Fig. 16.7 Bones of Hindlimb

16.1.4. Types of joints

A joint is the articulating functional junction of two or more bones. There are approximately 360 joints in our body. Joints are classified by the type of tissues that bind the bone at each junction. The major groups of joints are **fibrous joints**, **cartilaginous joint** and **synovial joints**.

Fibrous joints

These joints hold the bone by dense connective tissue containing collagenous fibers.

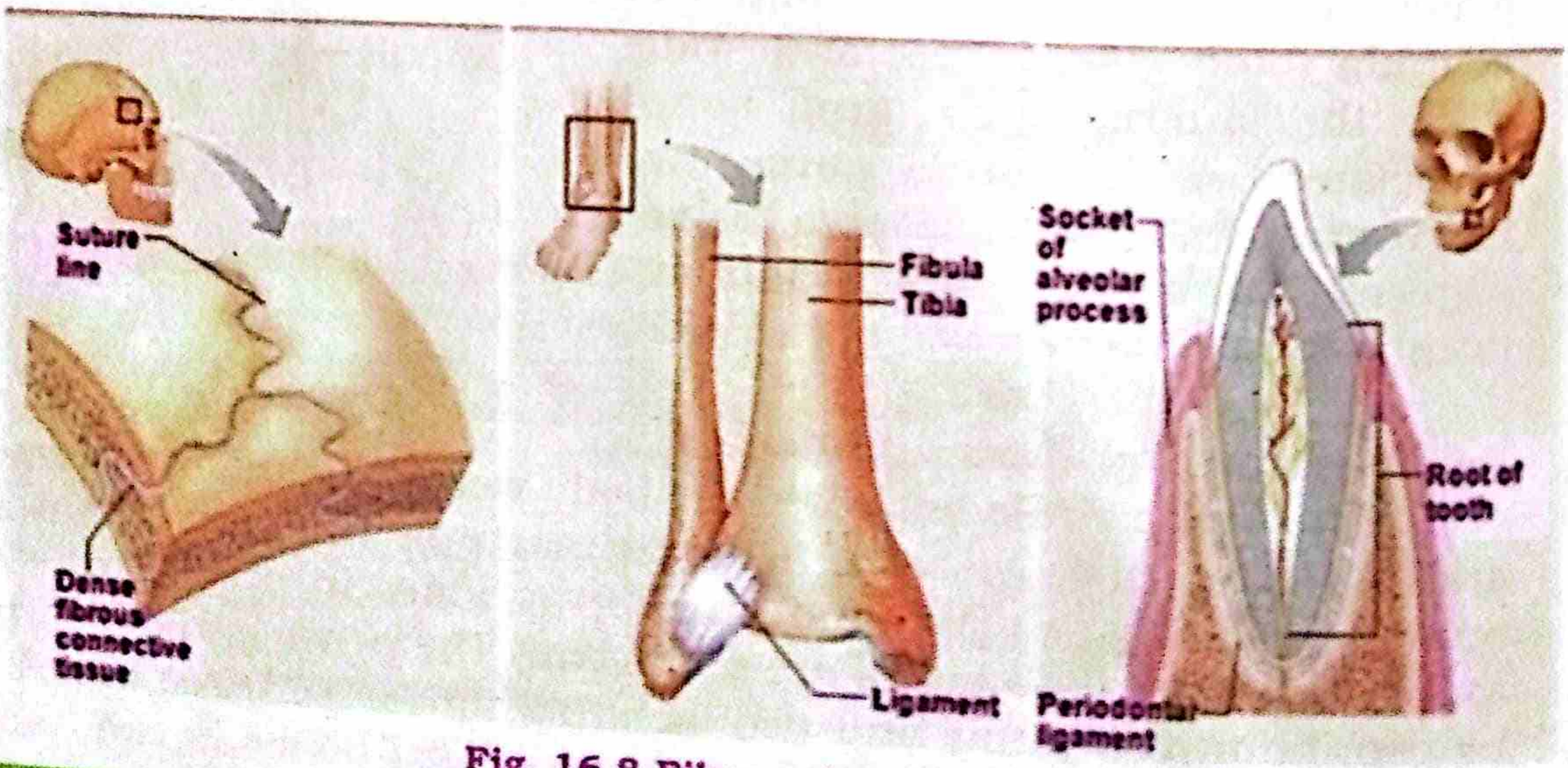


Fig. 16.8 Fibrous joint

Cartilaginous joints

Joints which join two bones articulated by hyaline or fibrocartilage.

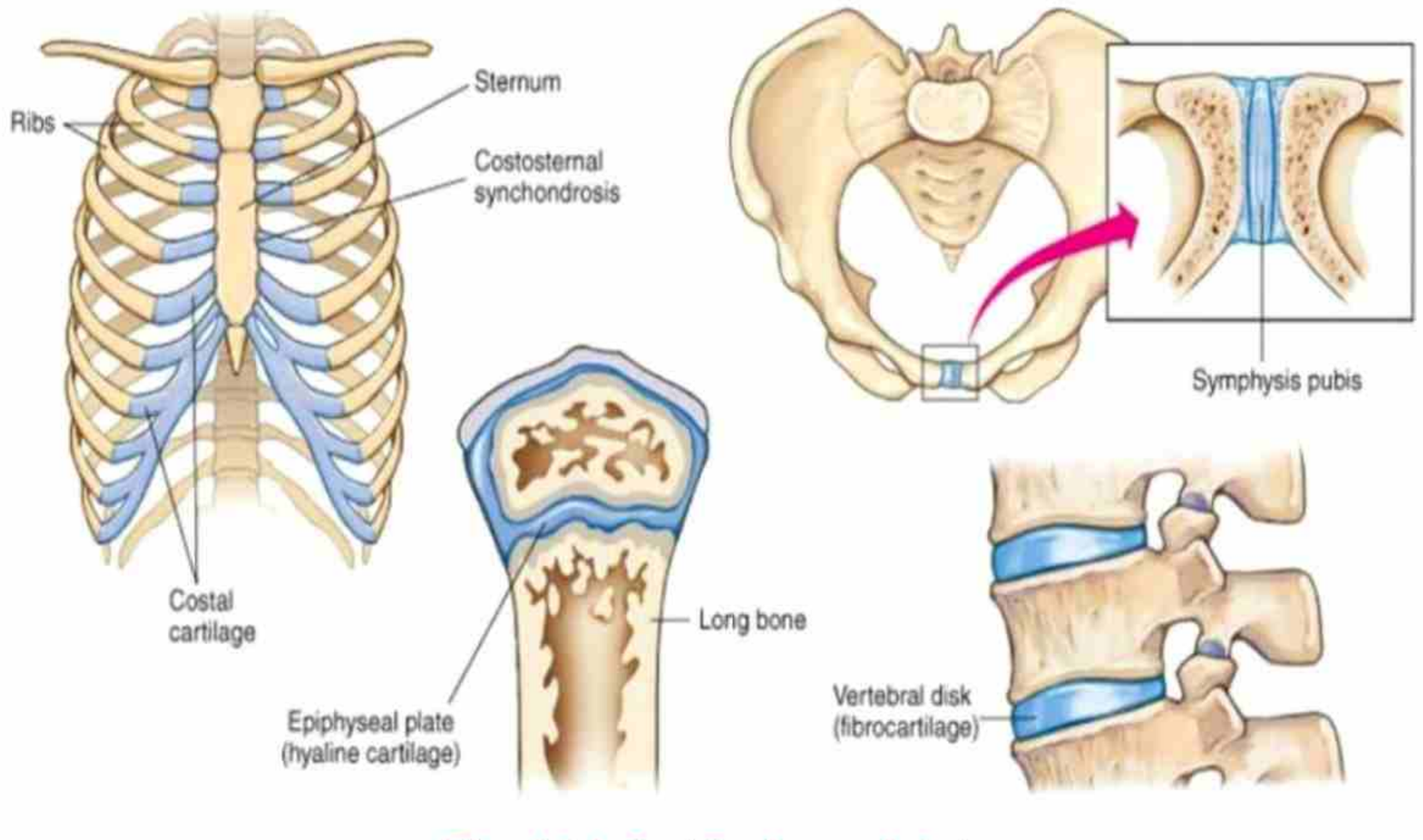


Fig. 16.9 Cartilaginous joints

Synovial joints

Most of the joints in skeletal system are synovial due to their free movability. These are more complex then other joints in structure. Synovial joints generally consists of a joint capsule and synovial membrane that secretes synovial fluid. The joint capsule holds together the bones and encloses the outer part of a joint. The inner membrane of capsule is few cells thick covers the surface within the joint capsule called the **synovial membrane**. Synovial memebrane surrounds a closed sac called **synovial cavity** and secrete **synovial fluid** to fill this cavity. Synovial fluid lubricate and nourish the articulating cartilage surface wihthin the joint.. There are different types of synovial joints present in our body. **Hinge joint** present in between the humerus and the ulna bones allowing flexion and extension in just one plane. **Pivot joint** present in proximal and distal radio-ulnar joint allows twisting movement. **Ball and socket joint** of shoulder and hips moves the organ in all direction,

condyloid joint is the modified but structurally different ball and socket joint that also allow the movement in all direction for example wrist joint (radio-carpal joint). **Gliding joint** is also called the plane join. It only permits limited movement like bending and slipping one bone over to another, for example, wrist and vertebral column.

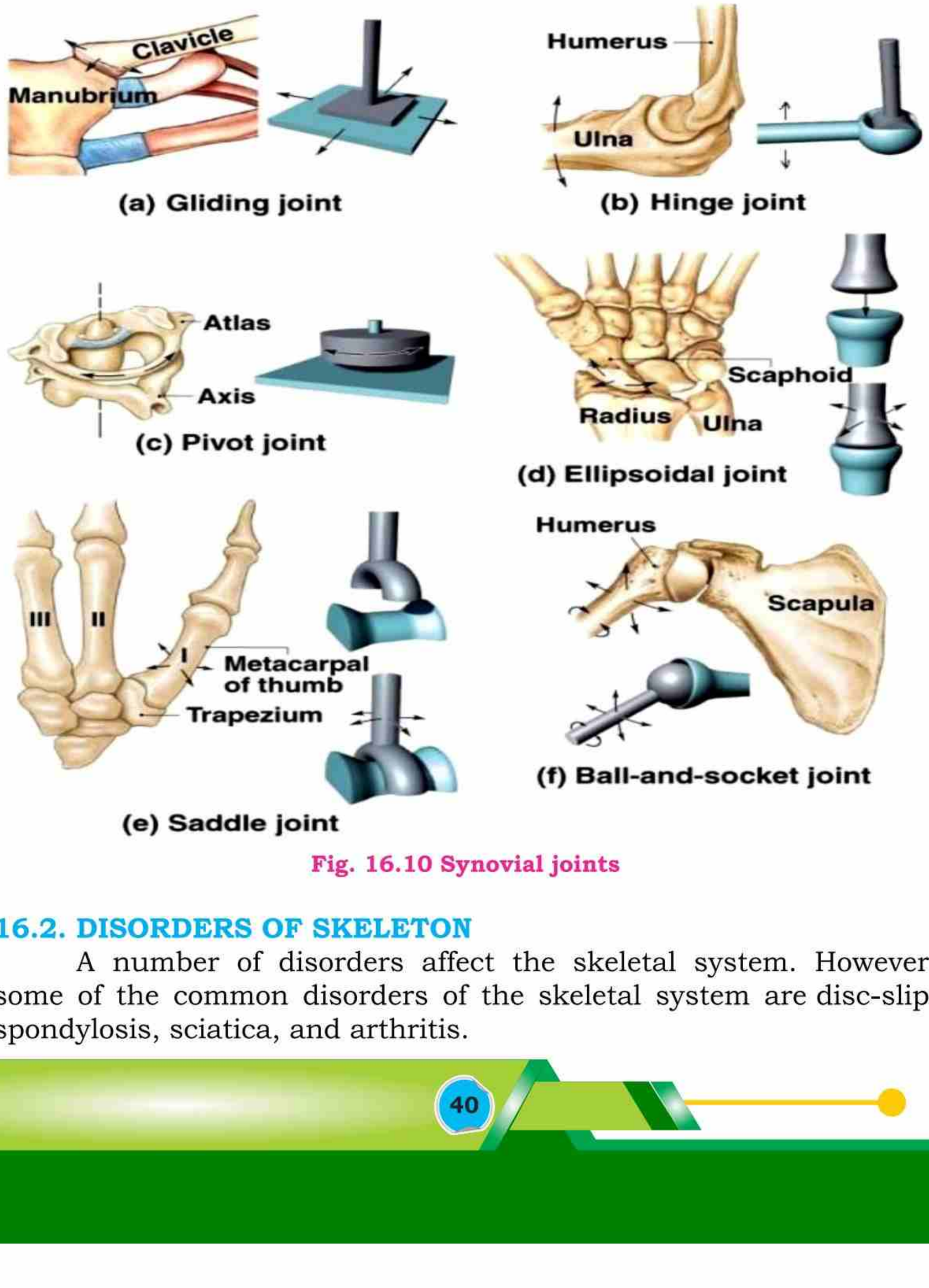


Fig. 16.10 Synovial joints

16.2. DISORDERS OF SKELETON

A number of disorders affect the skeletal system. However, some of the common disorders of the skeletal system are disc-slip, spondylosis, sciatica, and arthritis.

16.2.1. Common Disorders of Skeleton

Spondylosis

Spondylosis is related to abnormal or degenerative changes in vertebrae. These changes may develop abnormal outgrowth (spur), narrowing the gap between adjacent vertebrae and degeneration of intervertebral discs due to aging. It can occur in the cervical spine (neck), thoracic spine (upper and mid back), or lumbar spine (low back). Lumbar spondylosis and cervical spondylosis are the most common.

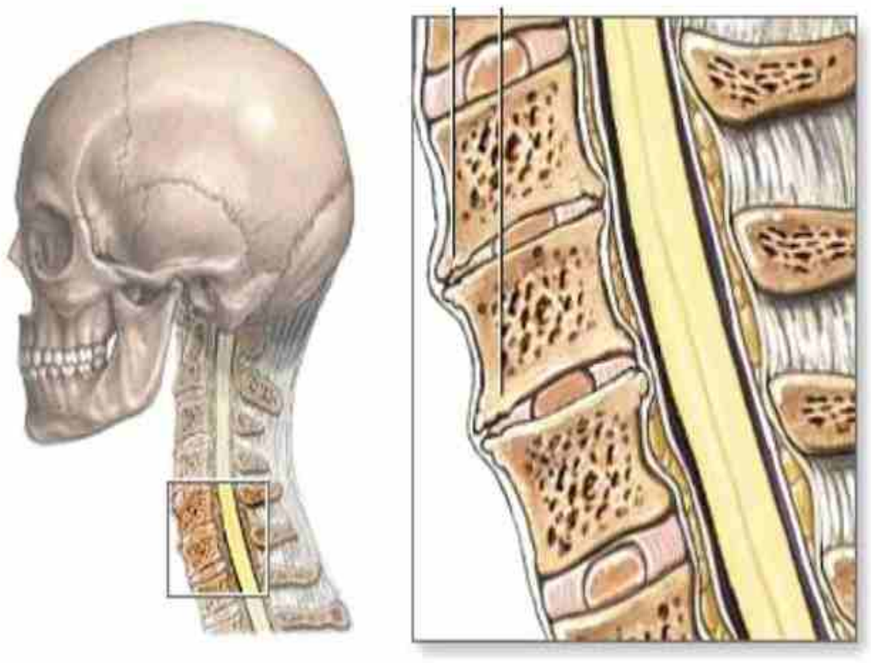


Fig. 16.11 Spondylosis

Degeneration of vertebrae results in the compression of nerves which can cause symptoms such as pain, numbness, and tingling.

Sciatica

Sciatica is the compression or injury in sciatic nerve located in posterior limbs. The sciatic nerve is the longest and thickest nerve in the body. It is made up of five nerve roots which come together to form a right and left sciatic nerve on each side of the body. Sciatic nerve runs through hips and goes down the leg, ending just below the knee then branches into other nerves, which continue down the leg and into the foot and toes. The main symptoms of sciatica pain originate in the lower back and radiate down the leg. Sciatica can come on suddenly or gradually. It depends on the cause.

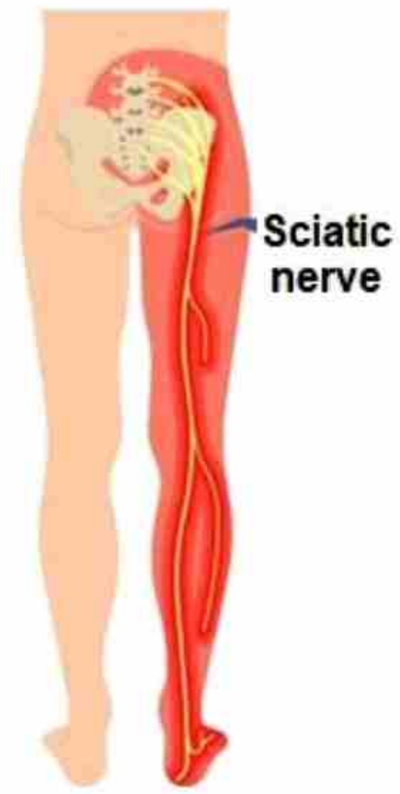


Fig. 16.12 Sciatica

Disc Slip

The vertebrae are cushioned by cartilaginous discs. These discs act as shock absorbers and protect vertebrae from daily activities like walking, lifting, running etc. Each disc has two regions; the tough outer ring and inner soft and gelatinous region. Any injury or weakness can cause the inner portion to protrude by breaking the outer ring. This is known as a slipped, herniated, or prolapsed disc. This results in severe pain and extreme discomfort. If the slipped disc compresses one of the spinal nerves, the victim may also experience numbness and pain along the affected nerve. Pain that extends to the arms or legs and never settled in any posture of the body.

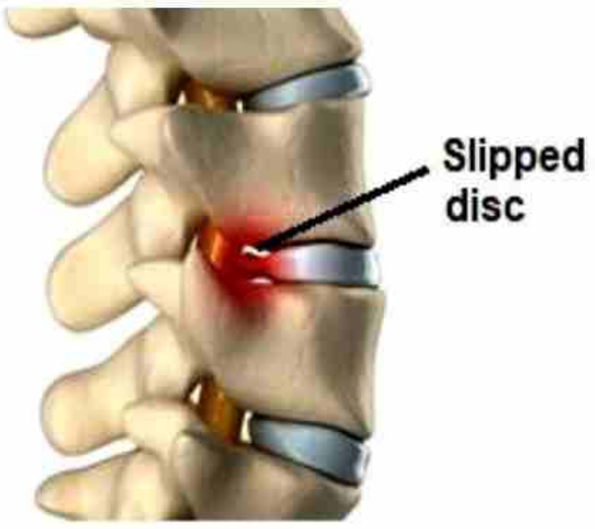


Fig. 16.13 Disc Slip

Arthritis

Arthritis is a disease that affects joints. It usually involves inflammation or degeneration of joints. It causes pain and inflammation, making it difficult to move or stay active. There are many types of arthritis. Each form causes different symptoms and may need different treatments. While arthritis usually affects older adults. **Osteoarthritis** develops when joint cartilage breaks down from repeated stress. It is the most common form of arthritis. **Ankylosing spondylitis,** or arthritis of the spine (usually your lower back). **Gout,** a disease that causes hard crystals of uric acid to form in the joints. **Rheumatoid arthritis** a disease that causes the immune system to attack synovial membranes in your joints.

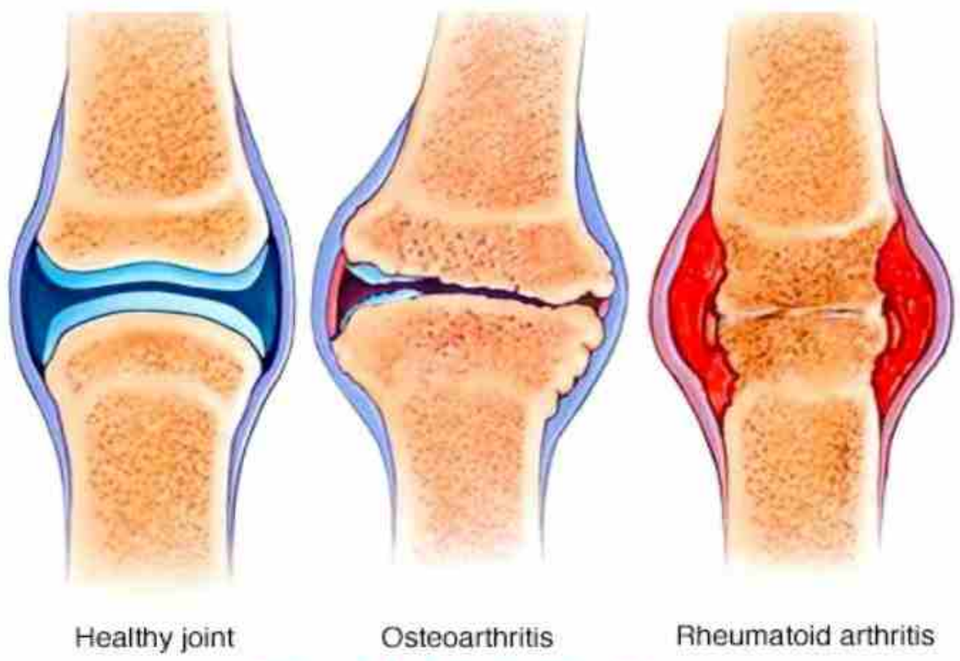


Fig. 16.14 Arthritis

16.2.2. Types of bone fractures

Fracture is the breaking of bone due to any injury. The types of fractures are simple fractures, compound fractures and complicated fractures. A **simple fracture** is also called closed fracture in which bone is cracked but does not break the skin and not exposed. A **compound fracture** is characterized by the complete breaking of bone and the piece of bone is visibly piercing outside the skin. When the fracture damages the surrounding structures including organs, veins, arteries, or nerves, it is called a **complicated fracture**.

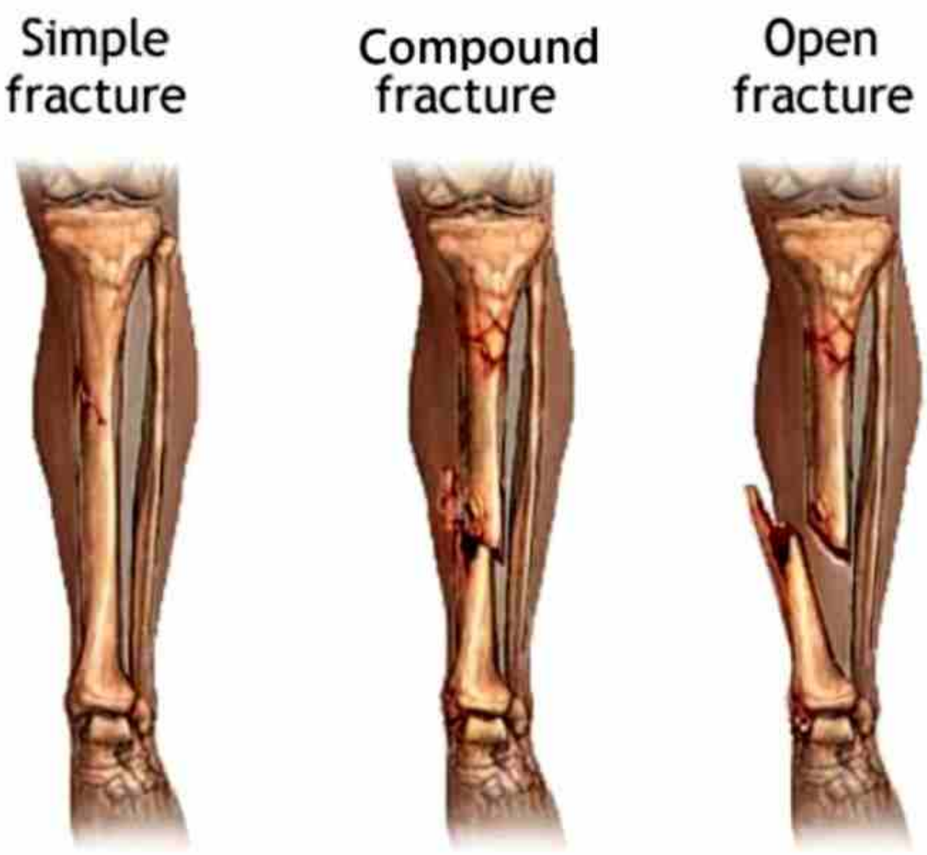


Fig. 16.15 Types of Bone Fractures

Fracture is accompanied by intense pain at the place of initial injury, tenderness at the site, a sensation of grating or grinding with movement, and inability to use the limb or body part supported by the bone. Physical signs include deformity of the part, swelling in the region of the fracture, discoloration of the overlying skin, and abnormal mobility of the bone.

The repair process of simple fractures.

The fractured or broken bone undergoes repair through four stages:

a) Hematoma stage

When fracture occurs the blood vessels within the bone and its surrounding periosteum break. Blood escapes and massively accumulates into the surroundings which form a clot called **hematoma**. The immune system activates and induces swelling at the site of injury. Receptors develop pain sensation and due to

suspended blood supply, the bone cells are deprived of nutrients and begin to die. The hematoma internally sealed the fracture site, preventing further blood loss and provides a framework for healing process.

b) Fibrocartilaginous callus formation

Within weeks new blood vessels and numerous osteoblasts develop from the periosteum and enter the hematoma. Osteoblast quickly divides and gives rise to the spongy bone in the region close to the new blood vessels. The next phase of healing begins by the formation of new tissues called granulation tissues. These tissues contain new blood vessels and a complex of fibroblasts, vascular endothelial cells, and macrophages within a matrix of collagen and fibrin. All of them are added up and develop a mesh work called **fibrocartilage callus** at the ends of the broken bone. The dead cells are phagocytosed by macrophages. The osteoblast develops the spongy bone and fibroblast cells produce collagen fibers to reform the fractured bone.

c) Bony callus formation stage

When the soft callus is formed, later it is calcified and turned into hard bony callus. As the bony callus formation progresses it is replaced with bone. The hard callus formation is initiated around three weeks after the fracture and continues for about three months. When cartilage becomes ossified, it contains osteoblasts, osteoclasts, and bone matrix.

d) Remodeling stage

Bone remodeling is the stage when old bone tissues are removed and replaced with new ones that join both fractured sides. Remodeling starts when the osteoblast cells detect the fracture and induces monocytes to fuse together to form a multinucleated osteoclast cell. The osteoclast matures and activates to start resorbing bones as the bone resorption proceeds, osteoblasts start producing collagen to fill in the lacunae created by the osteoclasts and calcium phosphate begin to deposit, forming hydroxyapatite. The osteoblast keeps producing new bony material and turns into osteocytes. Finally, the bony callus is then remodeled by osteoclasts

and osteoblasts and compact bone is added just like the original, unbroken bone and fracture is healed. This remodeling can take many months; the bone may remain uneven for years.

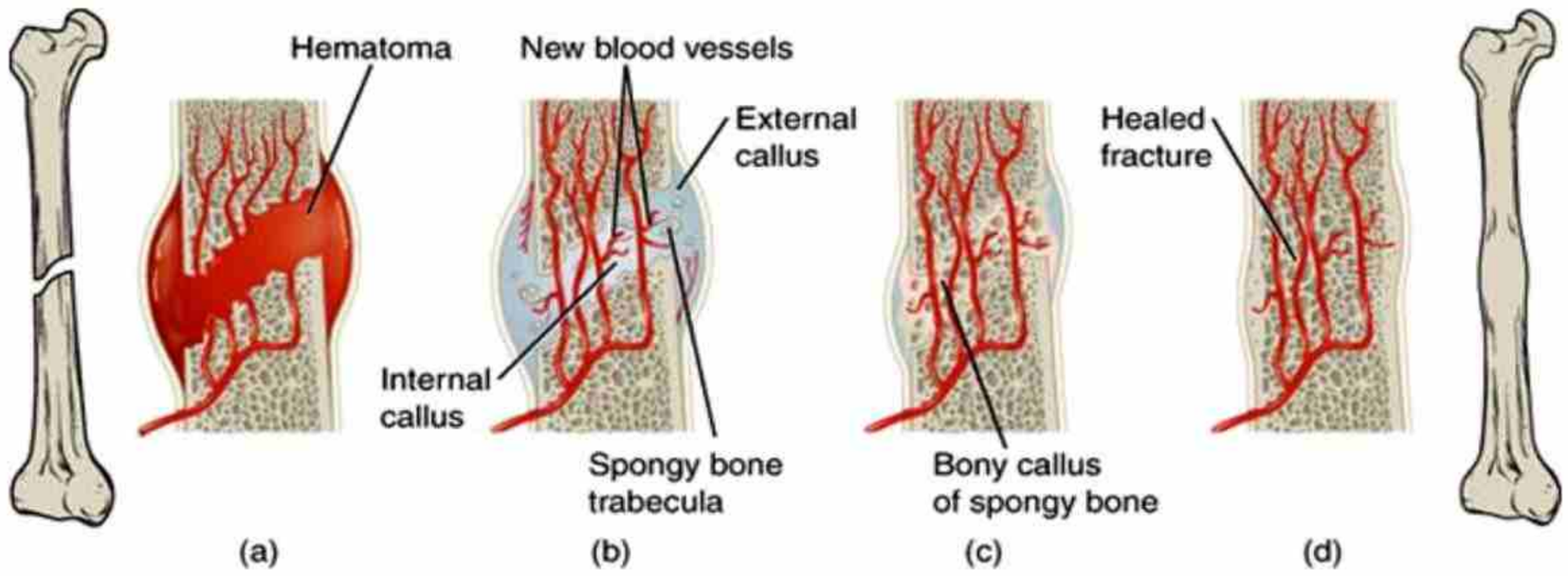


Fig. 16.16 Stages of fracture repair

16.2.3. The injuries in joints

Joints are injured when the ligaments are twisted or torn due to overuse of muscles, repeated heavy physical activities or any injury. The common types of joint injuries are as follows:

Dislocations

Dislocation is the complete change of position or separation of the bones in a joint due to any injury, arthritis or weakening of muscles and tendons. It may damage the nerves and surrounding tissues. The common symptoms of dislocation are severe pain, swelling, instability of joint, inability to move a joint, bruising.

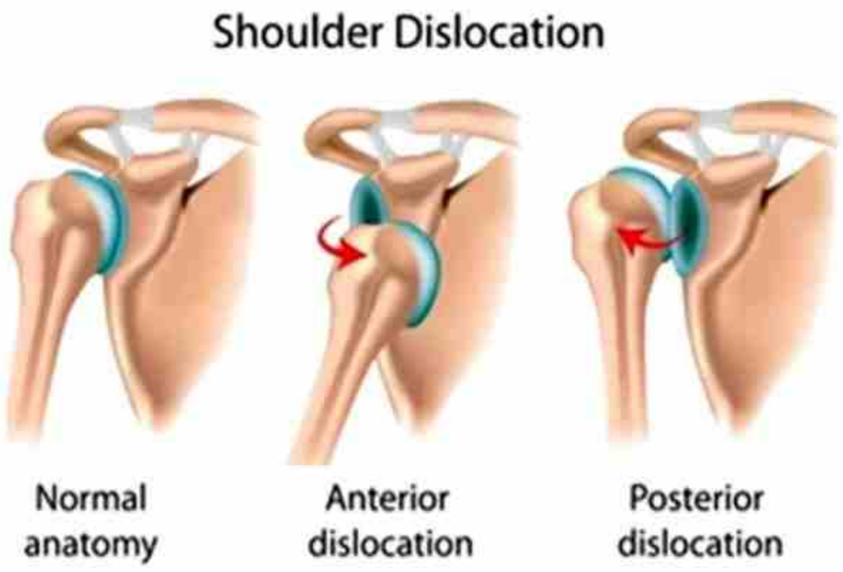


Fig. 16.17 Dislocation

Dislocation can be managed by surgery, physical bone manipulation by the doctor, rest, physical therapies.

Sprain

Sprain is related to the mild to severe grade of stretching or tearing of a ligament that holds a joint's bones together. Sprains can be the result of a sudden twist of the limb associated with the joint. Sprains usually occur in the ankles, knees, and wrists. The common symptoms of sprains are pain, swelling, inflammation and bruising. A person suffering with sprain must take rest, foment with ice packs, use bandages over the injury and sometimes surgery is needed.

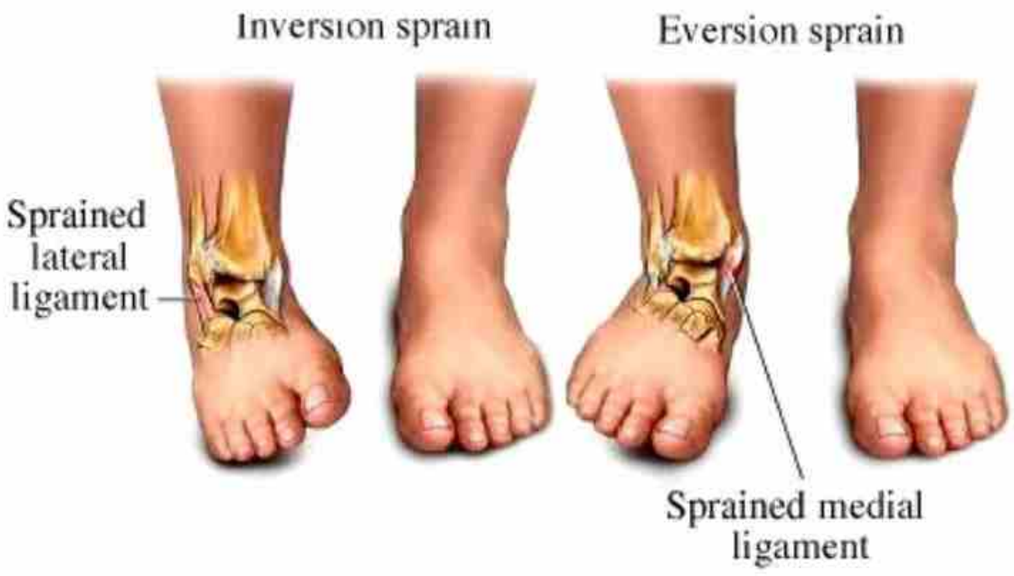


Fig. 16.18 Sprain

The first-aid treatment for joint injuries and fractures.

First aid refers to medical attention usually administered immediately after the injury occurs and where it occurred. Keep the patient in resting condition. Apply an icepack (cold compress) wrapped in a wet cloth to the injury for some time. Apply a compression elastic bandage firmly to the injury that extends well beyond the injury. Elevate the injured part. Use broad bandages (where possible) to prevent movement at joints above and below the fracture. Support the limb, carefully passing bandages under the natural hollows of the body. Place a padded splint along the injured limb. Place padding between the splint and the natural contours of the body and secure firmly.

16.3.1 Muscles

A muscle is the group or bundle of tissue in the body which can contract and relax to produce movement in various parts of the body and locomotion. Muscles also facilitate the movement of the body fluid, particularly lymph. There are three types of muscles involved in this process. The smooth muscles, cardiac muscles, and skeletal muscles.

Smooth muscles

Smooth muscles do not show striations hence called smooth muscles. These are present in hollow visceral organs like urinary bladder, respiratory tract, blood vessels, reproductive system etc. Smooth muscles cells are spindle shaped having single nucleus.

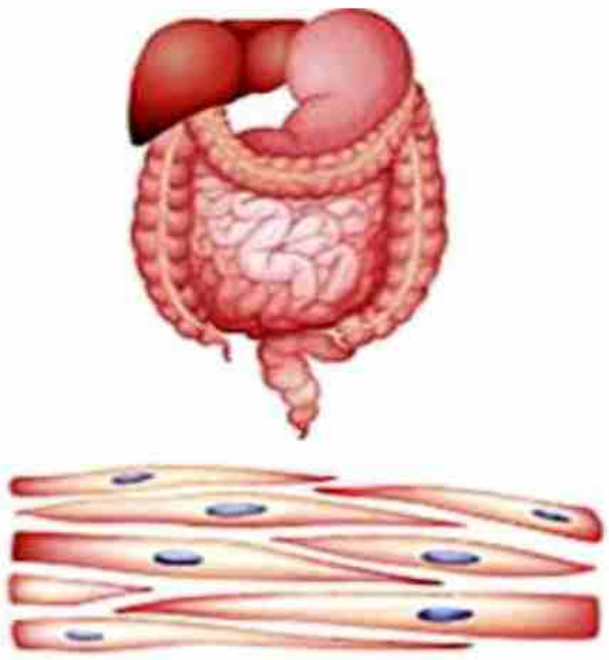


Fig. 16.19 Smooth Muscles

Cardiac muscles

Cardiac muscles are located only in the heart. These muscles are striated in structure but involuntary in function. Cardiac muscles are branched, bifurcated and their unit cells contain single or double cell nuclei. Cardiac muscle cells are strongly interconnected by a specialized structure called **an intercalated disc**. The cardiac muscles are arranged in a branching network where cells are joined together and make a **syncytium**.

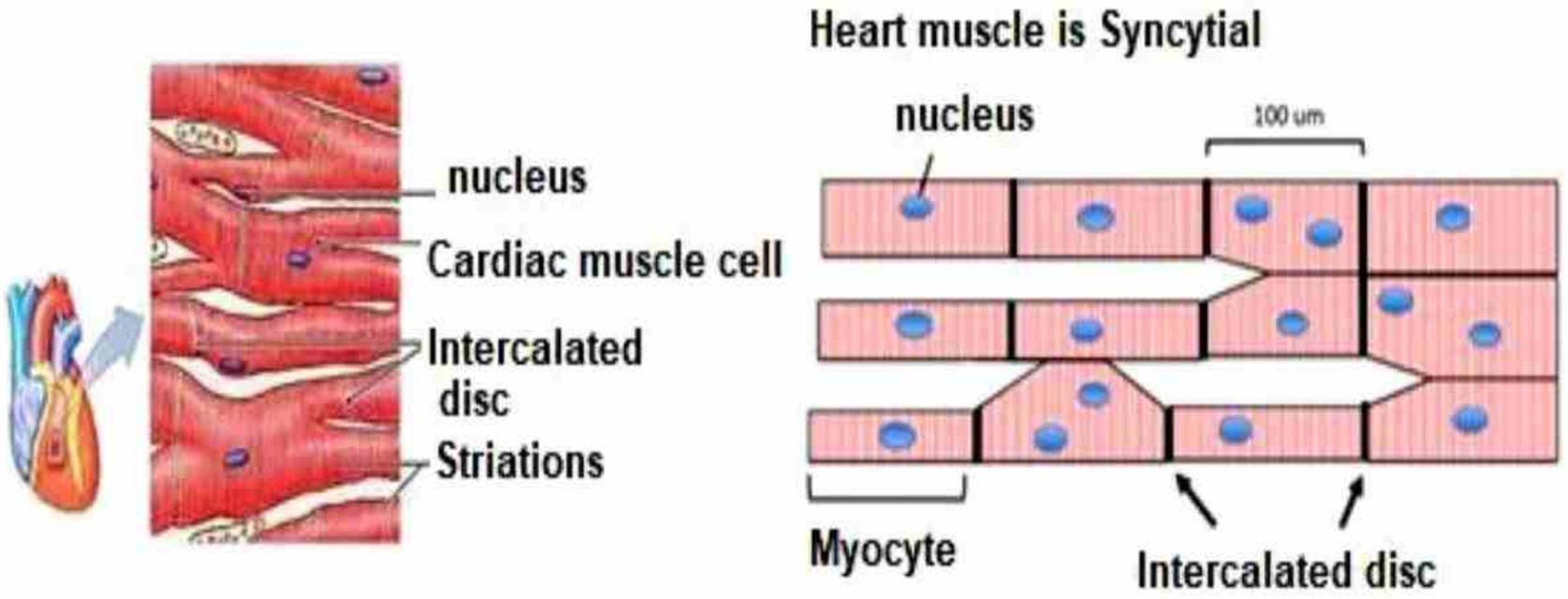


Fig. 16.20 Cardiac Muscles

The cardiac syncytium is a network of **cardiomyocytes** connected by intercalated discs that enable the rapid transmission of electrical impulses through the network. The cardiac muscles are the strongest among all. They work continuously throughout life and amazingly do not get fatigued. This is because they have numerous mitochondria and continuous supply of oxygenated blood.

Skeletal muscles

The muscles attached to skeleton are called skeletal muscles. The cells are striated, cylindrical and multinucleated. These are located in those organs which can perform voluntary movement like arms, legs, neck etc. They are arranged in bundles and the pattern of striations on muscle surface.

Fig. 16.21 Skeletal Muscles

16.3.2 Comparison of types of Muscles

Smooth muscles	Cardiac muscles	Skeletal muscles
They do not show striations	They show striations	They show striations
These muscles are spindle shaped	These muscles are cylindrically branched	These are cylindrical and unbranched
Present in hollow, visceral organs	Present in heart	Attached with skeleton
They are involuntary in action	They are involuntary in action	They are voluntary in action
They do not make cross bridges during movement	Cross bridges are formed	Cross bridges are formed
Instead of troponin, they contain calmodulin in actin filaments	They have troponin in actin filament	They have troponin in actin filament.

The structure of Skeletal muscle

A muscle is composed of thousands of **muscle fibers** grouped in bundles. The overall muscle organ is surrounded by a membrane called **epimysium.** Muscle fiber is gathered inside the epimysium in many groups. Each group of fibers is called a **fascicle** surrounded by a membrane called **perimysium**. Inside each fascicle a muscle fiber

is enveloped in a thin connective tissue layer of collagen called the **endomysium**.

Skeletal muscles have numerous supplies of blood vessels and nerves. The nerves are connected with muscle by neurons which initiate the mechanism of movement in muscle when order is given by nervous system.

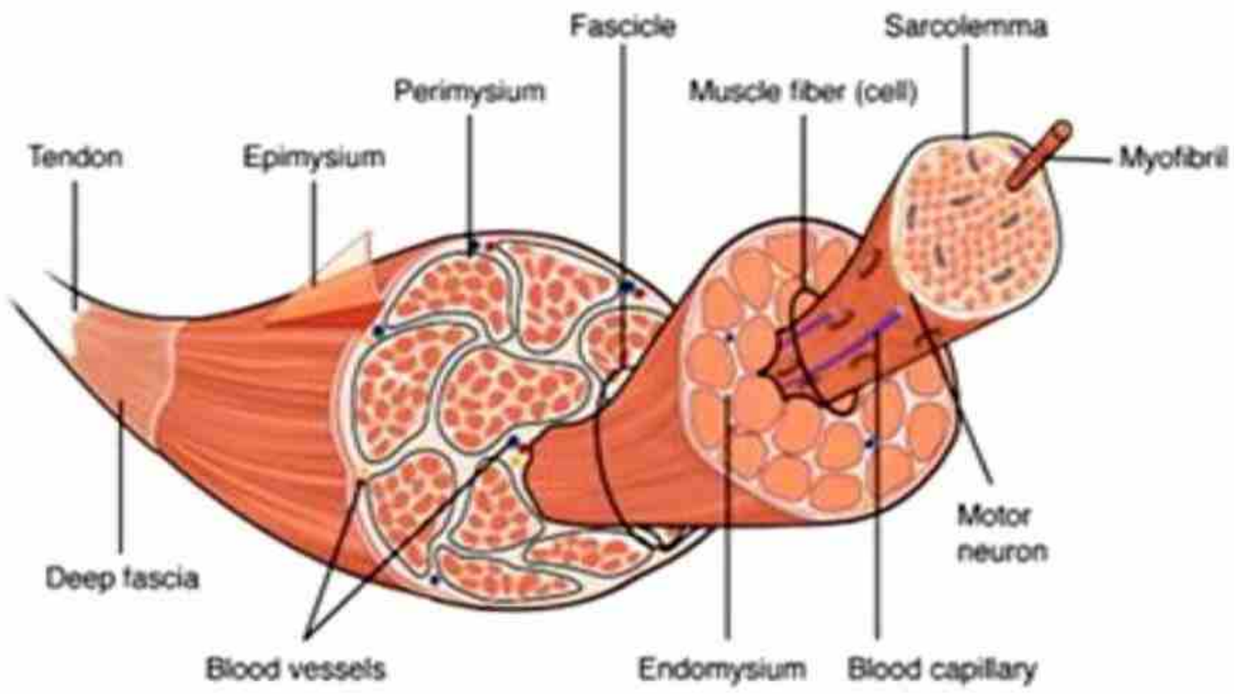


Fig. 16.22 Structure of Skeletal Muscle

The Ultra Structure of Skeletal Muscle Fiber

Muscle fiber is considered a cell of skeletal muscle with many **myofibrils**. Each muscle fiber has a covering just like a cell membrane called **sarcolemma**. The cytoplasm or **sarcoplasm** contains numerous nuclei and mitochondria. Each myofibril is connected with the axon of motor neuron at a place called **neuromuscular junction**. The specific neuromuscular junctions where mitochondria are abundant.

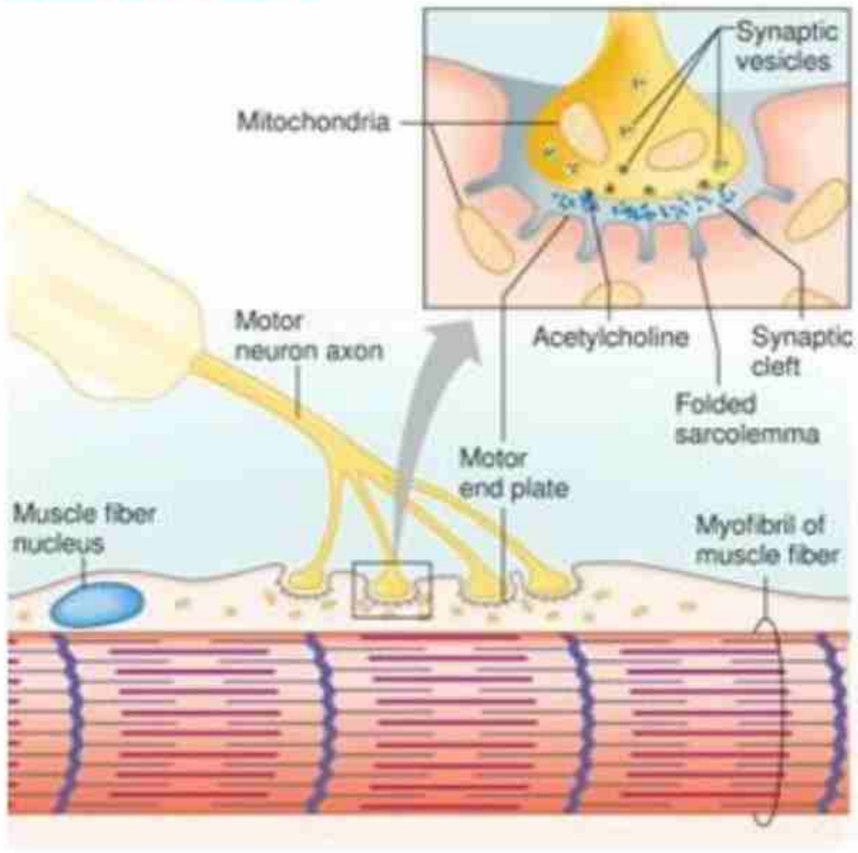


Fig. 16.23 Neuromuscular Junction

The sarcolemma is extensively folded s **motor end plate**. The sarcolemma permits calcium ions to enter or leave the myofibril from their specific proteinic gateways. Within the sarcoplasm, a membranous network is present that runs parallel to the myofibril called **sarcoplasmic reticulum**. It is the storage house for calcium ions used in muscle contraction. It extends inward to form a membranous channel called **T-tubules** that runs perpendicular and connected with sarcoplasmic reticulum.

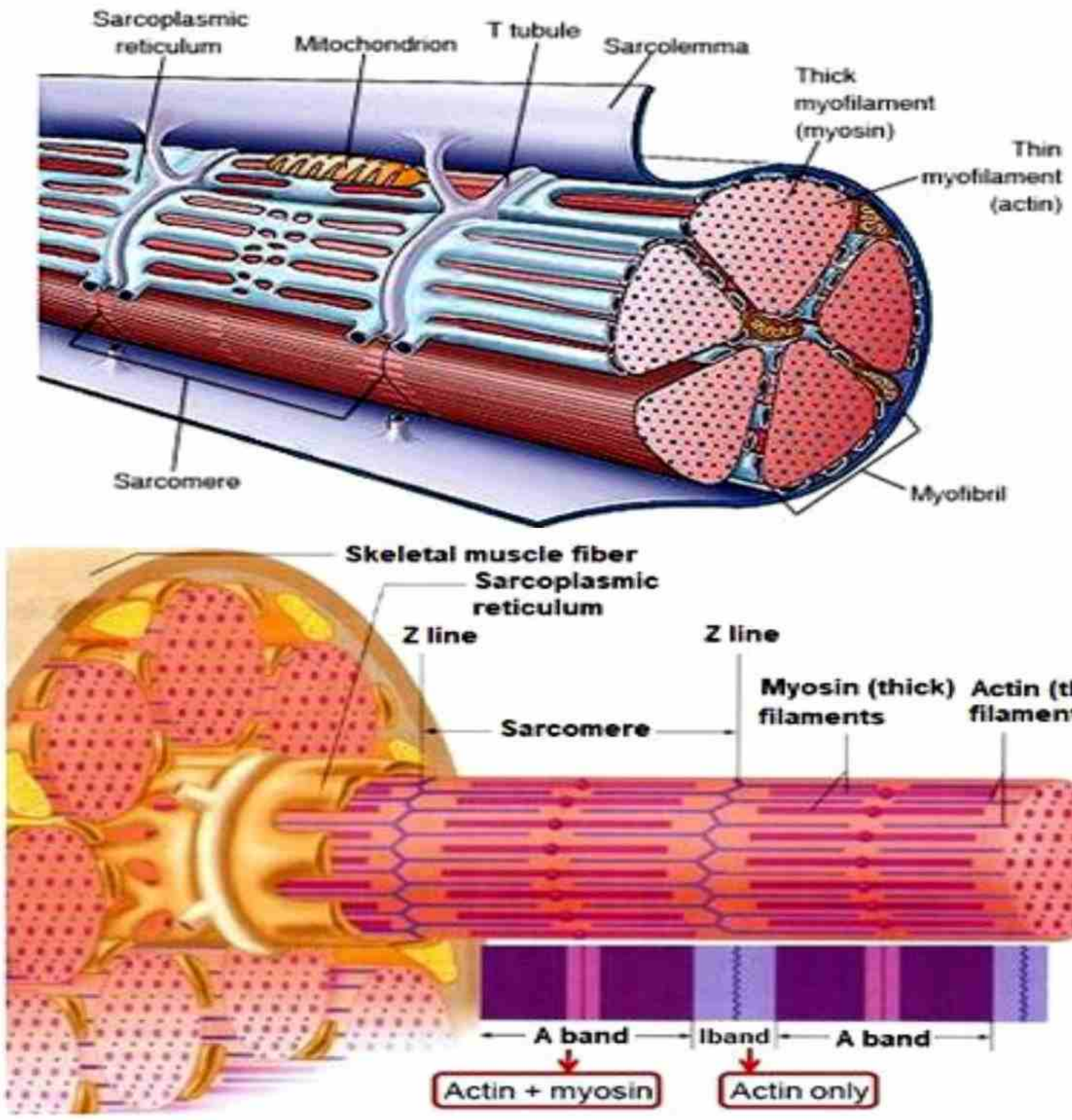


Fig. 16.24 Ultra Structure of Skeletal Muscle

Myofibril contains two kinds of protein filaments called **actin** and **myosin**. Each myosin filament is thick, 16nm in diameter and composed of myosin monomers. It has two twisted strands with projected heads outward which form a cross link with actin filament. Each actin filament is thin, 7-8 nm in diameter, double stranded, twisted and contains actin monomers associated with two other proteins called **troponin** and **tropomyosin**. Each actin monomer has a binding site for myosin cross bridges for attachment. Troponin is a complex of three different subunits called troponin C, I and T. Each subunit is assigned for specific function such as the troponin C (Tn-C) bind Ca^{2+}, the troponin I (Tn-I) inhibit actomyosin interaction and troponin T (Tn-T) is used for binding tropomyosin.

The organization of actin and myosin filaments develops alternating **light** and **dark** regions seem like striations or bands. The light region contains only actin filament called **'I' band (isotropic band).** Actin filaments of I band connected by **Z line or disc** (zwischen means middle).

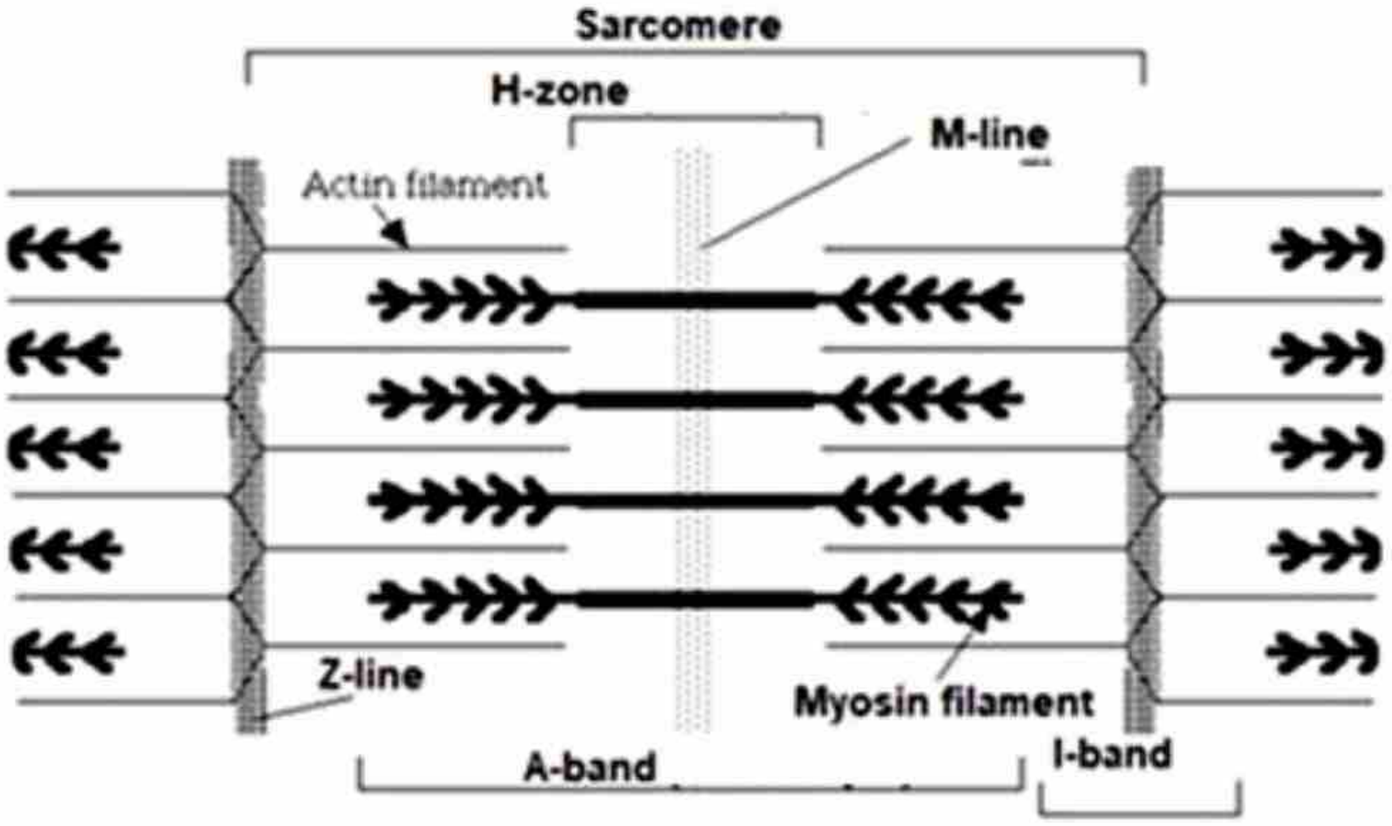


Fig. 16.25 Sarcomere of skeletal muscle

The dark region contains thick myosin filaments overlapping thin actin filaments called **"A" band (Anisotropic band)**. The myosin filaments are connected by **"M" line or disc** (Myomesin: protein). The A band has a slightly lighter middle region called **"H" zone** (Helle:

light) containing only myosin filament. The region between two 'Z' lines is called **sarcomere**.

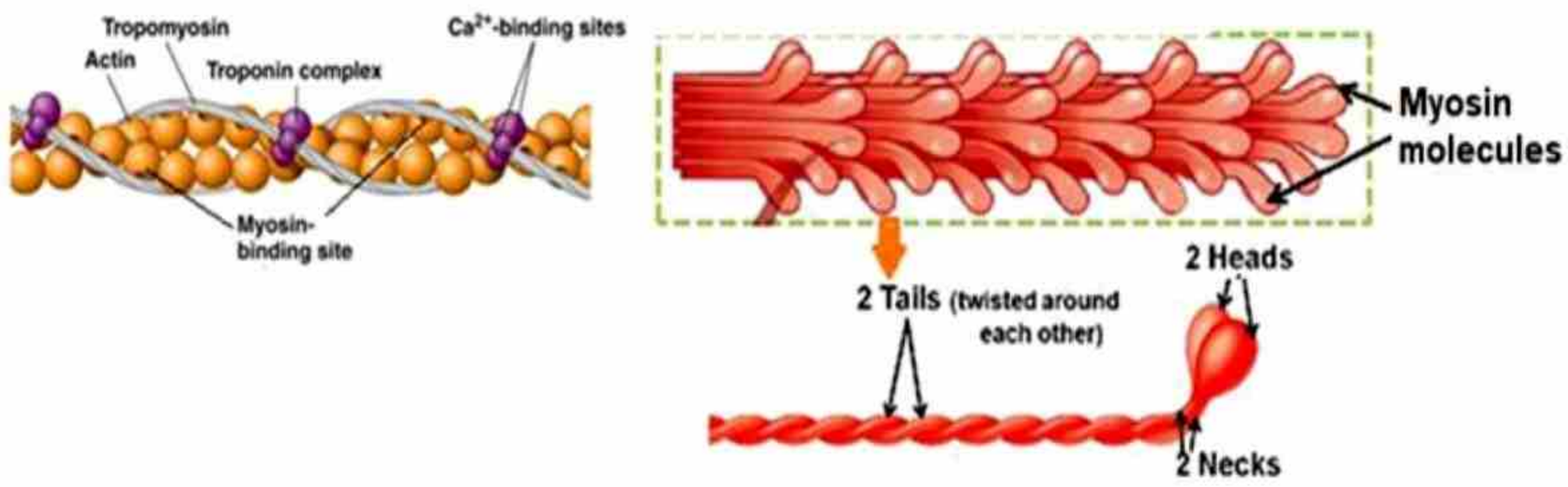


Fig. 16.26 Actin and Myosin filament

16.3.4 The sliding filament model of muscle contraction

The sliding filament model of muscle contraction, put forward by **Hugh Huxley and Jean Hanson** in 1954. According to this theory when sarcomere shortens, the thick and thin filaments do not themselves change their length. They just slide past one another, with the thin filaments moving toward the center of the sarcomere from both ends. As this occurs, the H zone and I bands get narrower, the regions of overlap widen, and the Z lines move closer together, shortening the sarcomere.

The sub-stages of sliding filament model are as follows:

The Cross Bridge Cycle

This cycle begins when muscle fibers are stimulated by receiving the nerve impulse at the motor end plate. Motor neurons release a neurotransmitter acetylcholine that opens the proteinic gateway in T-tubules and then in sarcoplasmic reticulum to release the stored calcium ions that initiate muscle contraction. The calcium ions are released and bind with the troponin of thin filament. This binding depolarizes tropomyosin along the actin filament, which in turn twists and exposes the myosin binding sites located on actin monomers. In the next step the myosin head rises by getting energy from ATP when bind ATP is hydrolyzed into ADP and phosphate by an enzyme ATPase. This causes the myosin head to extend and attach to the binding site of an actin and both actin and myosin

filaments are cross linked to form a cross bridge. This action called power stroke is triggered allowing myosin to pull the actin filament toward the M line, thereby shortening the sarcomere. ADP and phosphate are released during the power stroke. The myosin remains attached to the actin until a new molecule of ATP binds, freeing the myosin. Having been unbound from actin, the myosin heads resume their starting positions and are ready to begin a new sequence of actin binding. Thus, the presence of further calcium ions will trigger a new contraction cycle.

Relaxation

When nerve impulse ceases, two events relax the muscle fiber. During the first event the acetylcholine that remains in the synapse is rapidly decomposed by an enzyme called acetylcholine-esterase.

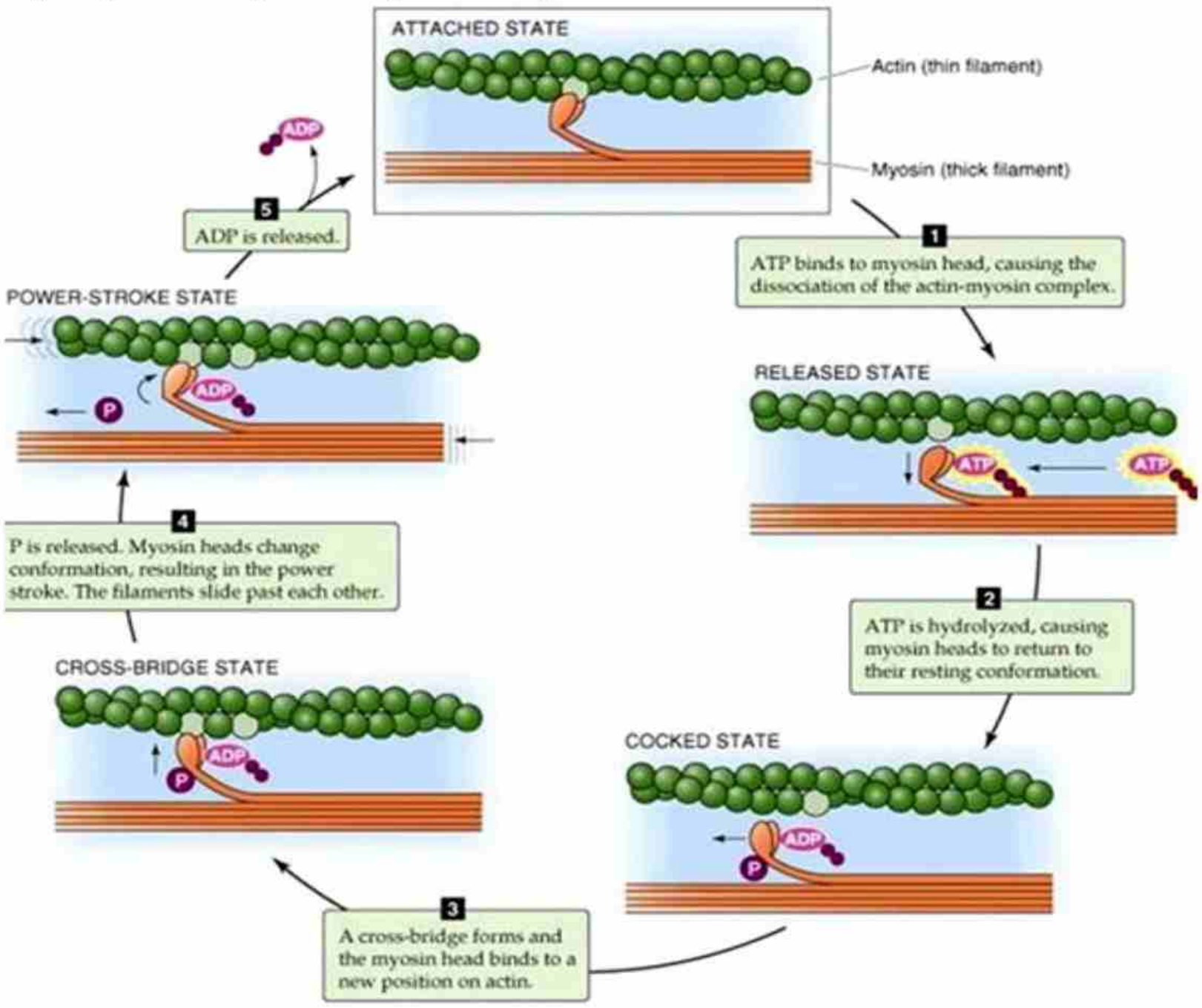


Fig. 16.27 Cross bridge cycle of skeletal muscle

This enzyme is present in synapse and on the membranes of the motor end plate. The action of acetylcholine-esterase prevents a single nerve impulse from continuously stimulating muscle fiber. During the second event when acetylcholine is broken down, the stimulus to the sarcolemma and the membranes within the muscle fiber ceases. The calcium pump (which requires ATP) quickly moves calcium ions back into the sarcoplasmic reticulum, decreasing the calcium ion concentration of the cytosol. Consequently, the muscle fiber relaxes.

16.3.5. The action of antagonistic muscles in the movement of knee joint

The ability of a muscle to oppose the action or effect of another muscle is called antagonistism. An antagonist muscle is relaxed while the other side opposite to antagonist muscle contracted called agonistic muscles. Knee joint is the largest and most complex of the synovial joints. It is formed by the articulation of distal end of femur and proximal end of tibial bone while anterior to the junction of these bones, patella bone is articulated. The antagonistic muscles of the knee joint are the group of hamstring muscles as **flexor muscles** and the group of quadriceps muscles as **extensor muscles**.

The **hamstring muscles** are made up of three individual muscles located in the back of the thigh, originating from hip, and inserting to the knee. Hamstring tendons attach to bones in pelvis, knee, and lower leg. Hamstring muscles serve a variety of functions, including bending the knee joint, extending, or rotating the hip joint.

Extra Reading Material

A hamstring muscle strain is the result of overstretched muscle fibers. Hamstring strains can range from mild to severe.

The **quadriceps** is made up of four different muscles. It is in the anterior region of the thigh. The quadriceps is a hip flexor and knee extensor. They form the main bulk of the thigh, and collectively are one of the most powerful muscles in the body. The quadriceps all work to extend (straighten) the knee. The quadriceps are primarily active in kicking, jumping, cycling, and running.

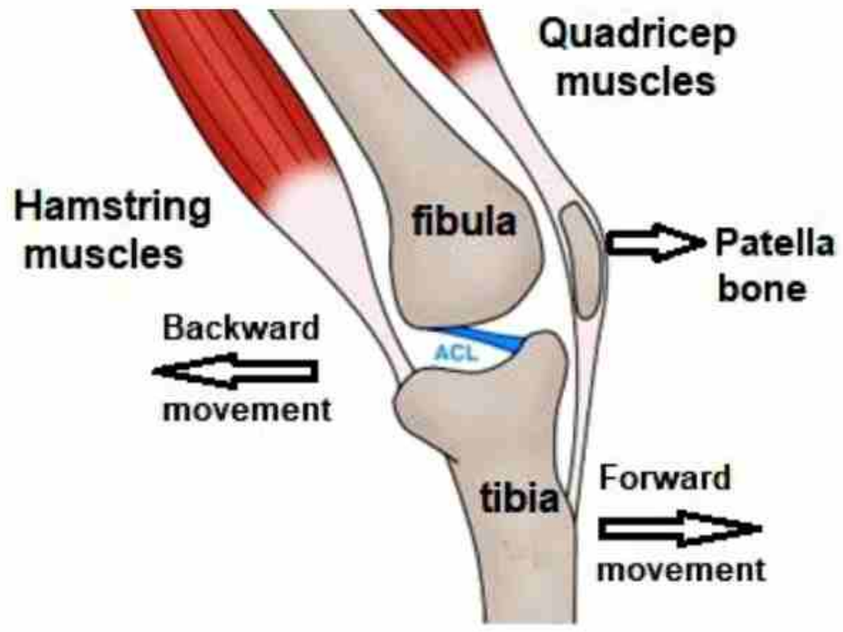


Fig. 16.28 Knee Joint Muscles

16.3.6 Muscle fatigue

A muscle exercised persistently for a longer period may lose its ability to contract, a condition called fatigue. It is most likely to arise from accumulation of lactic acid in the muscles due to anaerobic ATP production. The lowered pH from the lactic acid prevents muscle fibers from responding to stimulation. When lactic acid is produced, it diffuses out from the muscle fiber and is carried in the blood stream to the liver. Liver cells can react to lactic acid to form glucose. This requires ATP and ATP production is conditioned with the availability of oxygen. Therefore, when a person rests and acquires enough oxygen, lactic acid quickly breaks down and the muscle returns to normal.

Cramps

A muscle cramp is a painful stiffness in a muscle due to a sudden, involuntary contraction. A person feels sudden tightening as if they have flexed their muscle while it is actually relaxed. Muscle cramps have several causes like overuse of muscles while exercising, muscle injuries, dehydration, low levels of minerals like calcium, potassium, sodium, magnesium, low blood supply to the legs during physical activities. Usually, cramps can be relief by stretching or gently massaging the muscle, applying heat and use of ice when the muscle is sore, getting more fluids if dehydrated.

16.3.7 Differentiate between Tetany and Tetanus

TETANY	TETANUS
Tetany or tetanic seizure is a medical sign consisting of the involuntary contraction of muscles	Tetanus is an infectious disease affecting the central nervous system
caused by disorders that increase the action potential frequency of muscle cells or the nerves that innervate them	caused by a bacterium called *Clostridium tetani.*
Tetany can be the result of an electrolyte imbalance. Most often low calcium level, hypocalcemia, or magnesium, potassium deficiency, increased acidic (acidosis) or alkali (alkalosis) in the body.	Tetanus can be because of intravenous drugs inducted through contaminated needles by the abusers.
No toxins involve	Bacterium release neurotoxin called tetanospasmin, which acts on the synapses and causes muscular spasms and neuromuscular junction blockade
Severe vitamin D deficiency may be associated with hypocalcemia, which may cause tetany or seizures.	These functional impairments are manifested as flexor muscle spasms. The impact of the toxin on the sympathetic nervous system causes autonomic dysfunction.
a person may only die If tetany occurs in respiratory tract.	A person may die when the infection becomes severe.

SUMMARY

- Human skeleton acts as a framework of the body and the study of human bones is called osteology.
- Bone has distinct regions called epiphysis, diaphysis and metaphysis and covered by different layers
- Bones and cartilage are composed of numerous cells.
- Different types of cartilages are located in skeleton and plays vital role in protecting joints
- Human skeleton is formed by numerous bones and has two major divisions called axial and appendicular skeleton which include separate bones.
- Bones are joined to form different joints. The major groups of joints are called fibrous, synovial, and cartilaginous joints.
- The common disorders of the skeletal system are disc slip, spondylosis, sciatica, and arthritis.
- Repair of several types of bone fracture takes place in different steps in sequence i.e., hematoma formation, internal and external callus formation, replacement of cartilage by trabecular bone and remodeling.
- First-aid treatment is also used for the injuries in joints like dislocation and sprain.
- There are three types of muscles in the body that perform movement.
- Skeletal muscles are present in organs that work voluntarily, non-skeletal muscles in involuntary organs and cardiac muscles in heart.
- Skeletal muscle fiber contains numerous myofibril which contain two kinds of protein filaments namely actin and myosin.
- These filaments are cross linked and perform muscles contraction. Due to abnormal muscle contraction tetany and cramps takes place.

EXERCISE

1. Encircle the correct choice.

i) The type of bone cell that tears down bone during the building and remodeling process are
(a) Osteocytes (b) Osteoblasts
(c) Osteoclasts (d) Bone lining cells

ii) During bone formation, as the periosteum calcifies, it gives rise to a thin plate of compact bone called
(a) Periosteal bud (b) Periosteal bone collar
(c) Primary ossification center (d) Epiphyseal plate

iii) The ring like shape of the girdle is due to the joining of coxal bone with the sacrum of vertebral column at anterior side and below by a joint in between pubic part called
(a) Pubic symphysis (b) Iliac junction
(c) Pelvic symphysis (d) Syndesmosis

iv) Cartilage is a soft flexible form of connective tissue surrounded by a layer called
(a) Myocardium (b) periosteum
(c) Osteoderm (d) Perichondrium.

v) An antagonist muscle is relaxed while the other side opposite to antagonist muscle
(a) Contracted (b) Relaxed
(c) No change (d) Extremely relaxed

vi) The stage when old bone tissues are removed and gets replaced with new ones that joins both fractured sides called
(a) Bone remodeling stage (b) Bone callus formation
(c) Cartilaginous callus formation (d) Hematoma formation

vii) Which is related to the mild to severe grade of stretching or tearing of a ligament that holds the bones of a joint together?
(a) Spasm (b) Tetany
(c) Sprains (d) Cramps

viii) Muscle fiber are gathered in many groups each group of fibers is called a fascicle which is surrounded by a membrane called
(a) Sarcolemma (b) Perimysium
(c) Endomysium (d) Epimysium

ix) The heart muscles arranged in a branching network where cells are joined together and making a
(a) Syncytium (b)Sarcoplasmic reticulum
(c) Endoplasmic reticulum (d) T-tubules

x) These joints hold the bone by dense connective tissue contain collagenous fibers
(a) Fibrous joints (b) Syndesmosis
(c) Gomphosis (d) Synovial joints

2. Write short answers of the following questions:

1. How is the cartilage useful for our skeletal system?
2. Give a comparison of major types of joints
3. How is the healing of fractured bone initiated pain developing?
4. How to conduct a first aid treatment for joint injuries and fractures?
5. Give a comparison of types of muscles.
6. Why is calcium essential for cross bridge formation?
7. How the nervous coordination regulates muscle contraction mechanism?
8. How is tetany different from tetanus?
9. Explain the different types of cartilage.

3. Write detail answers of the following questions:

1. Explain the structure of skeletal muscles and ultra structure of skeletal muscle fiber with labelled diagram.
2. Explain the repair process of simple fractures
3. Explain the cross-bridge cycle of muscle contraction with labelled diagram

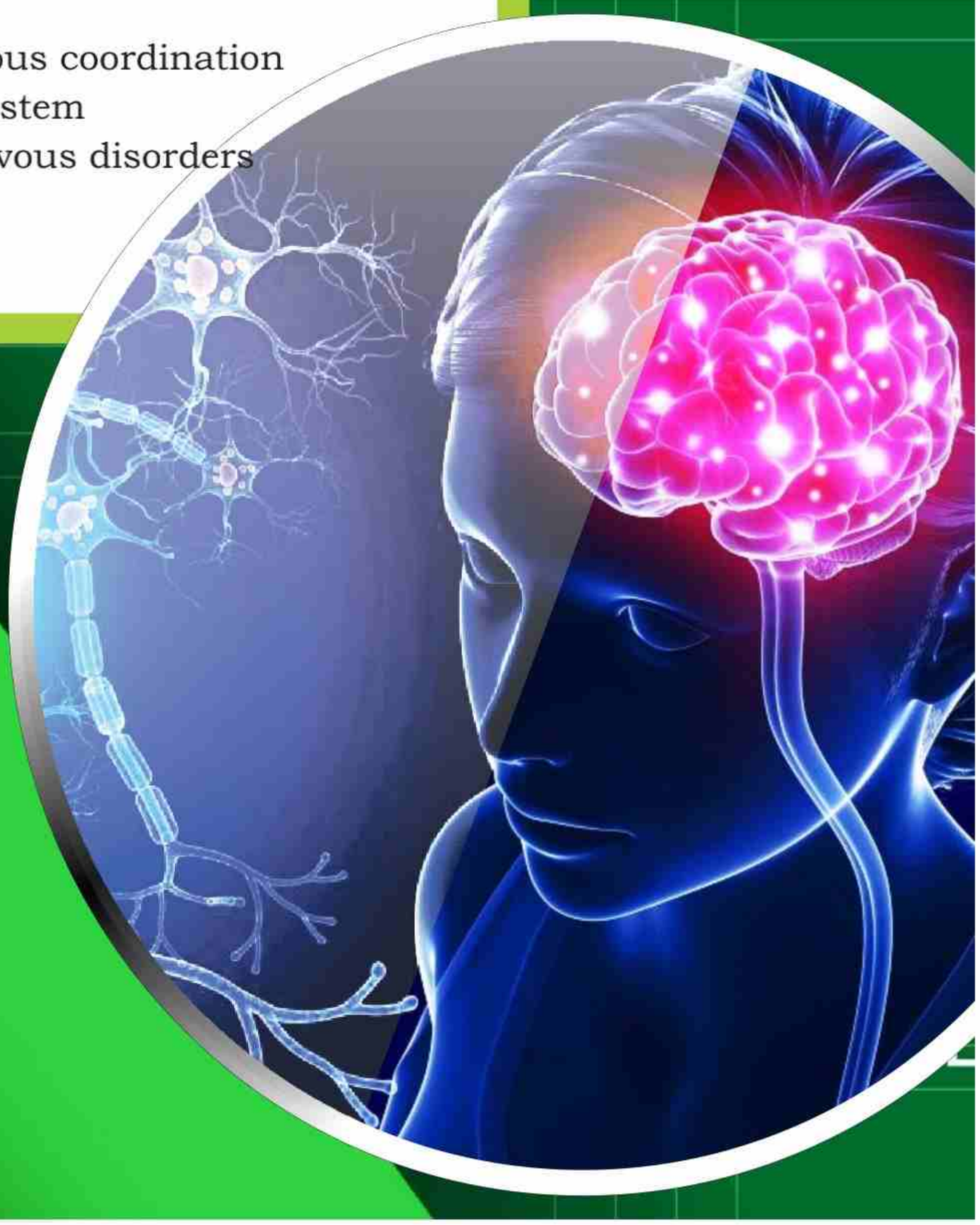
NERVOUS COORDINATION

Chapter 17

Major Concept

In this Unit you will learn:

- Nervous system of man
- Steps involved in nervous coordination.
- Neuron structure and types
- Nerve impulse
- Transmission of action potential between cells
- Basic organization of human nervous system
- Sensory receptors
- Effect of drugs on nervous coordination
- Disorders of nervous system
- Diagnostic tests for nervous disorders



NERVOUS COORDINATION

All animals except sponges use a network of nerve cells to gather information about the body's condition and the external environment, to process and integrate that information, and to send commands to the body's muscles and glands.

17.1.1 Steps involved in nervous coordination.

The system of the body that provides communication (coordination) through electrical and chemical signals is called the **nervous system**. Nervous coordination comprises highly specialized cells, called **neurons**. As the fundamental unit of the nervous system, each neuron must perform five functions.

- Receive information from the internal or external environment or from other neurons.
- Integrate the information it receives and produce an appropriate output signal.
- Conduct the signal to its terminal ending, which may be some distance away.
- Transmit the signal to other nerve cell, glands or muscles.
- Coordinate the metabolic activities that maintain the integrity of the cell.

17.1.1.1 Receptors as Transducers

The detection of the energy of a stimulus by sensory cells, most sensory receptors are specialized neurons or epithelial cells that exist singly or in groups with other cell types within sensory organs, such as the eye and ears. All receptors are **Transducers** "structures that convert signals from one form to another form". On the type of energy they detect (Transduce), receptors fall into five categories. **Mechanoreceptors** are stimulated by physical deformation caused by such stimuli as pressure, touch, stretch, motion and sound all forms of mechanical energy. **Pain receptors (Nociceptors)** a stimulus that causes or is about to cause tissue damage is perceived as pain. The receptors that transmit impulses perceived as pain are called pain receptors or nociceptors. **Thermoreceptors** these receptors are responding to either heat or cold help in regulation of body temperature by signaling both surface and body core temperature. **Chemoreceptors** These receptors transmit information

about the total solute concentration in a solution and specific receptors that respond to individual kinds of molecules, **osmoreceptors** in human brain (hypothalamus) detect changes in total solute concentration of the blood and stimulate thirst when osmolarity increases. Chemoreceptors found in nasal epithelium are **olfactory receptors** (smell) chemoreceptor found in tongue for tastes are **gustatory receptors**. **Photoreceptors** these receptors detect light stimuli, are organized in eyes (Rods and Cones).

All sensory inputs from receptors are received by the central nervous system (CNS). This collected information is further processed or analyzed for appropriate response by special type of neurons called interneurons.

Effectors

Effectors are generally muscles or glands. An effector produces a response to a stimulus. Effectors receive commands from the central nervous system to produce a response.

17.1.2 The Path of a Message Transmitted to the CNS

The CNS, which is made up of the brain and spinal cord, receives signals and reacts by designating particular assigned neurons through effector organs.

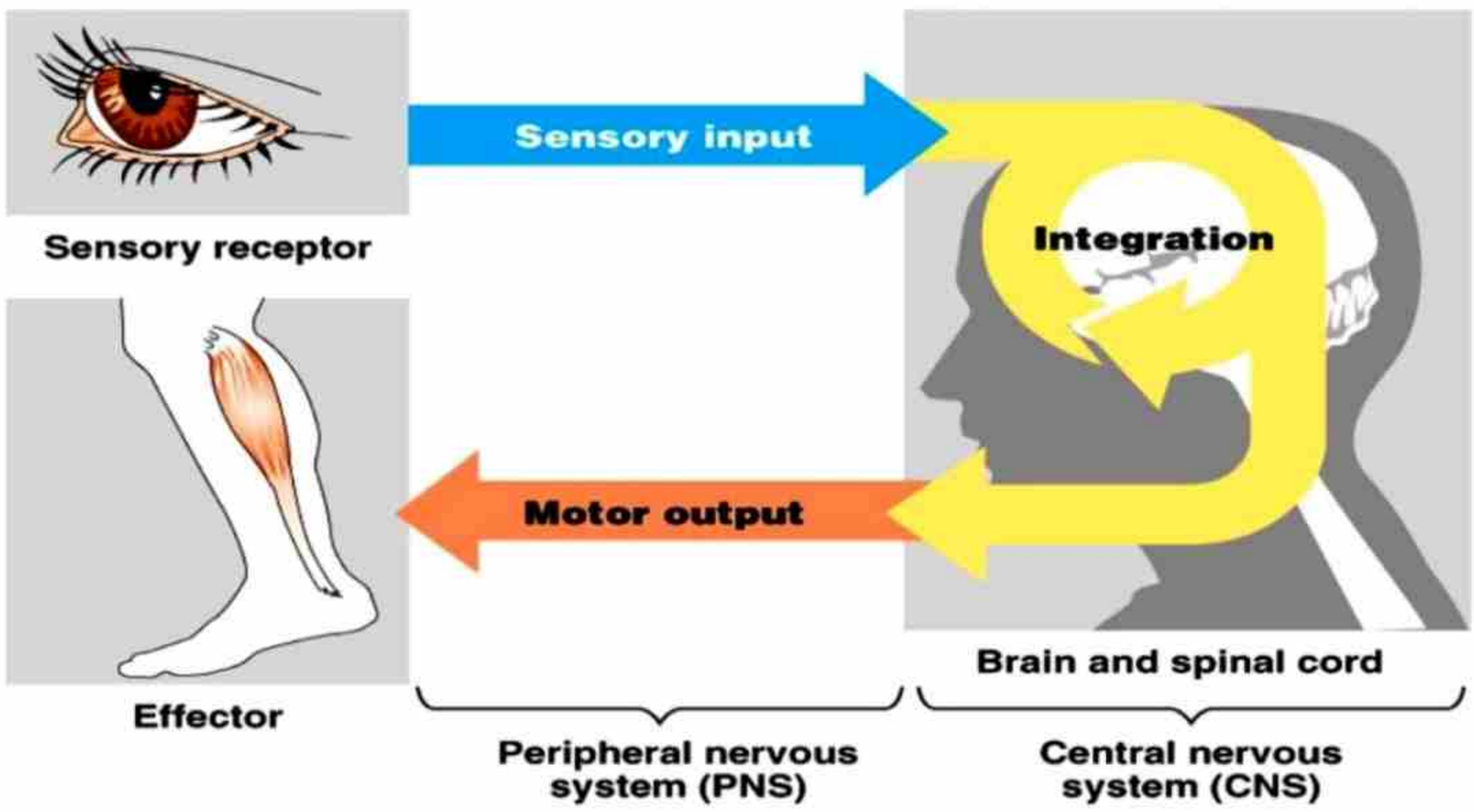


Fig.17.1 Pathway of Nervous Coordination

The messages are picked up by specific sensors, which could be the sensory neuron's nerve ends in an organ or another type of cell that signals the sensory neuron. A nerve impulse that goes to the brain or spinal cord is started by the sensory neuron. Sensors in the eyes, ears, muscles, skin, and other body components send messages to the spinal cord or brain via sensory neurons. In agreement with that, the effector organ receives a message from the brain or spinal cord via a motor neuron.

17.1.2. Neurons

The neuron is a functional and structural unit of the nervous system and is specialized for transmitting signals from one location in the body to another.

Structure of Neuron

A neuron has a relatively large cell body (soma) containing the nucleus and variety of cell organelles in cytoplasm, Nissl's bodies or granules are group of ribosomes and rough endoplasmic reticulum associated with protein synthesis. It is covered with membrane called **neurolemma**, one of the main functions of the cell body is to manufacture **neurotransmitters**, which are chemicals stored in secretory vesicles at the ends of axon.

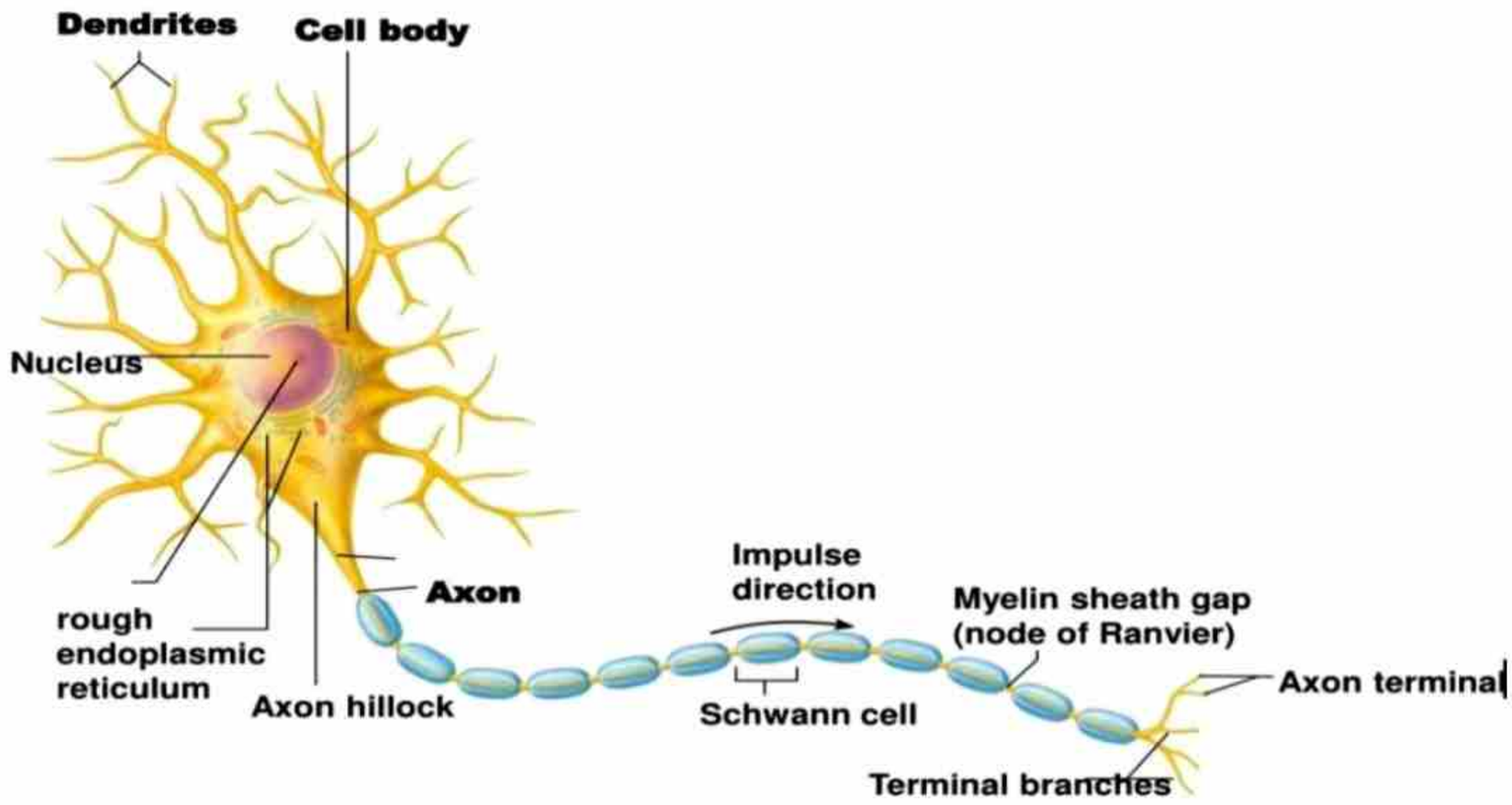


Fig.17.2 Structure of Neuron

Dendrites (Gr: Dendron = Tree)

Branched tendrils that extend outward from the cell body are specialized to respond to signals from other neurons or from the external environment, their branched form provides a large surface area to receive these signals.

Axon (Gr: Axon = Axis)

A long fiber extends outward from the cell body, making neurons the longest cell in the body. The cytoplasm of an axon is called an axoplasm covered with axolemma. The axon is primarily involved in carrying the electrical signals from the cell body to the neuron ending and transmitting it to other neuron or effectors.

Neuroglia (Glial cells)

Structurally and functionally neurons are supported by supporting cells, which are collectively called neuroglia. They serve a variety of functions, including supplying the neurons with nutrients, removing wastes from neurons, guiding axon migration and providing immune functions. Neuroglia are of two types **Schwann cells** and **Oligodendrocytes**.

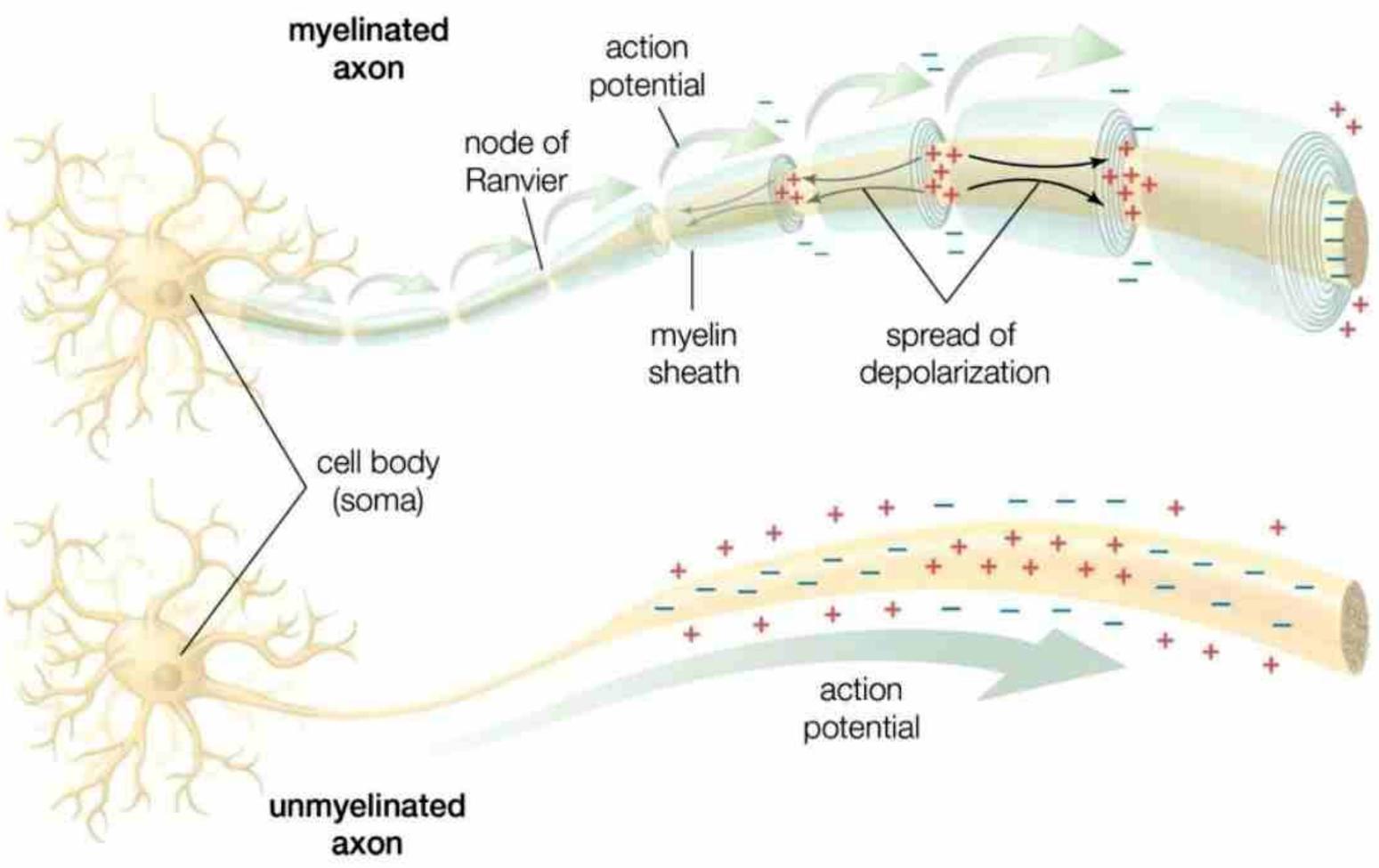


Fig.17.3 Myelinated and Unmyelinated Neuron

Schwann cells produce myelin in peripheral nervous system (PNS) and oligodendrocytes produce myelin in central nervous system (CNS). Axon that have myelin sheath are said to be myelinated fibers, and those that don't are unmyelinated fiber. A non-myelinated part of axon between two Schwann cells is called **Node of Ranvier** or **Neurofibril Nodes**.

Types of Neurons

Functionally, there are three types of neurons,

Sensory Neuron (Afferent neuron)

These neurons are generally found in the sensory organs, such as the eyes, nose, skin, tongue and ear. These nerve cells are triggered by the chemical and physical inputs of our environment, such as sound, heat, and light. The sensory neurons facilitate the movement of sensory impulses from receptors to the central nervous system (CNS).

Motor Neuron (Efferent neuron)

These neurons are the ones that facilitate the transmission of motor impulses from the central nervous system to the effectors. These types of neurons play a major role in the voluntary and involuntary movement of the body.

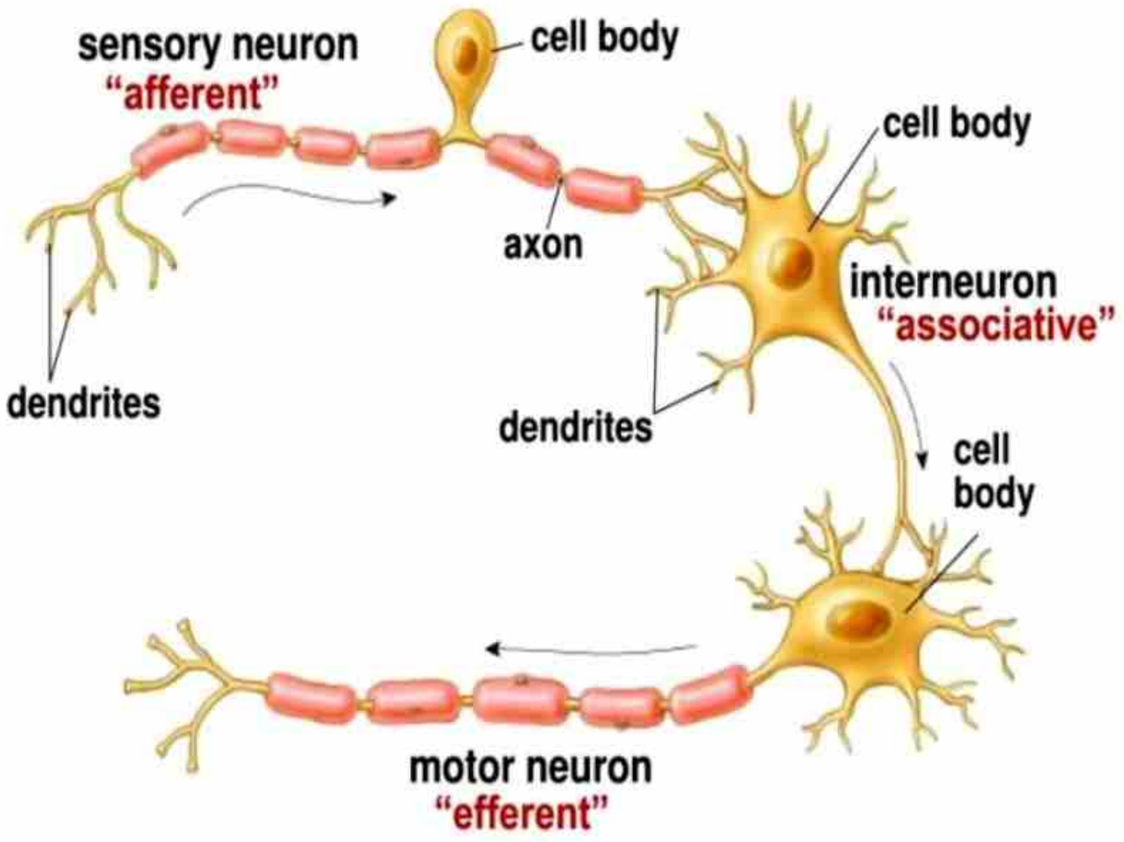


Fig.17.4 Types of Neuron

Interneuron (Association neuron)

These neurons act as a mediator between sensory neurons, motor neurons and the central nervous system. It helps in the smooth transmission of signals.

Reflex action

Each sensory neuron conveys a signal, from a sensory receptor to a motor neuron, which in turn sending signals to an effector the result is often a simple, automatic response called a reflex or **reflex action**. Pathway along which impulses are transmitted from a receptor to an effector called **reflex arc**. Examples of human reflexes include the familiar knee jerk and pain withdrawal reflexes. The pain withdrawal reflex uses one neuron of each type. Reflexes of this sort do not require the interneurons (Brain), although we know, other pathways inform the brain of pricked fingers.

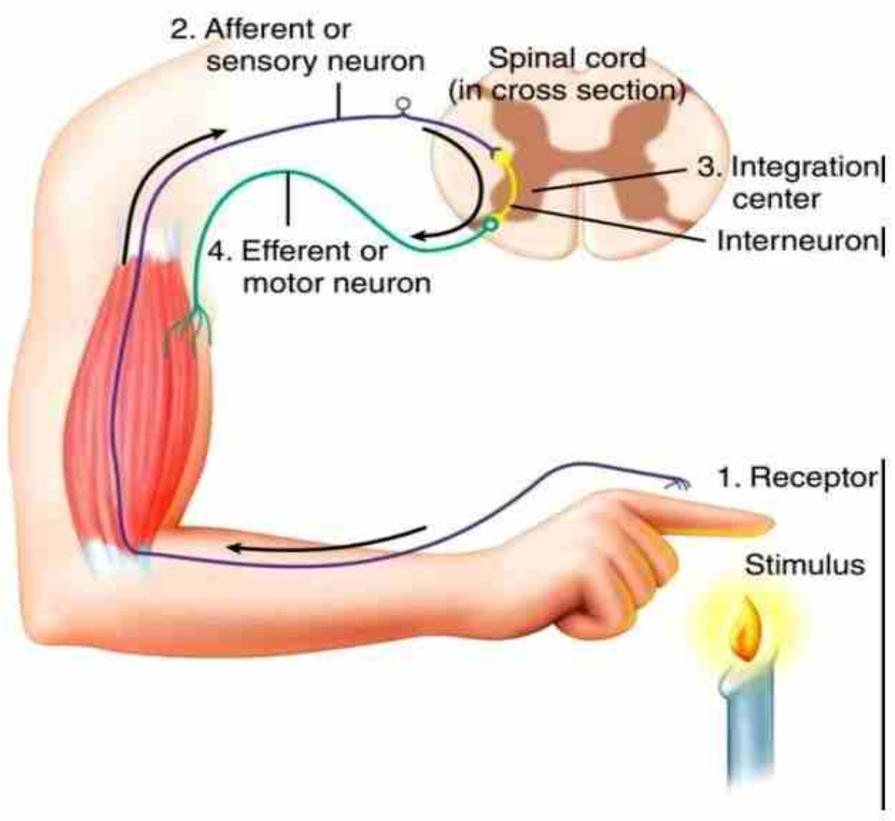


Fig.17.5 Reflex action

17.1.3 Nerve Impulse

Nerve impulse is an electrical signal that depends on the flow of ions across the membrane of a neuron. The signal begins as a change in the electrical gradient across the cell's plasma membrane.

Generation and transmission and nerve impulse

All living cells have an electrical charge difference across their neurolemma. Differences in charge give rise to an electrical voltage gradient across the membrane. The voltage measured across the neurolemma is called **membrane potential.**

The nerve impulse is the electrochemical transmission of messages through neurons. It travels through dendrites or axon due to the voltage proteinic gated channels in the neurolemma. These

channel open and close in response to the electrical voltage. Neurolemma is **polarized** and from inside negatively charged with respect to the outside due to distribution of ions.

Distribution of Ions

Polarization means the intracellular major positive ions are potassium (K^+) and sodium (Na^+) are major extracellular ions. The concentration of potassium (K^+) is 30 times greater inside the fluid than outside and the concentration of sodium (Na^+) is nearly 10 times greater outside than inside the fluid. Distribution is created largely by the sodium, potassium pumps which actively transport sodium out of the cell and potassium inside the cell. The channels in membrane are specific to ions and allow only one kind of ions and restrict other ions to pass through it. The negative ions inside the neurolemma are chloride (Cl^-), PO_4^{-2}, SO_4^{-2} and some proteins that are produced inside and cannot diffuse outside the cell.

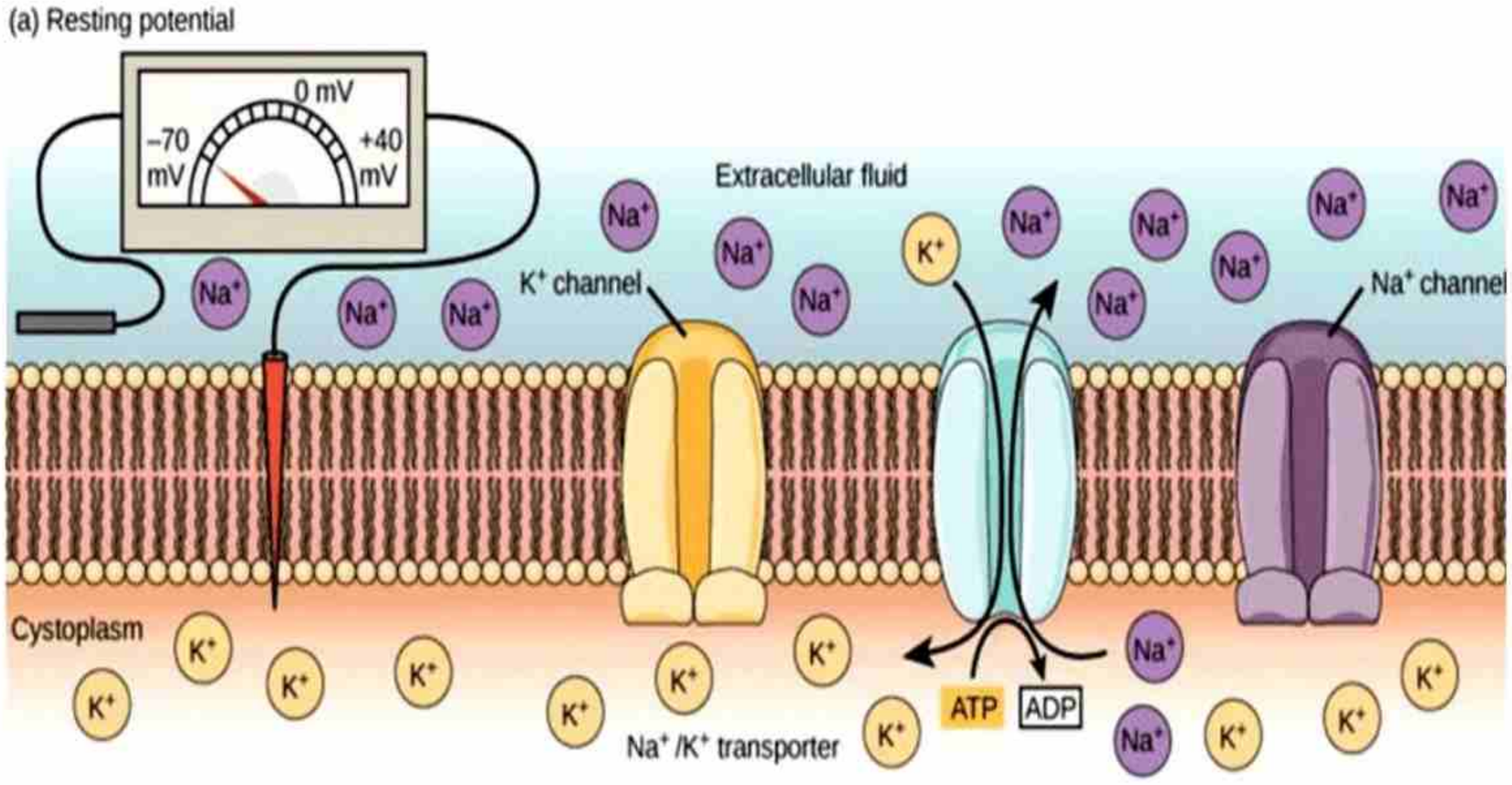
Resting membrane potential (RMP)

A resting nerve cell is the condition when it is not being stimulated to send a nerve impulse. The resting membrane is only slightly permeable to these ions while the threshold established during action potential. The potential difference the positive and negative charges across the cell membrane are called the membrane potential and are measured in millivolts. The resting membrane potential has a value of -70 millivolts. The negative sign is related to the inside excessive negative ions. Neurons are excitable means they respond to changes in their surroundings. These changes or stimuli affect the membrane potential. If the membrane potential becomes more negative than the resting potential the membrane becomes **hyperpolarized** and if the membrane becomes less negative than the resting potential, the membrane depolarized. Sufficient **depolarization** results in an action potential.

When the membrane is at rest, K^+ ions accumulate inside the cell due to a net movement with the concentration gradient. The negative resting membrane potential is created and maintained by increasing the concentration of cations outside the cell (in the extracellular fluid) relative to inside the cell (in the cytoplasm). The negative charge within the cell is created by the cell membrane being

more permeable to potassium ion movement than sodium ion movement. In neurons, potassium ions are maintained at high concentrations within the cell while sodium ions are maintained at high concentrations outside of the cell. The cell possesses potassium and sodium leakage channels that allow the two cations to diffuse down their concentration gradient.

However, the neurons have far more **potassium leakage channels** than **sodium leakage channels**. Therefore, potassium diffuses out of the neurolemma at a much faster rate than sodium leaks in. Because more cations are leaving the cell than are entering, this causes the interior of the cell to be negatively charged relative to the outside of the neurolemma. The actions of the sodium potassium pump help to maintain the resting potential, once established. Recall that sodium potassium pumps brings two K^+ ions into the cell while removing three Na^+ ions per ATP consumed. As more cations are expelled from the cell than taken in, the inside of the cell remains negatively charged relative to the extracellular fluid. It should be noted that chlorine (Cl^-) tends to accumulate outside of the cell because they are repelled by negatively charged proteins within the cytoplasm.



At the resting potential, all voltage-gated Na^+ channels and most voltage-gated K^+ channels are closed. The Na^+/K^+ transporter pumps K^+ ions into the cell and Na^+ ions out.

Fig.17.6 Resting membrane potential

Action Membrane Potential (AMP)

Action potential is triggered when any stimulus received by the neuron. The sodium channels open instantly and Na^+ ions rushed inside the cell depending upon the intensity of stimulus. The membrane potential changes from its resting value, depolarize and becomes positive on the inside the membrane. The action potential may reach up to 50 mV. Then the gates of sodium closed and potassium channels open which diffuses out of the membrane. As potassium goes out the membrane potential becomes negatively charged once again and repolarize. This return to the resting state usually takes from 10 to 30 milliseconds.

If a stimulus is capable to produce action potential in neuron it is called **threshold stimulus**. If stimulus is not capable to excite of fails to arise any response, it is called **sub-threshold stimulus**.

Depolarization

It refers to a graded potential state because a threshold stimulus of about -55 mV causes a change in the membrane potential. The threshold stimulus must be strong enough to change the resting membrane potential into action membrane potential. This results in the alternation in the electro-negativity of the membrane because the stimulus causes the influx of sodium ions (electropositive ions) by 10 times more than in the resting state. For this, sodium voltage-gated channels open. The action potential state is based on the "All or none" method and has two possibilities:
If the stimulus is not more than the threshold value, then there will be no action potential state across the length of the neurolemma.
If the stimulus is more than the threshold value, then it will generate a nerve impulse that will travel across the entire length of the neurolemma.

Voltage-gated sodium channel Open channel carries an influx of Na^+ ions, giving rise to depolarization. As the channel becomes closed or inactivated, the depolarization ends. After a cell has established a resting potential, that cell has the capacity to undergo depolarization. During depolarization, the membrane potential rapidly shifts from negative to positive. For this rapid change to take place within the interior of the cell, several events must occur along the neurolemma

of the cell. While the sodium–potassium pump continues to work, the voltage-gated channels that had been closed while the cell was at resting potential are opened in response to an initial change in voltage. As the sodium ions rush back into the cell, they add positive charge to the cell interior, and change the membrane potential from negative to positive. Once the interior of the cell becomes more positively charged, depolarization of the cell is complete, and the channels close again.

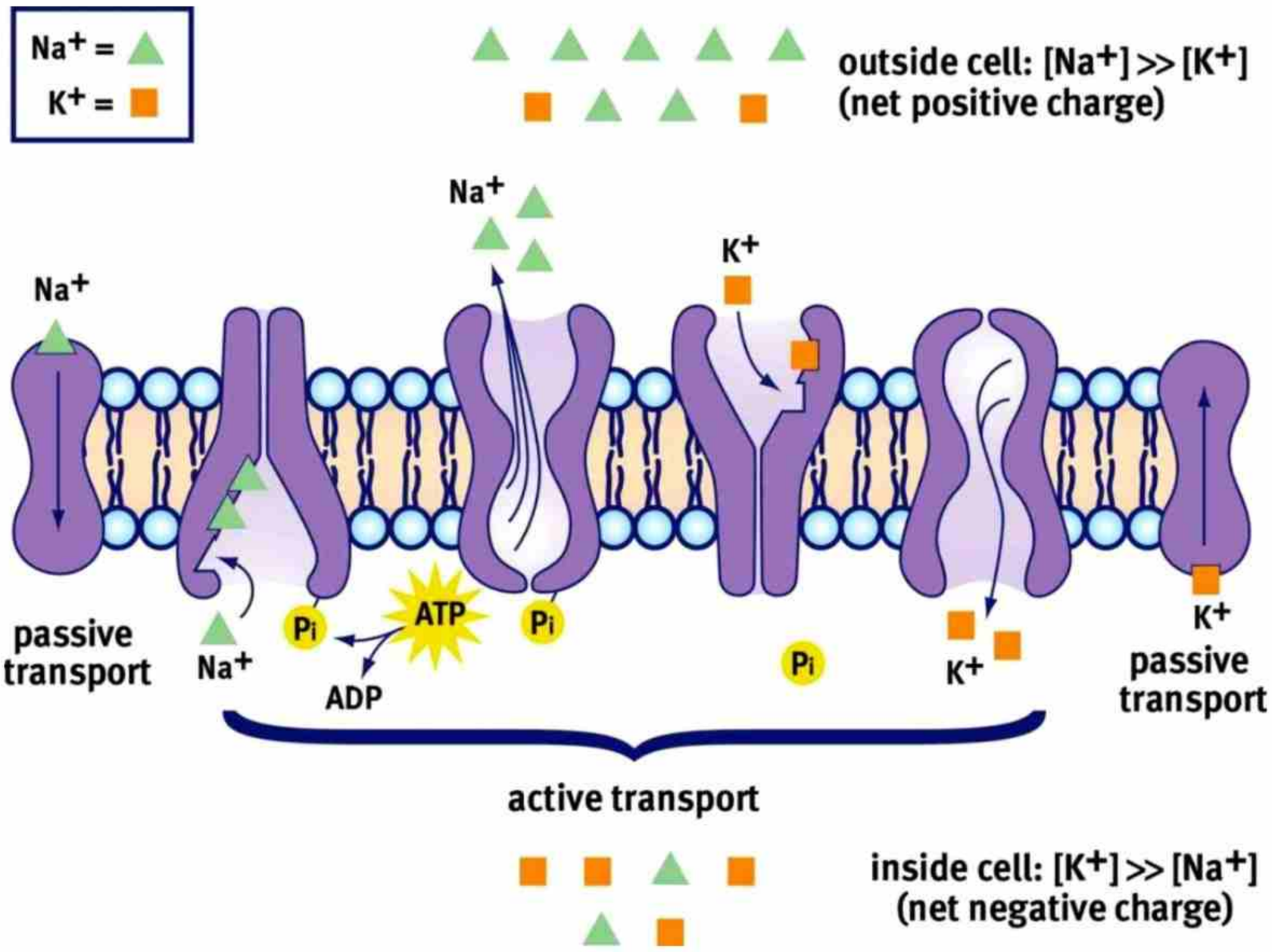


Fig.17.7 Ionic movement across neurolemma

Repolarization

It is a condition during which the electrical balance is restored inside and outside the neurolemma. Due to the high concentration of sodium ions inside the axoplasm, the potassium channels will open. During the repolarization state, efflux of potassium ions through the potassium channel occurs. As a result of the opening of potassium

voltage-gated channels, sodium voltage-gated channels will be closed. Thus, no sodium ions will move inside the membrane. Therefore, repolarization helps in maintaining or restoring the original membrane potential state.

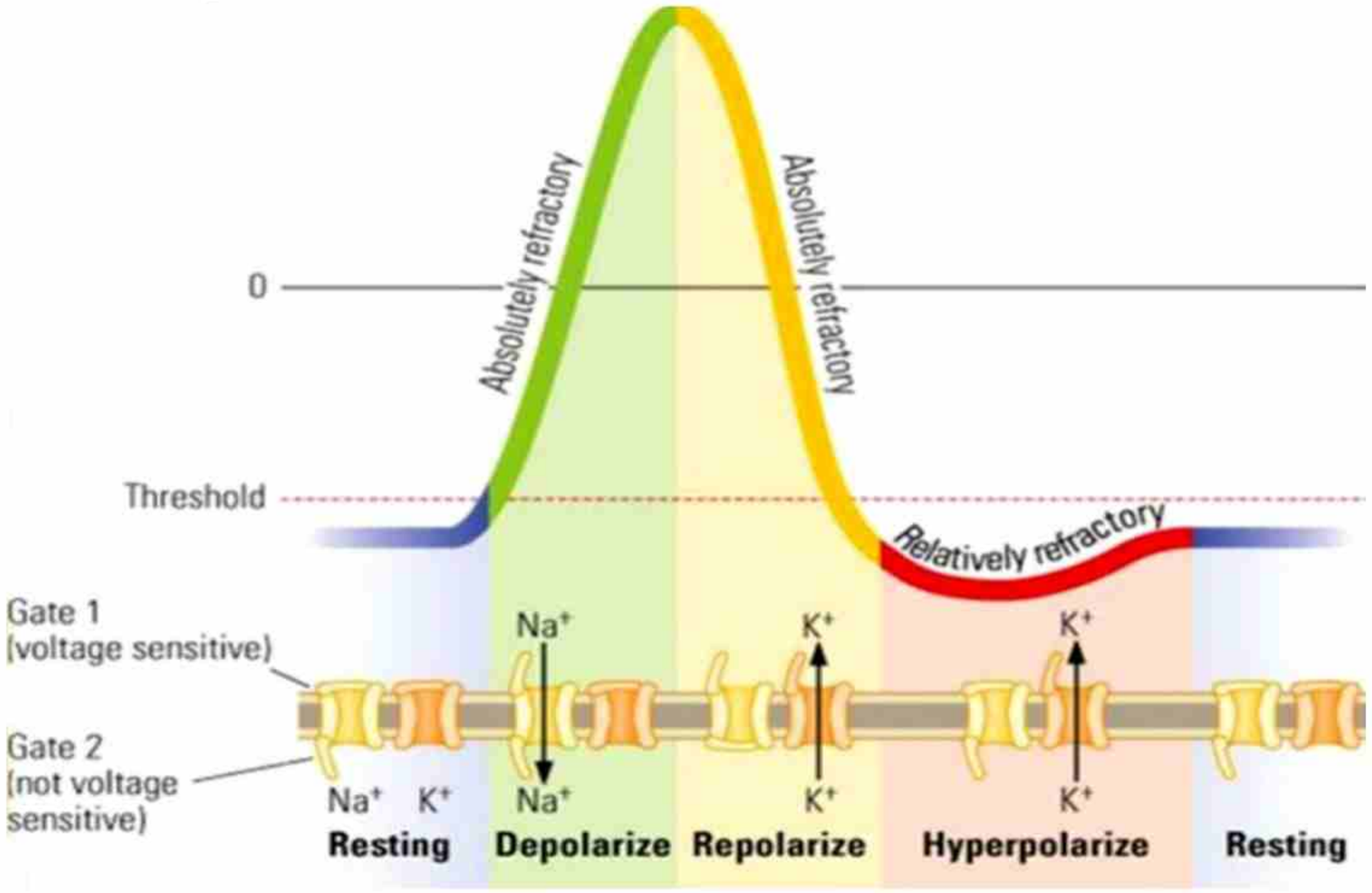


Fig.17.8 Action membrane potential

Until potassium channels close, the number of potassium ions that have moved across the membrane is enough to restore the initial polarized potential state. As a result of this, the membrane becomes hyperpolarized and has a potential difference of -90 mV. After a cell has been depolarized, it undergoes one final change in internal charge. Following depolarization, the voltage-gated sodium ion channels that had been open while the cell was undergoing depolarization close again. The increased positive charge within the cell now causes the potassium channels to open. Potassium ions (K^+) begin to move down the electrochemical gradient (in favor of the concentration gradient and the newly established electrical gradient). As potassium moves out of the cell the potential within the cell decreases and approaches its resting potential once more. The sodium potassium pump works continuously throughout this process.

Refractory Period

The refractory phase is a brief period after the successful transmission of a nerve impulse. During this period, the membrane prepares itself for the conduction of the second stimulus after restoring the original resting state. It persists for only 2 milliseconds.

During this, the sodium ATP driven pump allows the re-establishment of the original distribution of sodium and potassium ions. The sodium and potassium ATP pump, driven by using ATP, helps to restore the resting membrane state for the conduction of a second nerve impulse in response to the other stimulus. It causes the movement of ions both against the concentration gradient. For every two potassium ions that move inside the cell, three sodium ions are transported outside. This process requires ATP because the movement of ions is against the concentration gradient of both ions.

Hyperpolarization

The process of repolarization causes an overshoot in the potential of the cell. Potassium ions continue to move out through K+ channels or Cl- influx through CL- channels therefore the resting potential is exceeded and the new cell potential becomes more negative than the resting potential (-70 mv to -75mv). The resting potential is ultimately re-established by the closing of all voltage-gated ion channels and the activity of the sodium potassium ion pump.

Velocities of Nerve Impulse

Action potentials must travel rapidly. Animals have evolved two ways to increase the velocities of nerve impulses. The velocity of conduction is greater if the diameter of the axon is larger or if the axon is myelinated. Increasing the diameter of an axon increases the velocity of nerve impulse due to the electrical property of resistance. Electrical resistance is inversely proportional to cross sectional area.

So larger diameter axons have less resistance to nerve impulse (current flow) Transmission speed varies from several centimeters per second in very thin axons to about 100 m/sec in the giant axons. Myelinated axons conduct impulses more rapidly than unmyelinated axons because the action potential is myelinated axons are only produced at nodes of Ranvier (small gaps between successive

Schwann cells). Also extracellular fluid is in contact with the axon membrane only at the nodes, so that the flow of ions between the inside and outside of the axon can occur only in these regions. The action potential does not propagate over the length of the axon, but rather jump from node to node, skipping the insulated regions of the membrane between the nodes this mechanism, called **saltatory conduction** results in faster impulse transmission up to 150m/sec in some neurons.

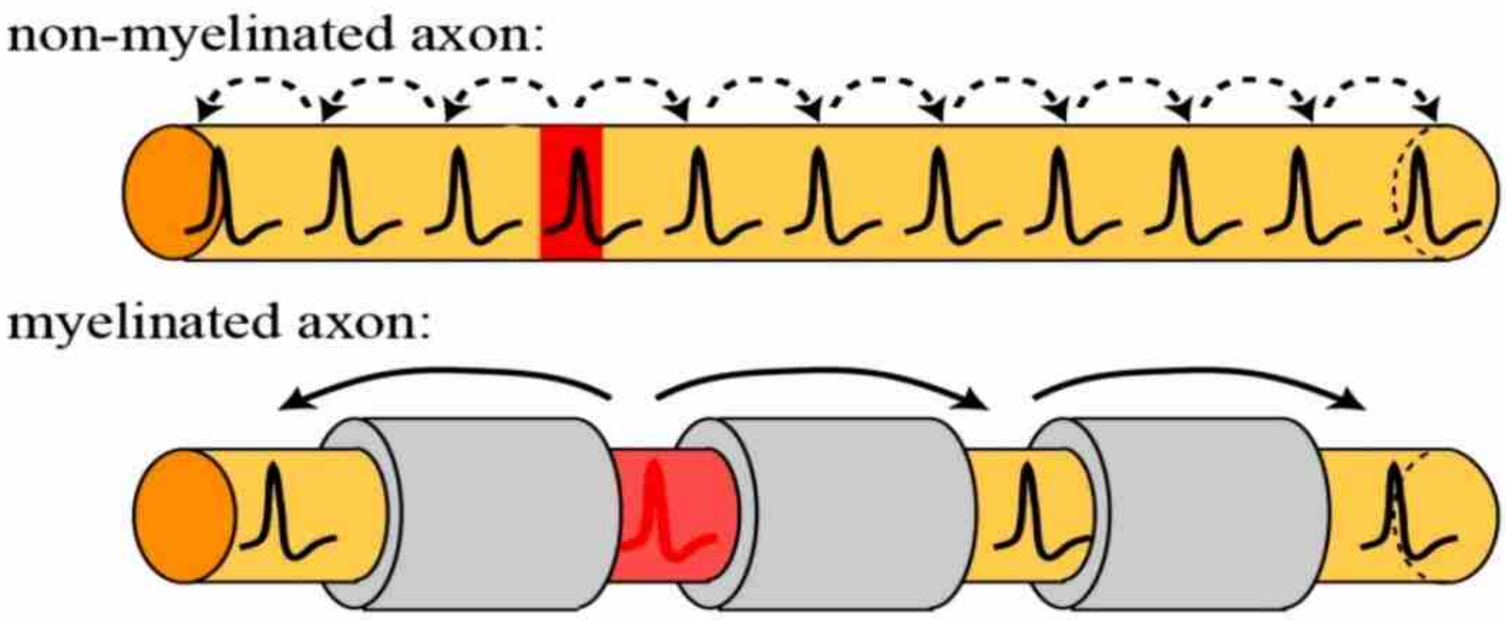


Fig.17.9 Velocities of Nerve impulse

17.1.4. Synapse

Synapse is a junction that controls communication between a neuron and another cell. Synapse is found between two neurons, between sensory receptor and sensory neuron, between motor neuron and the muscle cells, they control and between neuron and glands cells.

Structure of synapse

The neuron whose axon transmits action potential to the synapse is termed the pre-synaptic cell, and the cell receiving the signal on the other side of the synapse is the postsynaptic cell. There is a gap called a synaptic cleft between them.

Mechanism of Synaptic Transmission

The movement of impulse across the synapse is called a synaptic transmission. In animals two basic types of synapses are **electrical synapse** and **chemical synapse**.

An **electrical synapse** involves direct cytoplasmic connections formed by gap junctions between the presynaptic neuron and post synaptic neurons. These make it possible for impulses to transmit from neuron to neuron without delay and with no loss of signal strength. Electrical synapses in the central nervous system synchronize the activity of neurons responsible for some rapid stereotypical movement. Electrical synapses are common in invertebrate nervous systems, but less so in vertebrates.

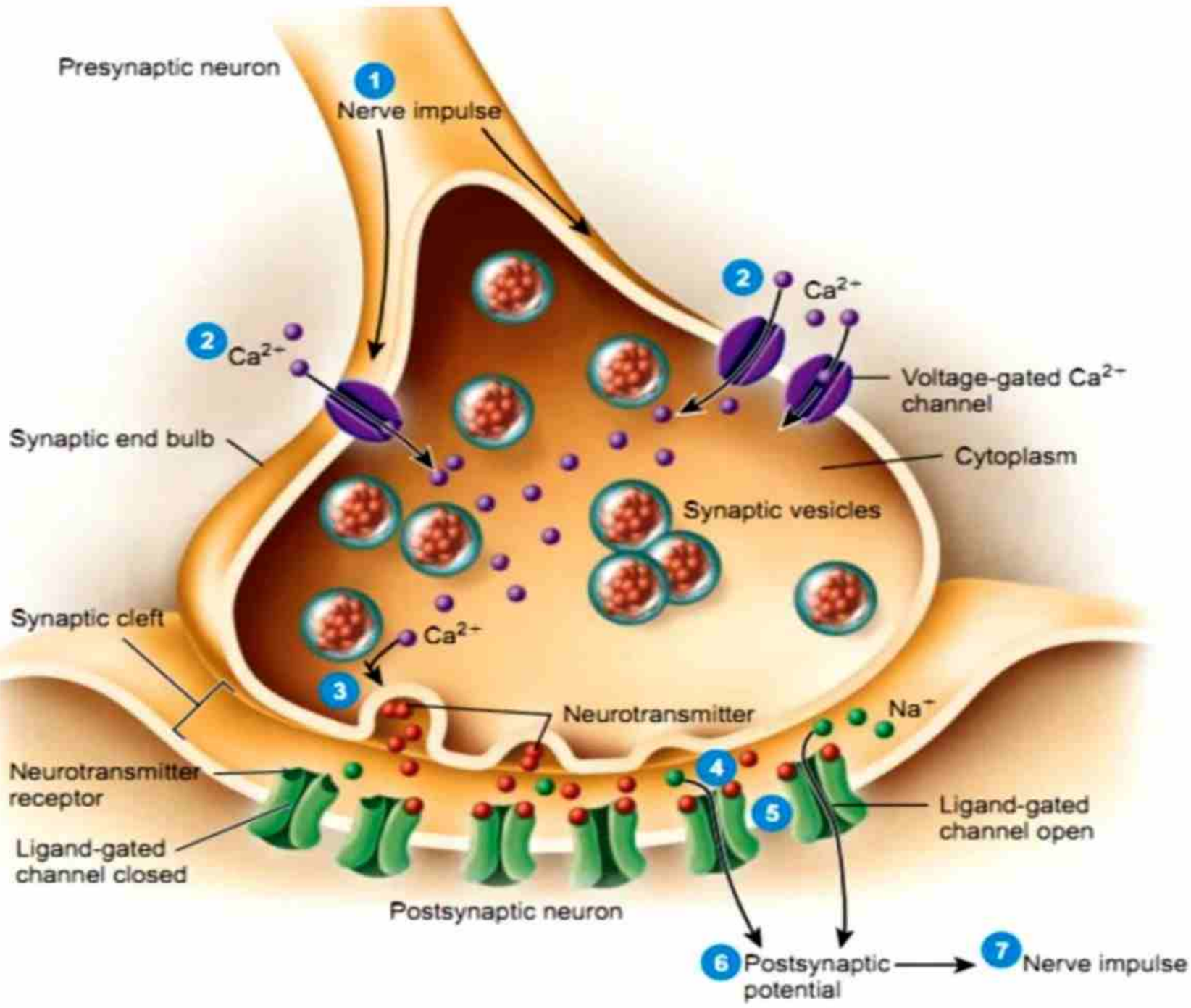


Fig.17.10 Synapse

The vast majority of synapses in vertebrates are **chemical synapse** the key to understanding the function of a chemical synapse is to examine its structure. The end of the presynaptic axon is swollen and contains numerous synaptic vesicles, each packed with

chemicals called **neurotransmitters**. When action potential arrives at the end of the axon, they stimulate the opening of voltage gated calcium (Ca^{++}) channels causing rapid inward diffusion of Ca^{++}. This influx of Ca^{++} triggers a complex series of events that leads to the fusion of synaptic vesicles with the plasma membrane and the release of neurotransmitters by exocytosis. Neurotransmitter when binds to its receptors alters the membrane potential of the post synaptic cell.

Depending on the type of receptors and the ions channels they control neurotransmitters binding to the post synaptic membrane may either excite the membrane by bring its voltage closer to the threshold potential or inhibits the post synaptic cell by hyperpolarizing its membrane. Neurotransmitter must be rapidly removed from the synaptic cleft to allow new signals to be transmitted. This is accomplished by a variety of mechanisms, including enzymatic digestion in the synaptic cleft, reuptake of neurotransmitters by the neuron and uptake by glial cells.

Classification of Neurotransmitters

Neurotransmitters are classified as excitatory and inhibitory.

i. Excitatory Neurotransmitters

At an excitatory synapse neurotransmitter receptors control a type of gated channel that allows Na^+ to enter the cell and K^+ to leave the cell cause depolarization, the electrical change cause by the binding of neurotransmitter to the receptor is called an **excitatory postsynaptic potential (EPSP)**. Chemicals cause these changes called excitatory neurotransmitters such as **Acetylcholine** is one of the most common neurotransmitters, it can be excitatory or inhibitory depending on the type of receptor.

The **biogenic amines** are neurotransmitters derived from amino acids most commonly function as transmitters within the CNS. They include **Epinephrine** and **norepinephrine**, which also function as hormones and a closely related compound called **dopamine**, another biogenic amine is **serotonin**. Norepinephrine functions in autonomic nervous system. Dopamine and serotonin affect sleep, mood, attention and learning, imbalance of these neurotransmitters is associated with several disorders. **Parkinson's**

disease is due to low level of dopamine and **schizophrenia** is due to excess level of dopamine.

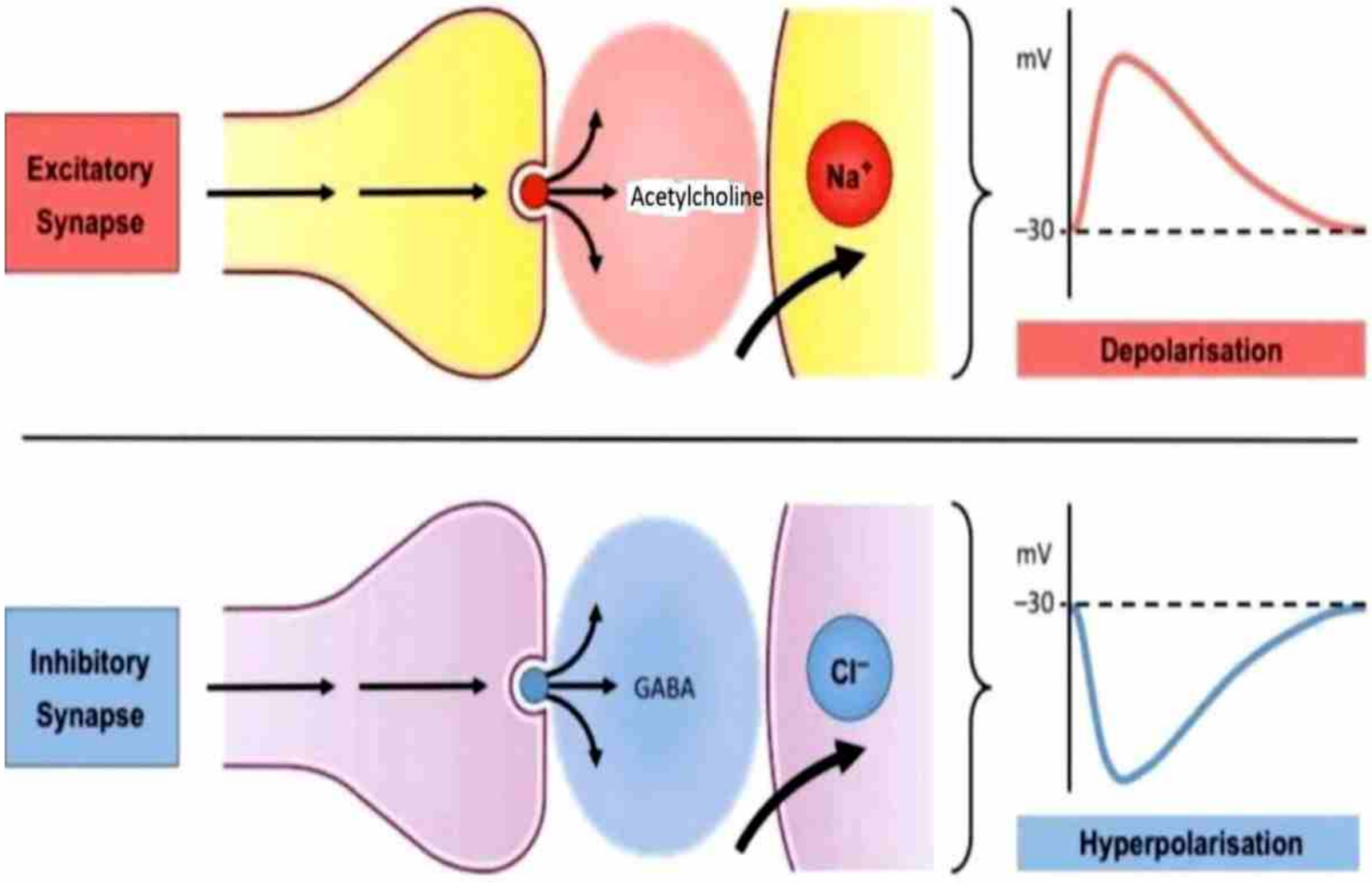


Fig.17.11 Excitatory and Inhibitory Synapse

ii. Inhibitory Neurotransmitters

At an inhibitory synapse, the binding of neurotransmitter molecules to the postsynaptic membrane hyperpolarizes the membrane by opening ion channels that make the membrane more permeable either to K^+, which rushes out of cell or to Cl^- which enters the cell because of a large concentration gradient or to both of these ions, membrane potential even more negative than the resting potential making it more difficult for an action potential to be generated, voltage change associated with chemical signaling at an inhibitory synapse is called **inhibitory postsynaptic potential (IPSP)**. Chemicals cause these voltage changes called inhibitory neurotransmitters such as **gamma amino butyric acid (GABA)**, **Glycine**, **glutamate** and **aspartate**.

17.1.5. Basic organization of human nervous system

The human nervous system consists of central nervous system (CNS) and peripheral nervous system (PNS). The CNS includes the brain and spinal cord, which have a central location, they lie in the midline of the body. The PNS consists of nerves projecting from CNS and have a peripheral location in the body.

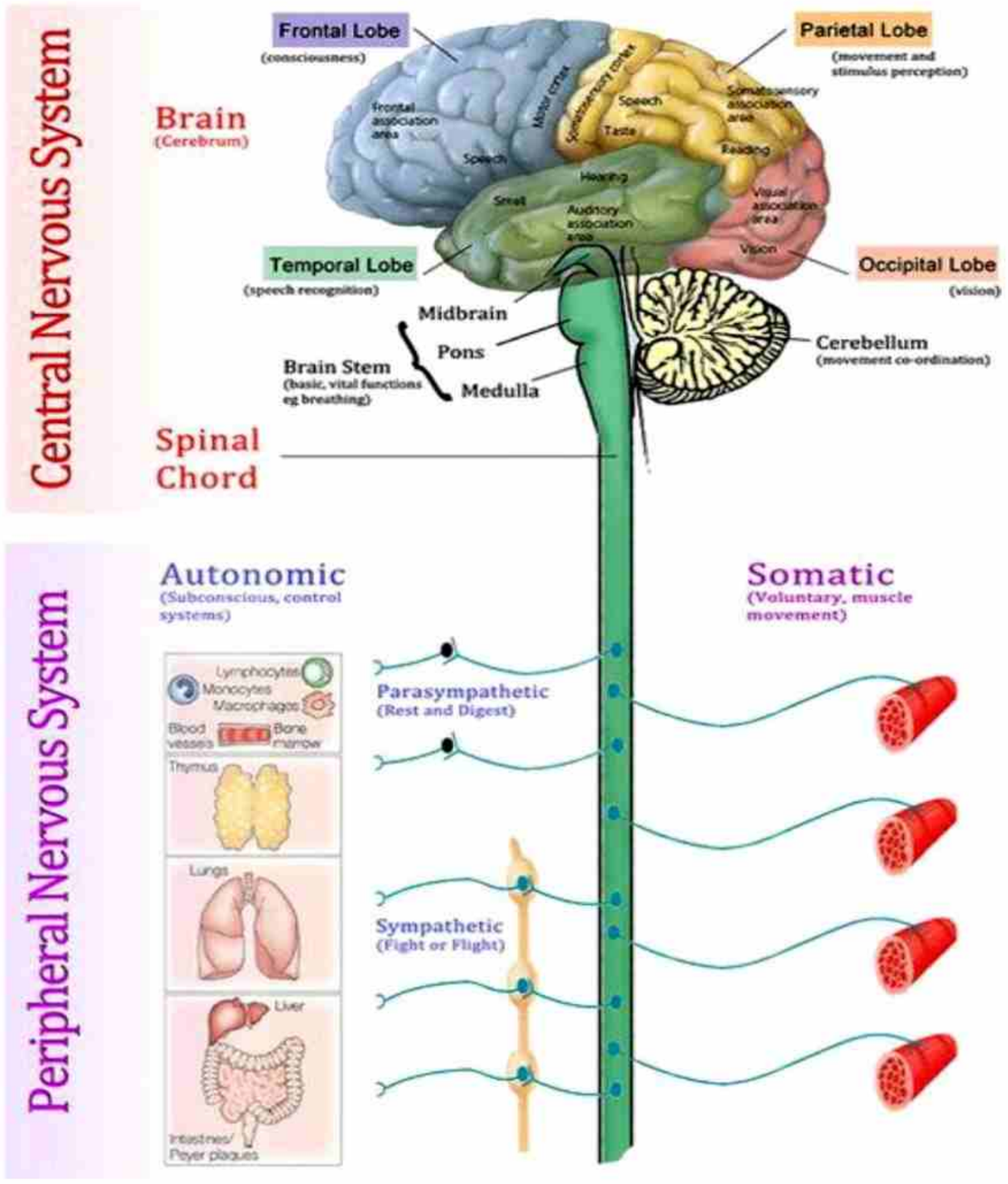


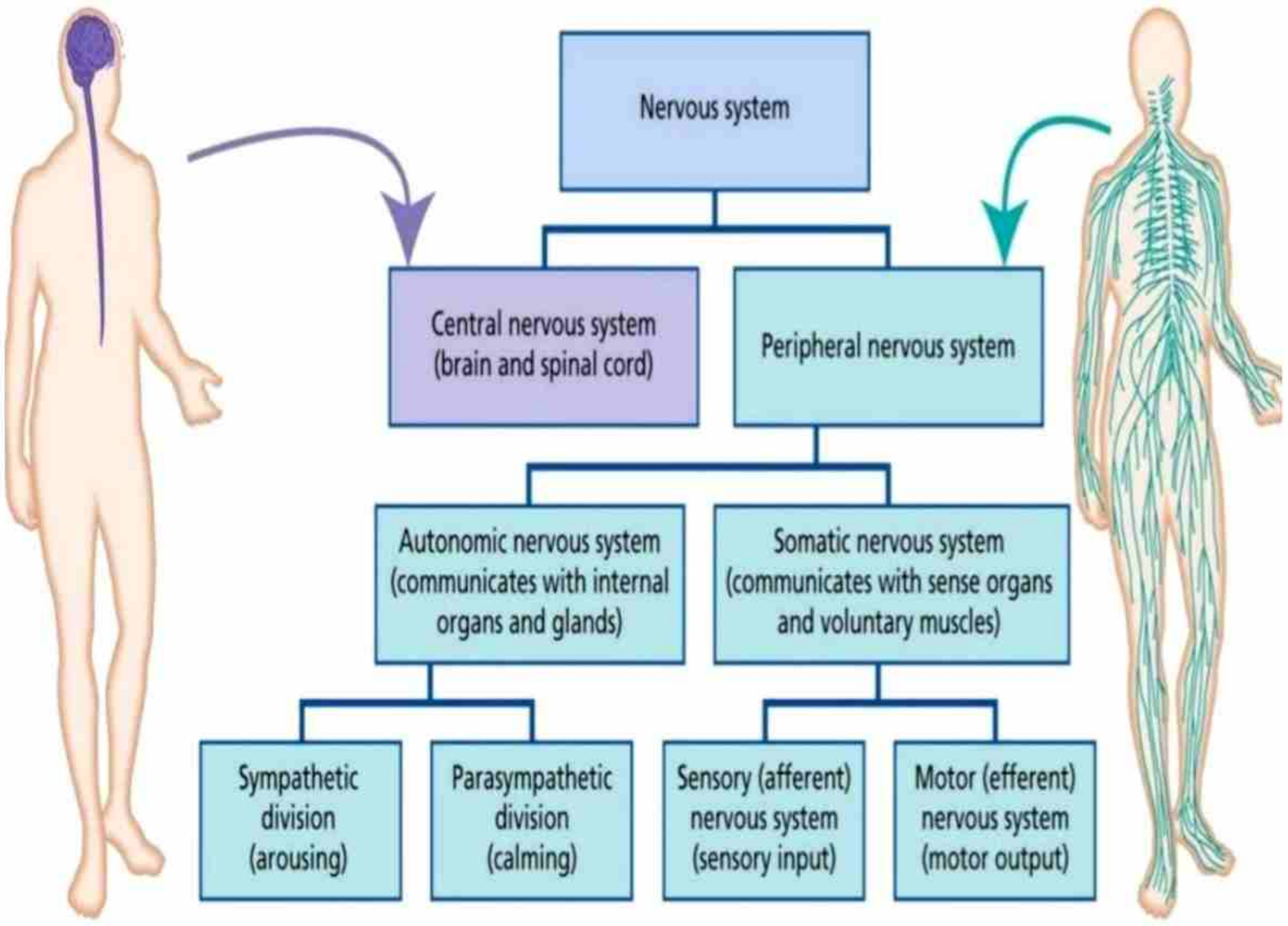
Fig.17.12 CNS and PNS

Architecture of Brain and spinal cord

Central Nervous System (CNS)

CNS is an integrating portion of the nervous system, where sensory information is received and processed, thoughts are

generated and responses are directed. The CNS primarily consists of association neurons (Inter neurons) between 10-100 billions.



The CNS is protected in three ways. The first line of defense is bony armor consisting of the skull that surrounds the brain and the vertebral column that protects the spinal cord. Beneath bony armor, a triple layer of connective tissue called meninges. Outer layer next to the cranium called **dura mater**, middle layer called **arachnoid mater** and inner next to the nervous tissue called **pia mater**. Between the arachnoid and pia mater clear lymph like liquid, the **cerebrospinal fluid (CSF)** cushions the brain and spinal cord.

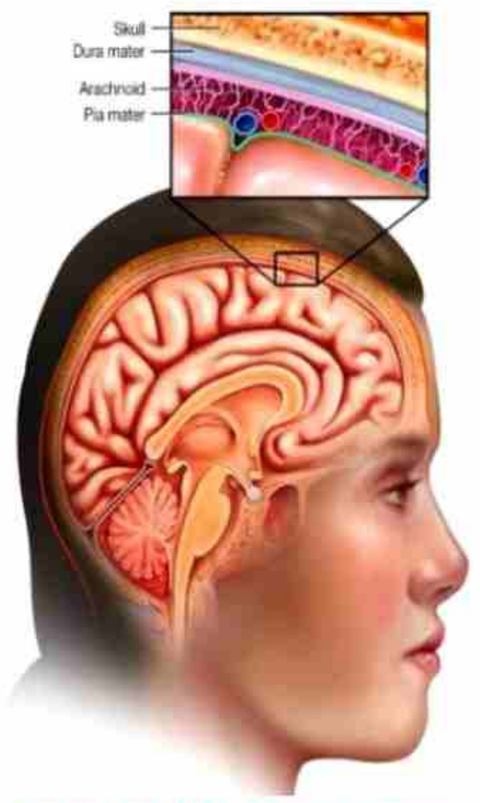


Fig.17.13 Meninges

Brain

The main component of the central nervous system in humans is the brain, which is housed in the skull and shielded by the cranium. The structure and general design of the human brain are similar to those of other animal brains, but the cerebral cortex is more developed in humans. The human brain is incredibly large and complicated, approximately 1.4 kg (3pounds) in weight, depending on the body weight and sex of each individual, it is divided into three parts, fore brain, mid brain and hind brain.

Forebrain The forebrain is the largest and most obvious part of human brain. Forebrain is divided into two regions, the **telencephalon** and the **diencephalon**.

The telencephalon is differentiated into two **cerebral hemispheres** or **cerebrum** that communicates with each other by means of a large band of axons, the **corpus callosum**. Each hemisphere consists of an outer grey matter or cerebral cortex and an inner white matter. Cerebral cortex is the most sophisticated information processing center of the brain. It contains over 10-50 billion neurons are packed into this thin surface layer.

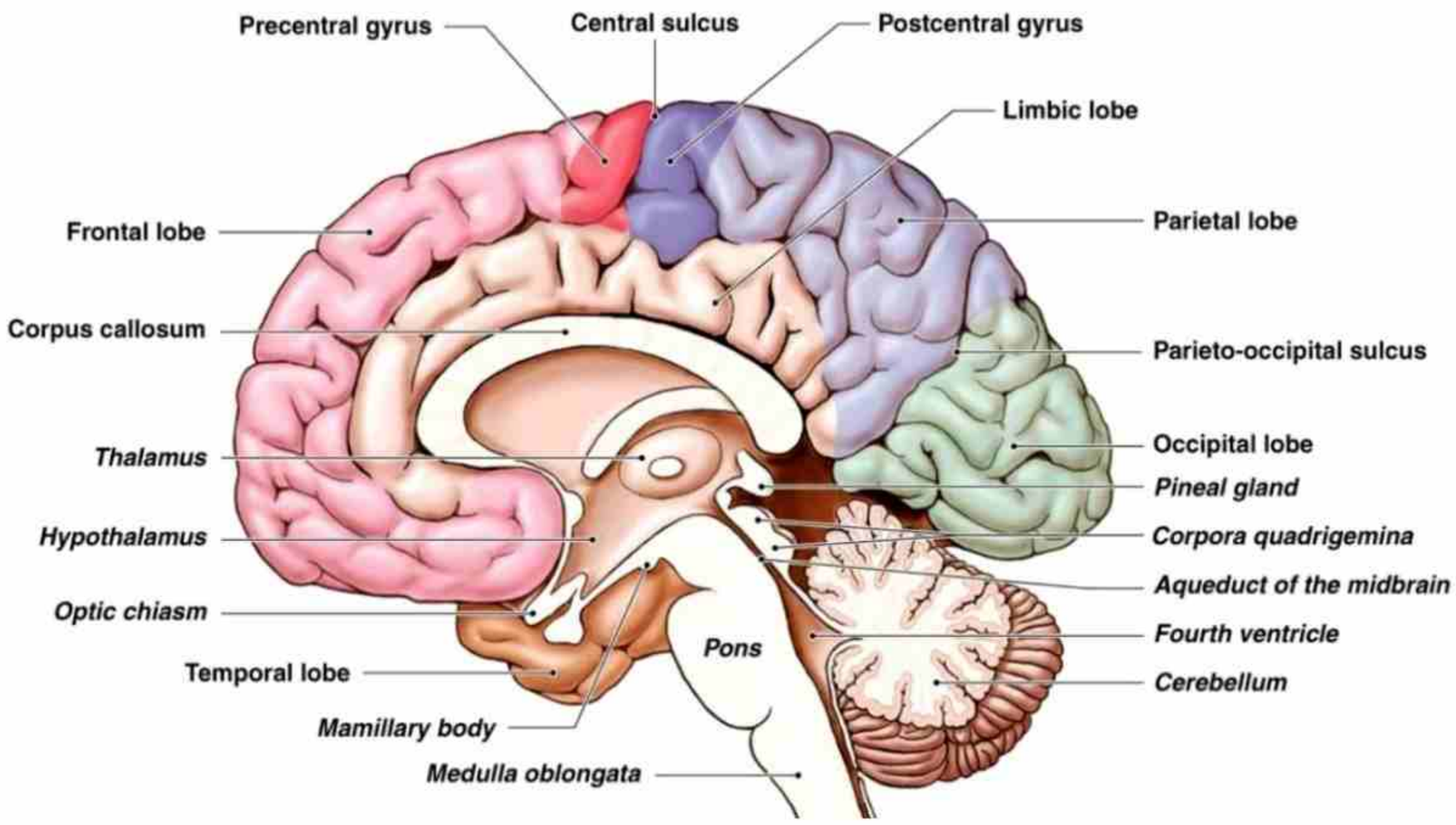


Fig.17.14 Architecture of Human Brain

The surface of the cerebral cortex is highly convoluted which increases the surface area of the cortex threefold. The cerebral cortex is divided into four regions based on anatomical criteria, **frontal**, **parietal**, **occipital** and **temporal lobes**. The activities of the cerebral cortex fall into sensory area, association area and motor area. **Sensory area:** this area receives inputs from different body parts. **Association area:** this area is a site of higher mental activities (intelligence, reasoning and memory) which interpret or analyze the incoming information. **Motor area:** this area controls the responses of the body.

The diencephalon consists of **thalamus** and **limbic system**. The thalamus is major integrating center, it is also the main input center for sensory information going to the cerebrum and the main output center for motor information leaving the cerebrum. Incoming information from all the senses is sorted out in the thalamus and sent onto the appropriate higher brain center for further interpretation and integration.

Limbic system is a diverse group of structures located in an arc between the thalamus and the cerebrum. It includes the hypothalamus, amygdala and the hippocampus. **Hypothalamus** contains many different clusters of neurons. Some of these are neurosecretory cells that release hormones through its hormone production and neural conduction, the hypothalamus act as a major coordinating center, controlling body temperature, hunger, thirst, water balance, the menstrual cycle and the autonomic nervous system. In addition, stimulation of specific area of the hypothalamus elicits emotions such as rage, fear, pleasure and sexual arousal. **Amygdala** is believed to be responsible for the production of appropriate behavioral responses to environmental stimuli. They control feelings and emotions of loner, fear,

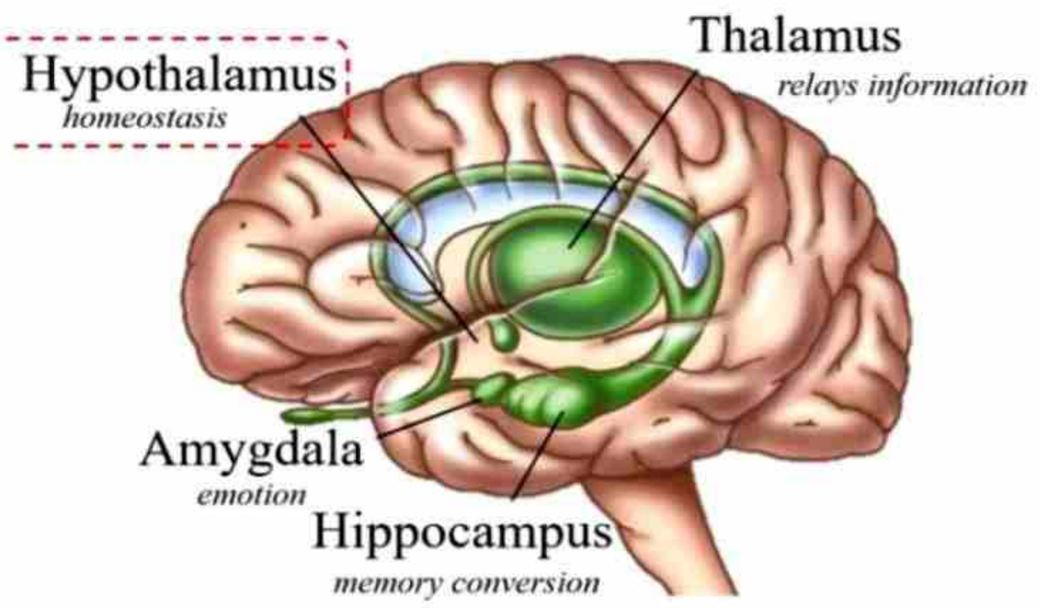


Fig.17.15 Limbic system

hater rage and sexual arousal. **Hippocampus** name from its shape, it resembles that of a seahorse. It plays an important role in the formation of long term memory and is thus required for learning. Short-term memory and procedural memory types (remember of how to do motor acts, like walking), on the other hand, are not mediated by the hippocampus. The cortex and cerebellum are principally responsible for managing them.

Mid brain is extremely reduced in humans but an important relay center midbrain contains **reticular formation**. Which extend all the way from the central core of the medulla, through the pons, the midbrain and on into lower regions of the forebrain, the reticular formation plays a role in sleep and arousal, emotion, muscle tone, certain movement and reflexes.

Hind brain

Hindbrain consists of medulla, pons and cerebellum.

Medulla

The medulla controls several autonomic functions, such as breathing, heart-rate, blood pressure, swallowing etc. **Pons** located above the medulla, tend to influence transitions between sleep and wakefulness and between stages of sleep, other influences include the rate of pattern of breathing. **Cerebellum** is crucially important in coordinating movement of the body. The cerebellum receives sensory information about the position of the joints and the length of the muscles, as well as information from the auditory and visual systems. It also receives input from the motor pathways, telling it which actions are being commanded from the cerebrum. The cerebellum uses this information to provide automatic co-ordination of movement and balance.

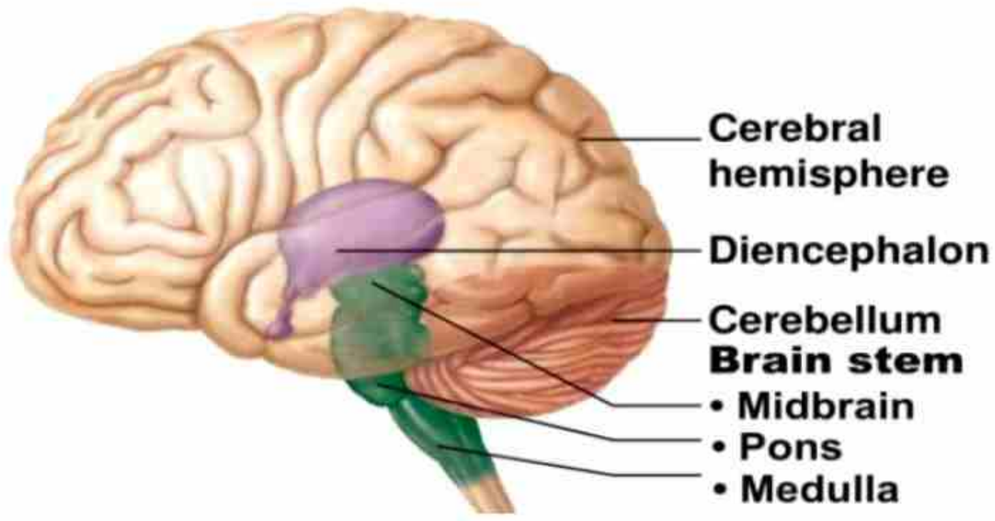


Fig.17.16 Mid and Hind brain

Brainstem is a region at the base of the brain that is located between the cervical spinal cord and the deep cerebral hemispheres. It plays a

crucial role in controlling some involuntary bodily functions like breathing and heartbeat. Humans have three distinct parts to their brainstem: the medulla oblongata (myelencephalon), the pons (metencephalon), and the midbrain (mesencephalon).

Spinal cord

The spinal cord is a neural cable extending from the brain down through the backbone, it is enclosed and protected by the vertebral column and layer of membrane called meninges, which also covers the brain. Inside the spinal cord are two zones, the inner zone is Grey matter and primarily consists of the cell bodies of interneurons, motor neuron and neuroglia.

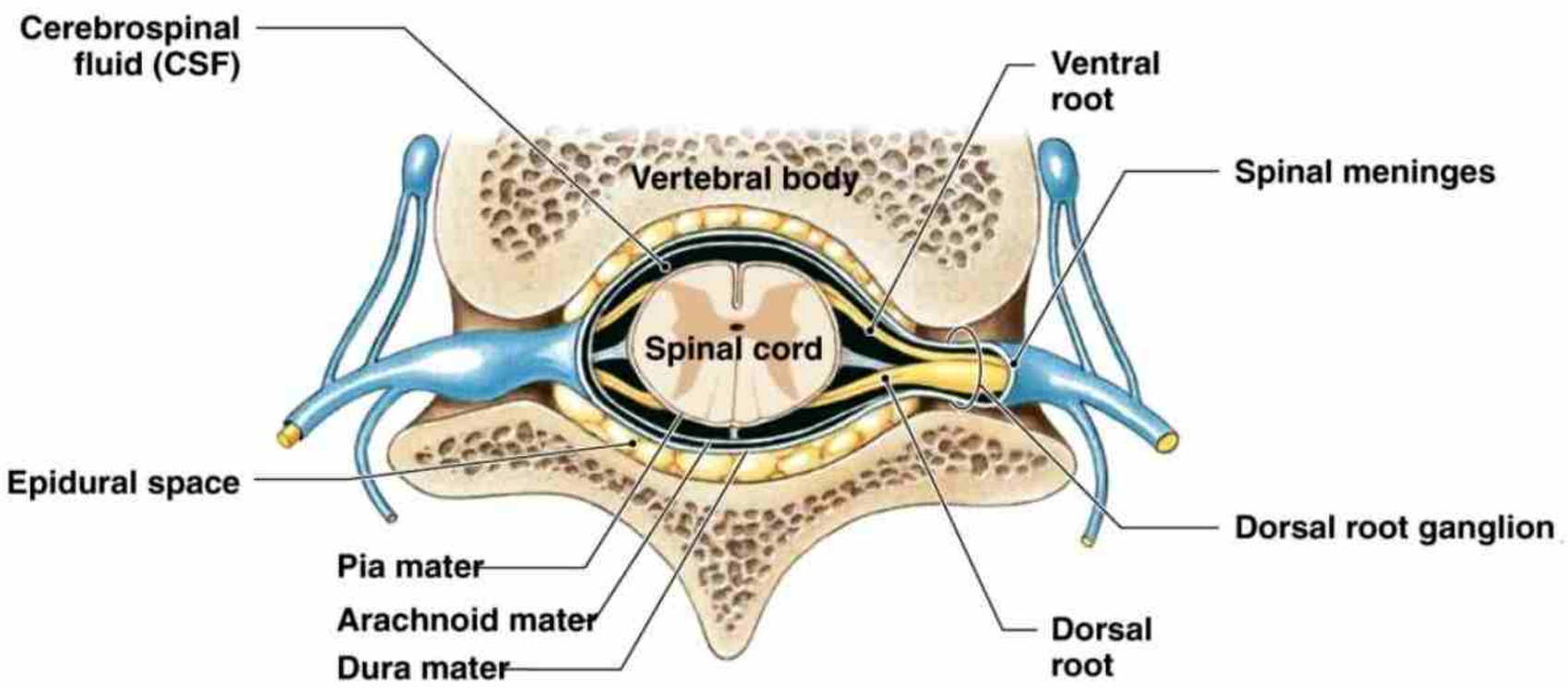


Fig.17.17 Cross section of Spinal cord

The outer zone is white matter and contains axon of sensory neuron in dorsal column and axon of motor neuron in ventral column, these nerve tracts may also contain the dendrites of the nerve cells. Messages from the body and the brain run up and down the spinal cord, the body's information highway. In addition to relaying messages, the spinal cord also functions in reflexes, the sudden, involuntary movement of muscles. A reflex produces a rapid motor response to a stimulus because the sensory neuron passes its information to a motor neuron in the spinal cord.

Cranial and spinal nerves in man: The peripheral nervous system consists of paired cranial and spinal nerves and associated ganglia. The cranial nerves originate in the brain and innervate organs of the head and upper body. The spinal nerves originate in the spinal cord and innervate the entire body. There are 12 pairs of **cranial nerves** and 31 pairs of **spinal nerves** in human. Most of cranial nerves contain both sensory and motor neurons, a few of the cranial nerves are sensory only (the olfactory and optic nerves). Spinal nerve separates into sensory and motor components. The axons of sensory neurons enter the dorsal surface of the spinal cord and form the **dorsal root** of the spinal nerves, whereas motor axons leave from the ventral surface of the spinal cord and form the **ventral root** of the spinal nerve. The cell bodies of sensory neurons are grouped together outside each level of the spinal cord, in the dorsal root ganglia. The cell bodies of motor neurons on the other hand, are located within the spinal cord and so are not located in ganglia.

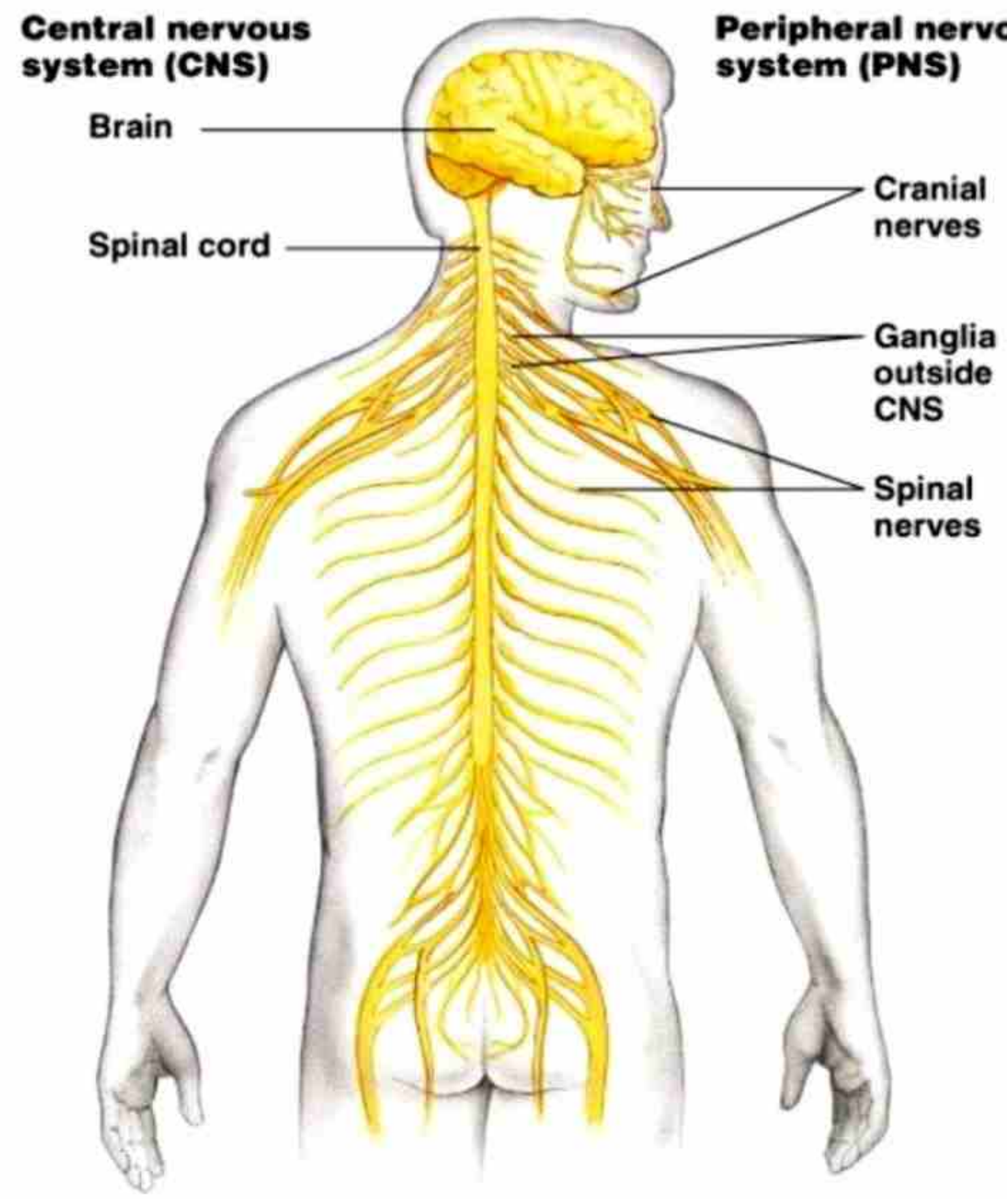


Fig.17.18 Cranial and spinal nerves

Somatic and Autonomic Nervous System

The motor portion of the peripheral nervous system is subdivided into two parts, somatic nervous system and autonomic nervous system.

Somatic Nervous System

The somatic nervous system is often considered voluntary because it is subjected to conscious control. Its neurons stimulate the skeletal muscles of the body to contract in response to conscious commands and as part of reflexes that do not require conscious control.

Autonomic Nervous system

The autonomic nervous system conveys signals that regulate the internal environment by controlling smooth and cardiac muscles and the organs of the gastrointestinal tract, cardiovascular, excretory and endocrine system this control is generally involuntary. The autonomic nervous system consists of two subdivisions that are anatomically, physiologically and chemically distinguishable, the sympathetic and parasympathetic division.

Sympathetic Nervous System

The sympathetic nervous system acts on organs in ways that prepare the body for stressful or highly energetic activity such as fighting, escaping or giving a speech during such "Fight-or-Flight" activities. It consists of thoracic and lumber nerves originate from spinal cord.

Parasympathetic Nervous System

The parasympathetic nervous system in contrast dominates during maintenance activities that can be carried on at leisure, often called "rest and rumination". Under its control, the digestive tract becomes active, heart rate slows, and air passage in the lungs constrict. It consists of cranial nerves from the brain and sacral nerves from spinal cord.

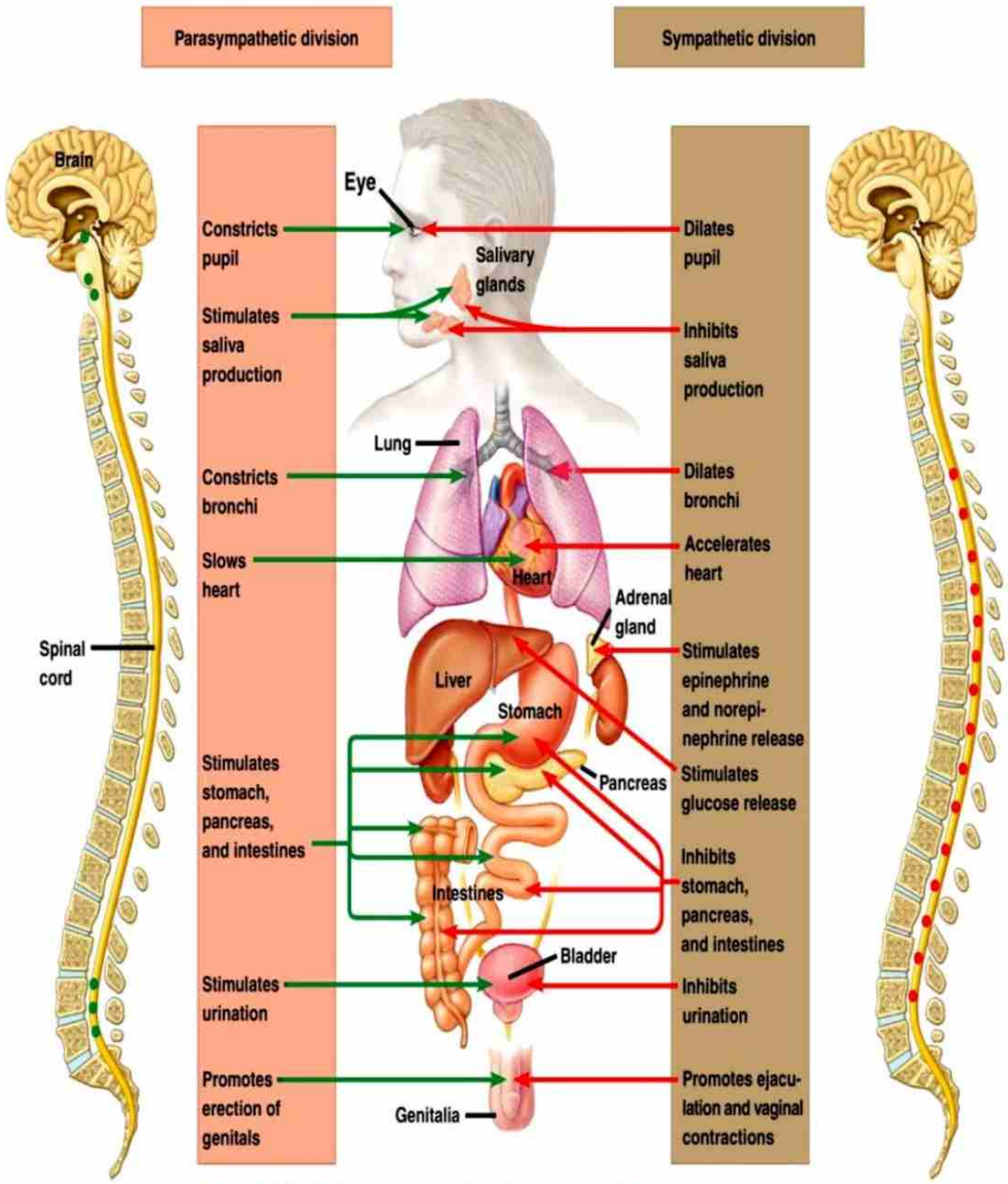


Fig.17.19 Autonomic Nervous System

17.1.6. Sensory receptors and their working

Smell receptors (Olfactory receptors)

In human the sense of **smell (olfaction)** involves chemoreceptors located in the upper portion of the nasal cavity. The human olfactory epithelium is small compared with that of many other mammals (dogs) whose sense of smell is far more active.

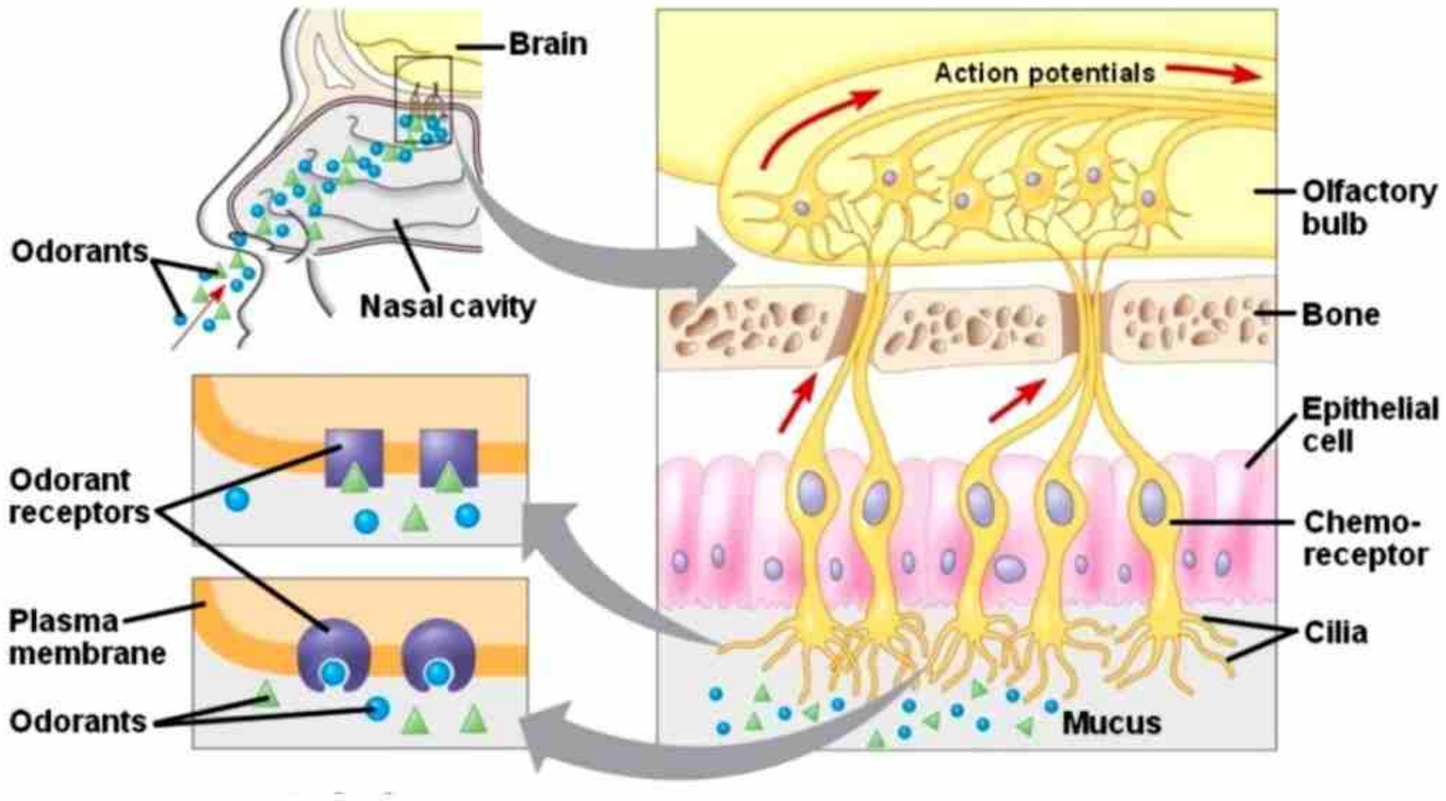


Fig.17.20 Smell receptor

Olfactory neurons dendrites end in tassels of cilia, project into the nasal mucosa, and their axons project directly into the cerebral cortex. When odorous substance diffuses into this region it binds to specific receptor molecules on the plasma membrane of the olfactory cilia, there may be 1000 types of receptor proteins embedded in the olfactory cilia. Each receptor protein is specialized to bind a particular type of molecule and stimulate the olfactory neuron to send a message to the brain.

Taste receptors

The receptors cells for taste (Gustation) are modified epithelial cells organized into taste buds, human tongue bears about 10000 taste buds. Most of the taste buds are on the surface of the tongue or an associated with nipple like projections called papillae on the tongue. Although we cannot distinguish different types of taste receptors from this structure, we recognize five basic taste

Fig.17.21 Taste receptors

perceptions, **sweet**, **sour**, **salty**, **bitter** and **umami** (perception of glutamate and other amino acids that give a hearty taste to many protein rich foods such as meat, cheese and butter).

Sensory receptors in human skin

Several types of mechanoreceptors are present in skin. Some in the dermis and others in the underlying subcutaneous tissues, these receptors contain sensory cells which detect various forms of physical contact, known as the sense of touch. The phasic receptors include hair follicle receptors and **Meissner's corpuscles**, which are present on surfaces that do not contain hair, such as the fingers, palms and nipples. The tonic receptors consist of **Ruffini's corpuscles** in the dermis and touch, dome endings (**Merkel's disks**) located near the surface of the skin. These receptors monitor the duration of touch and the extent to which it is applied. Deep below the skin pressure sensation receptors called **Pacinian corpuscles**. In human a class of naked dendrites in the epidermis of the skin called **nociceptors**, so named because they can be sensation to noxious substances as well as tissue damage.

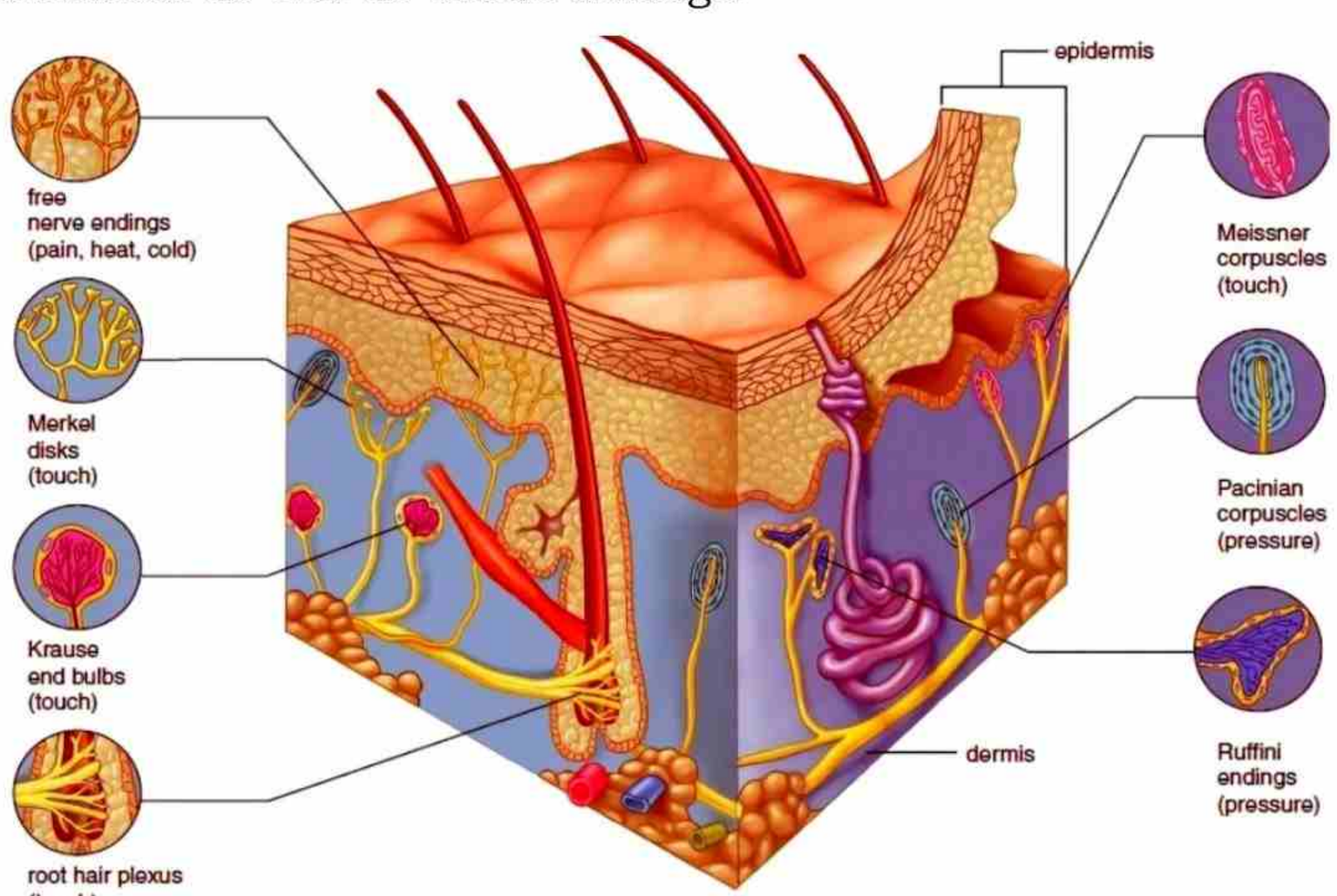


Fig.17.22 Receptors in Human Skin

17.2. EFFECT OF DRUGS ON NERVOUS CO-ORDINATION

Drugs that provide pain relief, such as morphine or Demerol, block synapses in the pain pathways of the brain or spinal cord. In ways that we are just beginning to understand, the brain can modulate its perception of pain through its own narcotic like **endorphins**. In critical situation such as combat or during escape from a fire, endorphins may allow us to function by blocking our perception of pain until the emergency is over.

Narcotic Drugs:

Common narcotic drugs are heroine, cannabis, nicotine, alcohol and inhalants.

Heroin:

A white powder with a bitter taste abused for its euphoric effects. It is a highly addictive drug is derived from the morphine alkaloid found in opium poppy plants. It exhibits euphoric (Rush) anti-anxiety and pain relieving properties.

Fig.17.23 Opium poppy

Cannabis:

It is the dried flowering tops and leaves. The cannabis plant (*Cannabis sativa*) is broadly distributed and grows in temperate and tropical areas, together with tobacco, alcohol and caffeine. It is one of the most widely consumed drugs throughout the world. In many countries, herbal cannabis and cannabis resin are formally known as marijuana and hashish (hash) cause mild euphoria, with alteration in vision and judgment.

Fig.17.24 Cannabis sativa

Nicotine:

It is an alkaloid of **tobacco**, nicotine binds directly to specific receptor on post synaptic neurons of the brain. Nicotine receptors are a class of receptors that normally binds the neurotransmitter acetylcholine, Nicotine stimulates heart rate, blood pressure and increased muscular activity.

Fig.17.25 Tobacco leaves

Alcohol:

Alcohol interferes with the brain's communication pathways, and can affect the way the brain looks and work. These disruptions can change mood and behavior and make it harder to think clearly and move with coordination.

Inhalants:

These are volatile substances easily bought and found in the home or workplace such as spray paints, markers, glues, and cleaning fluids. They contain dangerous substances that have psychoactive (mind altering) properties when inhaled.

Drug addiction and drug tolerance

Drug addiction is a complex neurobiological disorder, which affects a person's brain and behavior in a way that they lose the ability to resist the urge to use drugs.

Drug addiction

Drug addiction or dependence on illegal drugs like cocaine, nicotine you can get addicted to substances like medication drug, alcohol nicotine, marijuana and other legal drugs as well, dependence start with an experiment, you take drugs because you like the way it feels, repeated misuse of drugs changes how your brain works, it makes you lose self-control and messes with the desire to take drugs.

Drug tolerance

Drug tolerance means loss of efficiency with repeated drug exposure when nicotine and caffeine is used for long time, larger and larger doses must be taken to produce the same effect.

17.3. DISORDERS OF NERVOUS SYSTEM AND DIAGNOSTIC TESTS

Nervous disorders may be classified as vascular, infections, structural, functional and degenerative.

17.3.1 Vascular disorders of the CNS

Nervous disorders due to abnormality in blood circulation is called vascular disorder of the nervous system e.g. stroke and Hematoma

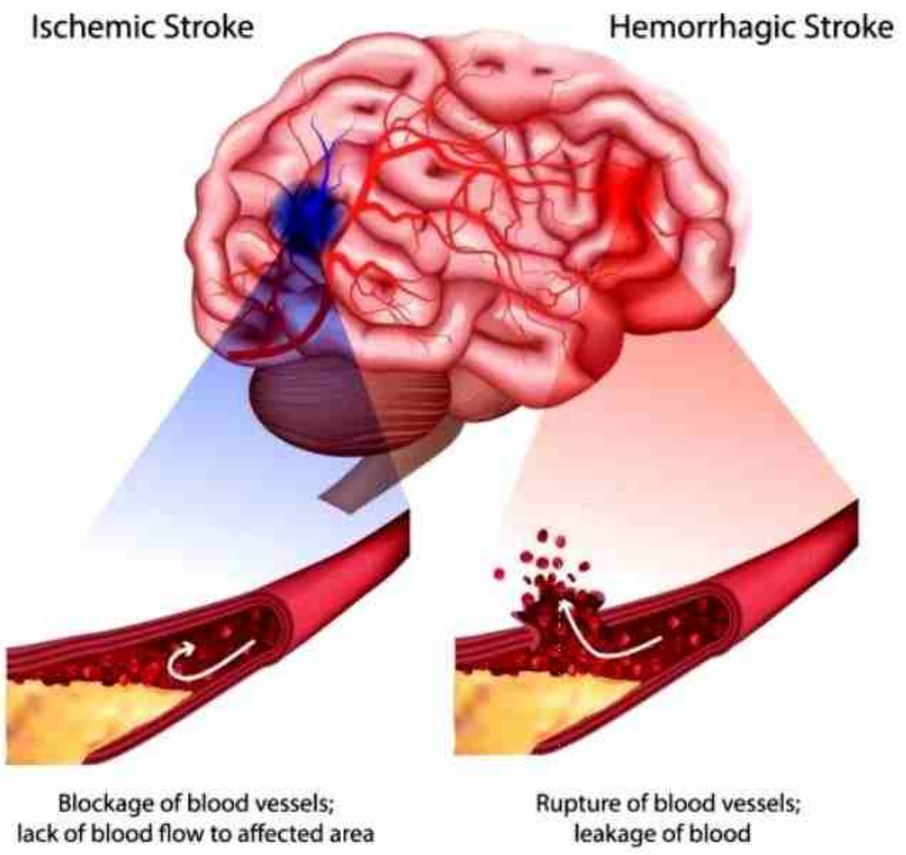


Fig.17.27 Stroke

Stroke: It is caused by an interference with blood supply to the brain. They may occur when a blood vessels bursts in the brain, when blood flow in cerebral artery is blocked by a blood clot.

Cause: The cause of stroke includes hypertension, smoking, diabetes mellitus, high alcohol intake and cocaine abuse.

Symptoms: The loss of blood flow to the brain damage tissues within the brain symptoms of stroke show up in the body parts controlled by the damaged area of the brain. Loss of balance and co-ordination severe and sudden headache, paralysis, weakness in the arm, face and leg.

Treatment: a stroke is a medical emergency; immediate treatment can save lives and reduce disability treatment depends on the

severity and type of stroke. Treatment will focus on restoring blood flow anticoagulants and platelets aggregation inhibitor is given blood pressure management and nursing care is essential.

Hematoma: The massive accumulation of blood into the space between the brain and its outermost covering is called hematoma.

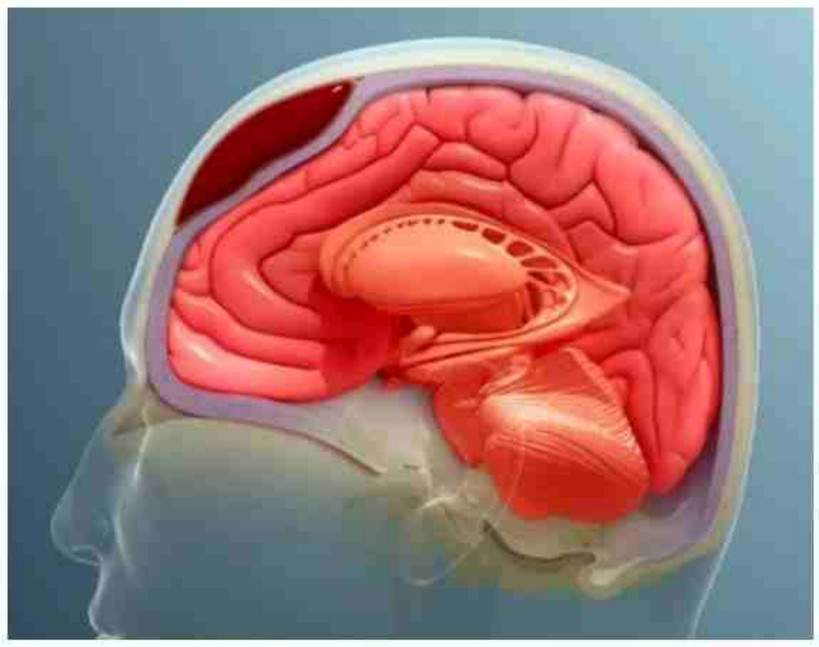


Fig.17.28 Hematoma

Cause: Hematoma is due to hypertension.

Symptoms: Hematoma symptoms include loss of consciousness sudden, confusion, pale skin color and seizures.

Treatment: It depends on the extent of the hematoma and the presence of other injuries. Depending on the severity of the injury, management may include surgery to drain blood and remove the blood clot.

17.3.2 Infectious Disorders of the CNS

Nervous disorders due to infection of virus, bacteria, fungi and protozoan e.g., meningitis and encephalitis

Meningitis It is an inflammation of the fluid and membranes (meninges) surrounding your brain and spinal cord.

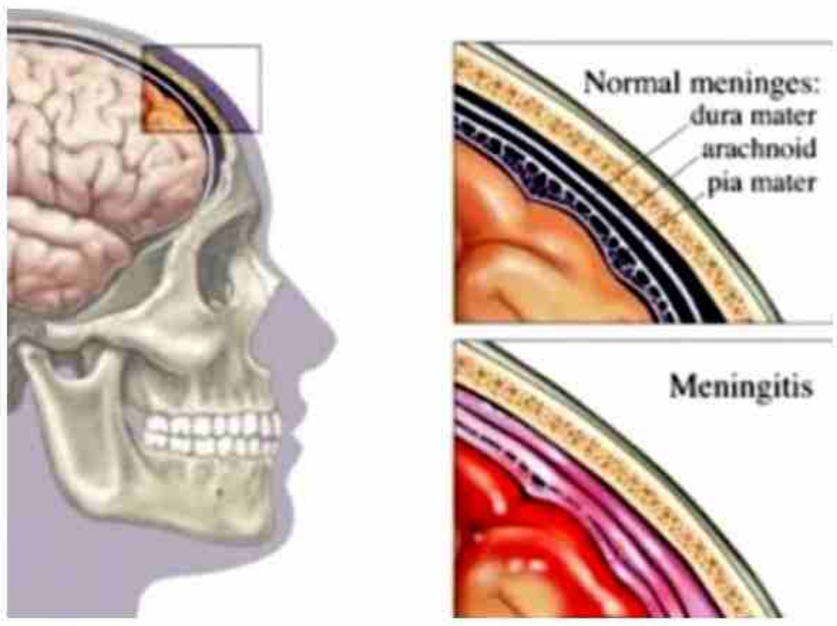


Fig.17.29 Meningitis

Cause: viral infections are the most common cause of this disease, followed by bacterial infections and, rarely, fungal infections.

Symptoms: Usually include sudden high fever, stiffness in neck, and headache with nausea or vomiting, it may cause paralysis coma or death.

Treatment: Depends on the type of disease. Bacterial meningitis must be treated immediately with intravenous antibiotics and more recently, corticosteroids. Viral meningitis cannot be cured with antibiotics and most cases improve on their own in several weeks, spread through coughing, sneezing (air borne rout).

Encephalitis: It is an inflammation of the brain.

Cause: Virus and rarely fungus cause encephalitis.

Symptoms: Encephalitis symptoms include fever, headache and confusion may cause muscle weakness, dementia and irritability.

Treatment: Encephalitis needs to be treated urgently. Treatment involves tackling the underlying cause, relieving symptoms and supporting bodily functions.

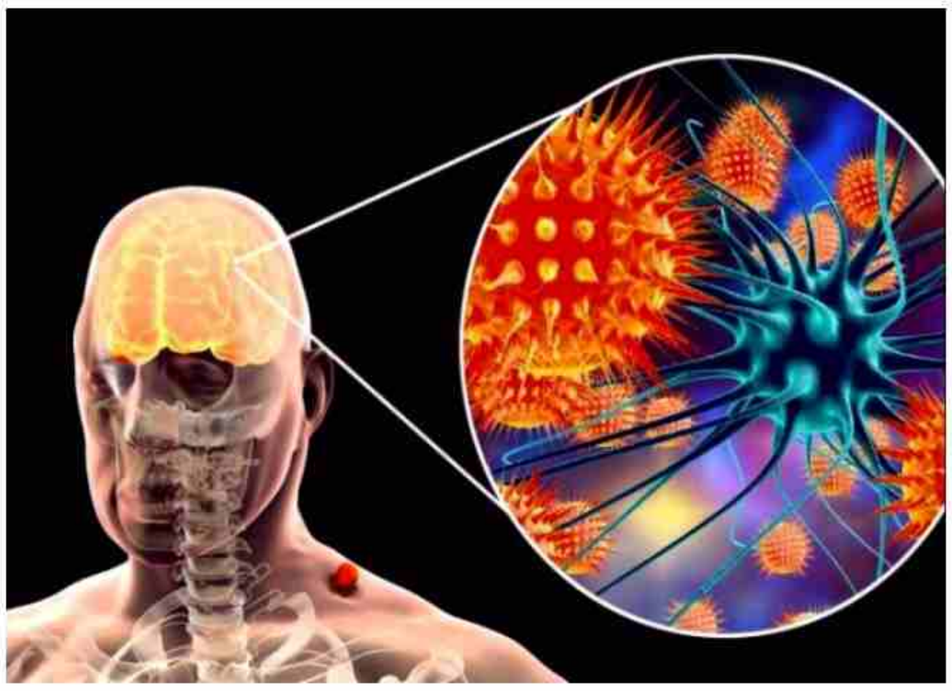


Fig.17.30 Encephalitis virus

17.3.3 Structural disorder of CNS

Nervous disorder which disturbs the structure of brain and spinal cord.

Tumour:

A brain tumour is a growth of cells in the brain that divides in an abnormal, uncontrollable way.

Cause:

It is caused by mutation and radiations.

Fig.17.31 Tumour

Symptoms:

The sign and symptoms depend on the size, location and rate of growth of brain tumour it may include, headache, vision problems, seizures, paralysis, coma and death.

Treatment:

Include surgery, radiation therapy, chemotherapy and targeted therapy.

17.3.4 Functional Disorder of the CNS

Headache:

Headache is defined as pain arising from the head or upper neck of the body. Pain originates from the tissues and structures that surround the skull, the brain itself has no nerves that give rise to the sensation of pain there are three major categories of headache based upon the source of the pain.

Primary headache:

Includes migraine, tension, and cluster headaches.

Secondary headache:

It is due to an underlying or infection problem in the head or neck, dental pain from infected teeth, pain from an infected sinus, and bleeding in the brain or infections like encephalitis or meningitis.

Cranial neuralgias, facial pain and other headache:

Cranial neuroglia means inflammation of one of the 12 cranial nerves coming from the brain that control the muscles and carry sensory signals to and from the head and neck.

Cause:

It is caused by inflammation or irritation of structures that surrounds the brain.

Symptoms:

Pain that begins in the back of the head and upper neck.

Treatment: Most people successfully treat themselves with pain medications to control headaches.

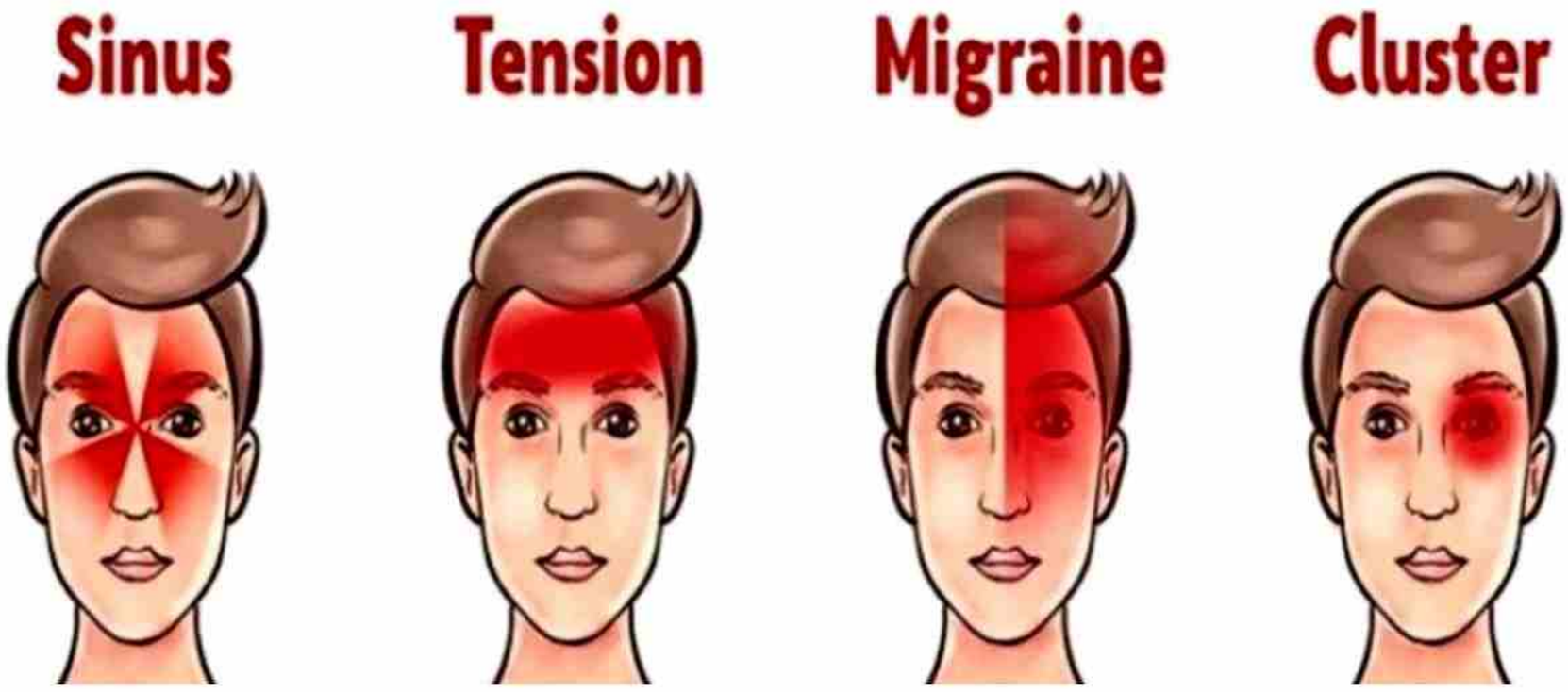


Fig.17.32 Types of Headaches

17.3.5. Degenerative Disorders of the CNS

Nervous disorder due to degeneration in different part of CNS

Alzheimer's disease

Alzheimer's is a progressive disease, where dementia symptoms gradually worsen over a number of years. In its early stage memory loss is mild, but with late stage individual loss the ability to carry on a conversation and respond to their environment.

Cause: It is due to inheriting certain genes.

Extra Reading Material

Multiple sclerosis: It is an autoimmune disease affects central nervous system.

Huntington's disease: It is due to gradual breakdown in brain nerve cells, it affects physical movement, emotions and cognitive abilities

Symptoms: In the early stage, new or recent memories are difficult to recall and hard to learn. In mild stage individual may have delusion, hallucination.

Treatment: There is no cure for Alzheimer. The goal of treatment is to manage symptoms and slow the progression of the disease.

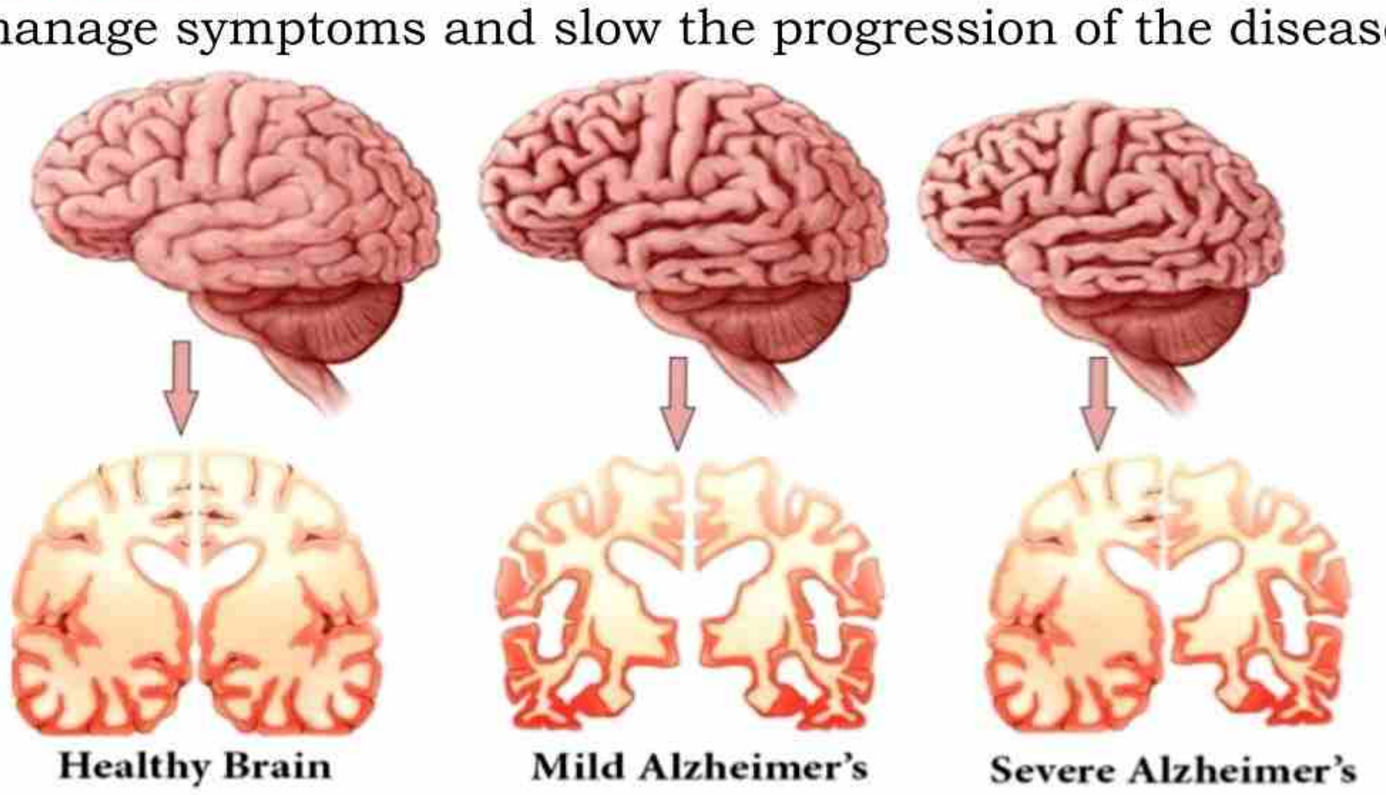


Fig.17.33 Alzheimer's disease

Parkinson's disease

It is a brain disorder caused either by degeneration or damage to nerve tissues within the basal ganglia of the brain.

Cause: Death of dopamine producing neurons.

Symptoms: It includes tremors in the arm or leg which is worse at the time when limb is in rest. Later the disease affects both sides of the body and cause stiffness, weakness and trembling of the muscles.

Treatment: There is no cure for Parkinson disease, but treatments are available to help relieve the symptoms and maintain your quality of life.

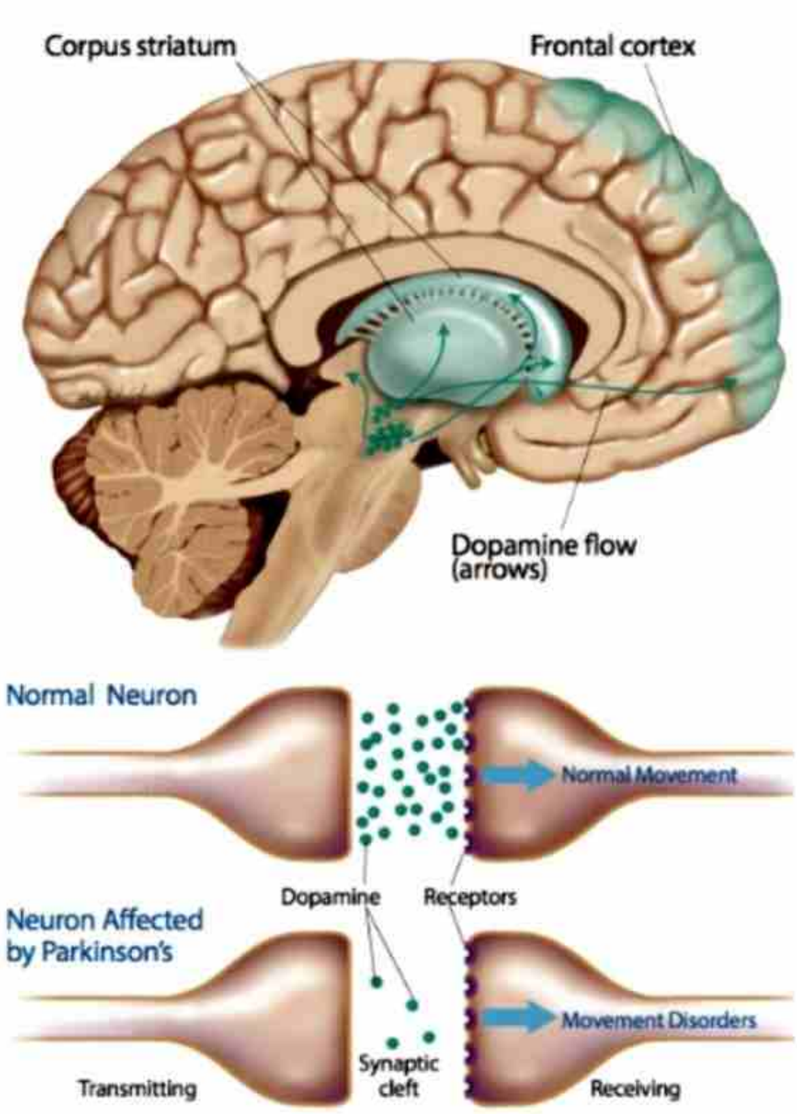


Fig.17.34 Parkinson's Disease

17.3.6 Diagnostic Test for nervous disorders

To diagnose a nervous disorder number of diagnostic test have been developed e.g. EEG, CT scan and MRI

Electroencephalogram (EEG)

It is a neuroimaging test which can detect and record minute changes in electrical activity within the brain this test using macro-electrodes (large, flat electrodes stuck to the skin or scalp). It produces a chart (an encephalogram) which shows how brain waves vary by frequency and amplitude of electrical output from the brain changes over time.

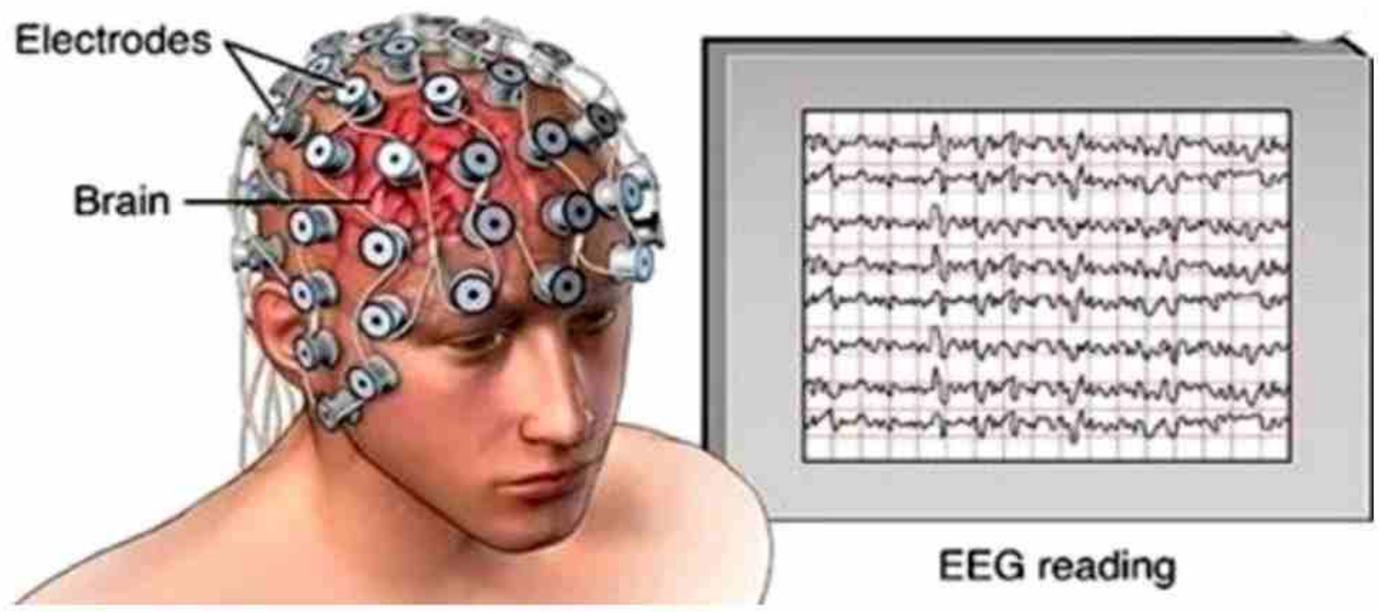


Fig.17.35 Electroencephalogram

Computed tomography (CT scan)

Computed tomography refers to a computerized x-ray imaging procedure in which an x-ray beam rotates around the body, producing signals that are processed by the machine's computer to generate cross sectional images or slices. These slices are called tomographic images and can provide more detailed information than conventional x-rays.

Fig.17.36 CT scan

Magnetic Resonance Imaging (MRI)

It is a radiological technique that uses magnetism, radio wave and a computer to produce detailed image of body structures. The MRI scanner is a tube surrounded by a circular magnet. The patient is placed on a moveable bed that is inserted into the magnet. The magnet creates a strong magnetic field that aligns the protons of hydrogen atoms. Which are then exposed to a beam of radio wave, this spins the various protons of the body, and they produce a faint signal that is detected by the receiver portion of the MRI scanner, a computer processes the receiver information, which produces an image.

Fig.17.37 MRI

SUMMARY

- Nervous co-ordination mainly comprises on highly specialized cells, called neurons.
- All receptors are transducers that convert signals from one form to another form.
- Schwann cells produce myelin in peripheral nervous system (PNS) and oligodendrocytes produce myelin in central nervous system (CNS).
- Nerve impulse is an electrical signal that depends on the flow of ions across the membrane of a neuron.
- The voltage measured across the plasma membrane is called membrane potential and it is typically in the range from -50mv to -100mv in an animal cell.
- Action potential is a sudden reversal of the electrical charge across the membrane, triggered by a temporary, localized increase in its permeability to sodium.
- Depolarization makes the membrane potential less negative, whereas hyperpolarization makes the membrane potential more negative.
- The level of depolarization needed to produce an action potential is called threshold potential.
- Velocity of conduction is greater if the diameter of the axon is larger or if the axon is myelinated.
- Synapse is junction that control communication between a neuron and another cell.
- The movement of impulse across the synapse is called a synaptic transmission.
- Electrical synapse involves direct cytoplasmic connections formed by gap junctions between the presynaptic neuron and post synaptic neurons.
- Biogenic amines are neurotransmitters derived from amino acids most commonly function as transmitters within the CNS.
- Human nervous system consists of central nervous system and peripheral nervous system.
- Central nervous system is integrating portion of the nervous system.

- The CNS is protected in three ways the first line of defense is bony armor, beneath bony armor a triple layer of connective tissue called meninges and cerebrospinal fluid cushion the brain and spinal cord.
- The forebrain is the largest and most obvious part of human's brain.
- The midbrain is extremely reduced in humans but an important relay center.
- Hind brain consists of medulla, pons and cerebellum.
- The PNS consists of paired cranial and spinal nerves and associated ganglia.
- Sense of smell involves chemoreceptors located in the upper portion of the nasal cavity.
- The receptors cells for taste are modified epithelial cells organized into taste buds.
- Drug that provide pain relief, such as morphine or Demerol, block synaspses in the pain pathways of the brain or spinal cord.

EXERCISE

1. Encircle the correct choice.

i) Most of the neurons in the human brain are

(a) Sensory neurons (b) Motor neurons
(c) Interneurons (d) Auditory neurons

ii) A nervous system can alter activities in its target cells in muscles and gland because

(a) They are electrically coupled by gap junctions.
(b) The target cells have receptor proteins for the signals released by the nervous system.
(c) The nervous system releases signals into the blood to control the target cells.
(d) The target cells that become disconnected from the nervous system rapidly die.

iii) For a neuron with an initial membrane potential at -70mv, an increase in the movement of potassium ions out of that neuron's cytoplasm would result in
(a) Depolarization of the neuron
(b) Hyperpolarization of neuron
(c) The replacement of potassium ions with sodium ions.
(d) The replacement of potassium ions with calcium ions.

iv) Action potentials move along axons
(a) More slowly in axons of large than in small diameter.
(b) The direct action of acetylcholine on the axon membrane.
(c) Activating the sodium-potassium pump at each point along the axon membrane.
(d) More rapidly in myelinated than in non-myelinated axons.

v) The surface on a neuron that discharges vesicles is the
(a) Dendrite (b) Axon hillock
(c) Presynaptic membrane (d) Postsynaptic membrane.

vi) An inhibitory postsynaptic potential occurs in a membrane made more permeable to
(a) Potassium ions (b) Sodium ions
(c) Calcium ions (d) ATP

vii) The major inhibitory neurotransmitter of the brain is
(a) Acetylcholine (b) Epinephrine
(c) GABA (d) Endorphin

viii) Where are neurotransmitter receptors located
(a) On the nuclear membrane
(b) In the myelin sheet
(c) At nodes of Ranvier
(d) On the postsynaptic membrane

ix) Which selection is incorrectly paired?
(a) Forebrain → Diencephalon
(b) Fore brain → Cerebrum
(c) Midbrain → Brainstem
(d) Midbrain → Cerebellum

x) Which of the following receptors is incorrectly paired with the type of energy is transduces?
(a) Mechanoreceptors → Sound
(b) Pain receptors → Electricity
(c) Chemoreceptors → Solute concentration
(d) Thermo receptors → Heat

2. Write short answers of the following questions:

i) Why receptors are called transducers?
ii) Why neurolemma is polarized?
iii) What do you mean by threshold potential?
iv) Why impulses move faster in myelinated neurons?
v) Why interneurons are called association neuron?
vi) What do you mean by saltatory conduction?
vii) Differentiate between following
(a) Electrical and Chemical synapse
(b) CNS and PNS
(c) Excitatory neurotransmitters and Inhibitory neurotransmitters
(d) Parasympathetic nervous system and Sympathetic nervous system
viii) Define following terms
(a) Endorphins
(b) Pacinian corpuslces
(c) Nociceptors
(d) Reflex arc
(e) Stroke
(f) Meningitis

3. Write detailed answers of the following questions:

i. Describe structure and function of neurons.
ii. Describe mechanism of action membrane potential.
iii. Explain vascular and infectious disorders of CNS.
iv. Describe anatomy and physiology of human brain.
v. Describe sensory receptors and their working.

CHEMICAL COORDINATION

Chapter 18

Major Concept

In this Unit you will learn:

- Hormones :The Chemical Messengers
- Endocrine system of Man
- Feedback Mechanism

CHEMICAL COORDINATION

Evolution of complex multicellular organisms came, the need to coordinate the activities of cells in different parts of the body. Cell-to-cell communication is crucial to the control of movement, growth, reproduction, and the maintenance of homeostasis. Many different mechanisms have evolved by which cells within organisms communicate among themselves. Certain chemicals are involved in communications, which are **neurotransmitters**, **pheromones** and **hormones**. Neurotransmitters are chemical messenger between the neurons discussed in previous chapter. Pheromones are chemicals secreted by an organism in minute amounts to stimulate particular reaction from another organism of the same species.

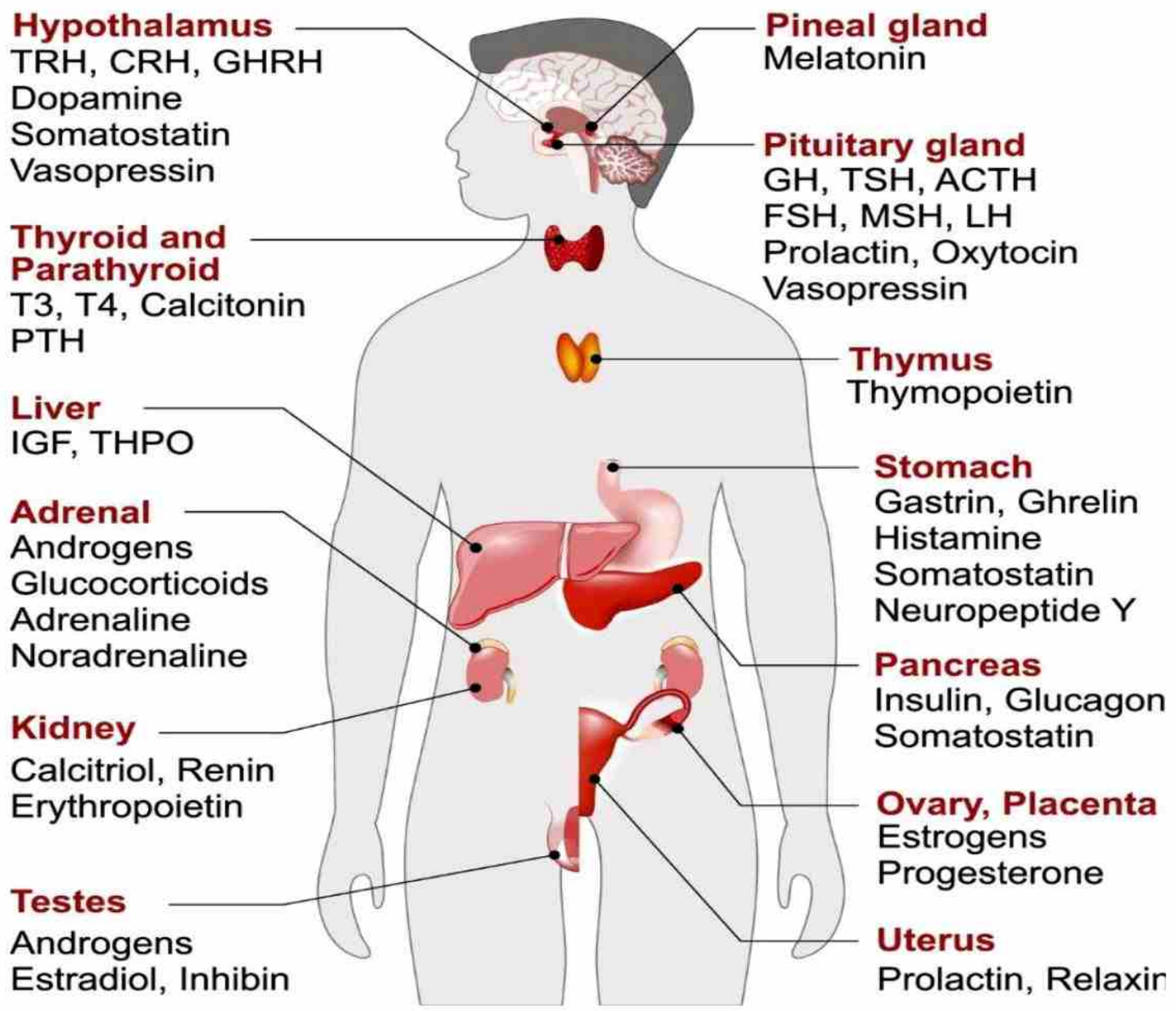


Fig.18.1 Endocrine glands

A hormone (Gr: Hormon: Excite) is a chemical messenger that is secreted by specialized tissues called **glands**, that is transported in the blood stream. Hormones may reach all parts of the body, but only certain types of cells, the **target cells**, are equipped to respond. Thus a given hormone traveling in the blood stream elicits specific response in from selected target cells, while other cell types ignore the particular hormone.

18.1 CHEMICAL NATURE OF HORMONES

Chemicals that function as hormone must exhibit two basic characteristics. First, they must be sufficiently complex to convey regulatory information to their target cells. Second, hormones must be adequately stable to resist destruction prior to reaching their target cells. Three primary chemical categories of hormones are

i) Peptide and Protein hormones

Hormones composed of chains of amino acids ranging from a few to over a hundred amino acids in length. Short chain amino acid hormones are called **peptide hormones** (ADH = Antidiuretic hormone). Long chain amino acid hormones are called **protein hormones** (GH = Growth hormone) and Insulin.

ii) Amino acid derivate hormones

These hormones are manufactured by enzymatic modification of specific amino acids. This group includes **biogenic amines** discussed in previous chapter (nervous co-ordination). They include hormones secreted by the adrenal medulla, thyroid and pineal gland. Those secreted by the adrenal medulla are derived from **tyrosine** (Amino acid) known as **Catecholamines**, they include **epinephrine** (adrenaline) and **nor-epinephrine** (nor-adrenaline) other hormones derived from tyrosine are the thyroid hormones. The pineal gland secretes a different amine hormone, **melatonin** derived from **Tryptophan**.

iii) Steroid hormones

These hormones are manufactured by enzymatic modifications of **cholesterol**. They include the hormones testosterone, estrogen (Estradiol), progesterone, aldosterone and cortisol.

Path of Chemical messenger

In human all cells have a blood supply, once hormones enter the bloodstream, they reach nearly every cell of the body. But in order to exert their precise control, hormones must act only on certain **target cells**. Hormones specificity is determined by **receptors** on target cells. If a cell lacks a specific receptor for a hormone, the hormone will not affect the cell. In addition, the same hormone may have several different effects depending on the nature of the target cell it contacts. Receptors for hormones are found in two general locations on target cells on the cell membrane and inside the cell.

Mode of Hormone Action

Hormone triggers changes in target cells by one of two general mechanisms depending on their chemical nature. Hormones may be categorized as **hydrophilic** (polar) or protein nature hormones and **lipophilic** (non-polar) steroid and thyroid hormones.

Protein hormones (Hydrophilic)

These hormones are soluble in water but insoluble in lipids, hence these hormones cannot cross the cell membrane. Instead they react with protein receptors protruding from the outside surface of target cell membrane. In general hormones (Primary messengers) that bind to surface receptors trigger rapid, short term responses.

More frequently, a second messenger system is used. In this system when the hormone binds to the receptor, the shape of the receptor is altered, triggering a series of biochemical reactions that alter the activity of cell. In many cases, the binding of the hormone on the receptor activate on enzyme. Activated enzyme catalyzes the conversion of ATP to cyclic Adenosine mono phosphate (cAMP).

A mononucleotide that regulates many cellular activities **cAMP** is often called a **second messenger**. Because it transfer the signal from the first messenger, the hormone to molecules within cell. The hormone signal can cause the target cell to react in a number of different ways. The reaction may involve the induction of protein synthesis, the activation or inactivation of enzymes, a change in cell membrane permeability, changing rates of mitosis and cell development, and the induction of product secretion. Furthermore, a

single hormone may be able to cause a number of reactions in a single cell..

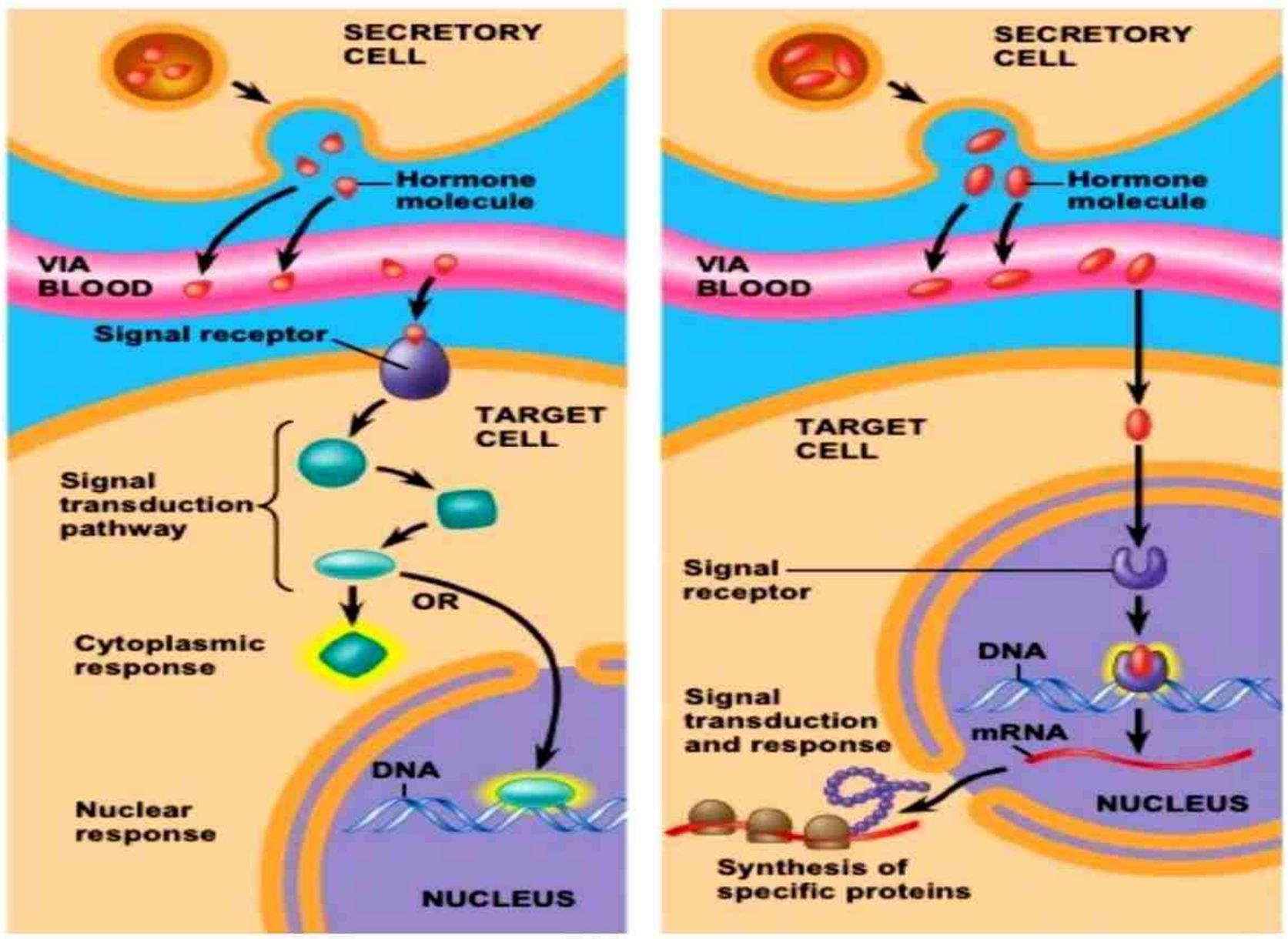


Fig.18.2 Protein and steroid hormone action

Steroid Hormones (Lipophilic)

Steroid hormones and thyroid hormones are lipid soluble and are therefore able to diffuse into the cell membrane and binds to receptors inside the cell, both steroid and thyroid hormones alter the activity of genes. It may take from minutes to days for these hormones to exert their full effects. These hormones bind to protein receptors in the nucleus. The receptors hormone complex binds to DNA and initiates the Transcription of messenger RNA from specific genes. The messenger RNA then moves into the cytoplasm and directs the synthesis of new proteins.

18.2 ENDOCRINE SYSTEM OF MAN

The endocrine system includes all of the glands and patches that secrete hormones, for example pituitary gland, thyroid gland,

adrenal gland and so on. Cells in these glands secrete hormones into extracellular fluid, where it diffuses into surrounding blood capillaries. For this reason, hormones are referred to as endocrine secretions. In contrast cells of some gland excrete their products into particular ducts or into the gut. For example, the pancreases excrete hydrolytic enzymes into the lumen of the small intestine with the help of pancreatic duct. These glands are termed as **exocrine glands**.

18.2.1 Hypothalamus

The hypothalamus is a part of the brain that contains clusters of specialized cells called neurosecretory cells. The hormone releasing cells in the hypothalamus are two sets of neurosecretory cells, whose secretions are stored in or regulate the activity of the pituitary gland. A set of neurosecretory cells in the hypothalamus exerts control over the anterior pituitary lobe by secreting two kinds of hormones into the blood **releasing hormones** make the anterior pituitary lobe to secrete its hormones, and **inhibiting hormones** from the hypothalamus make the anterior pituitary stop secreting hormone. Another set of neurosecretory cells produce two hormones **ADH** and **oxytocin**, which are stored and secreted from posterior pituitary glands.

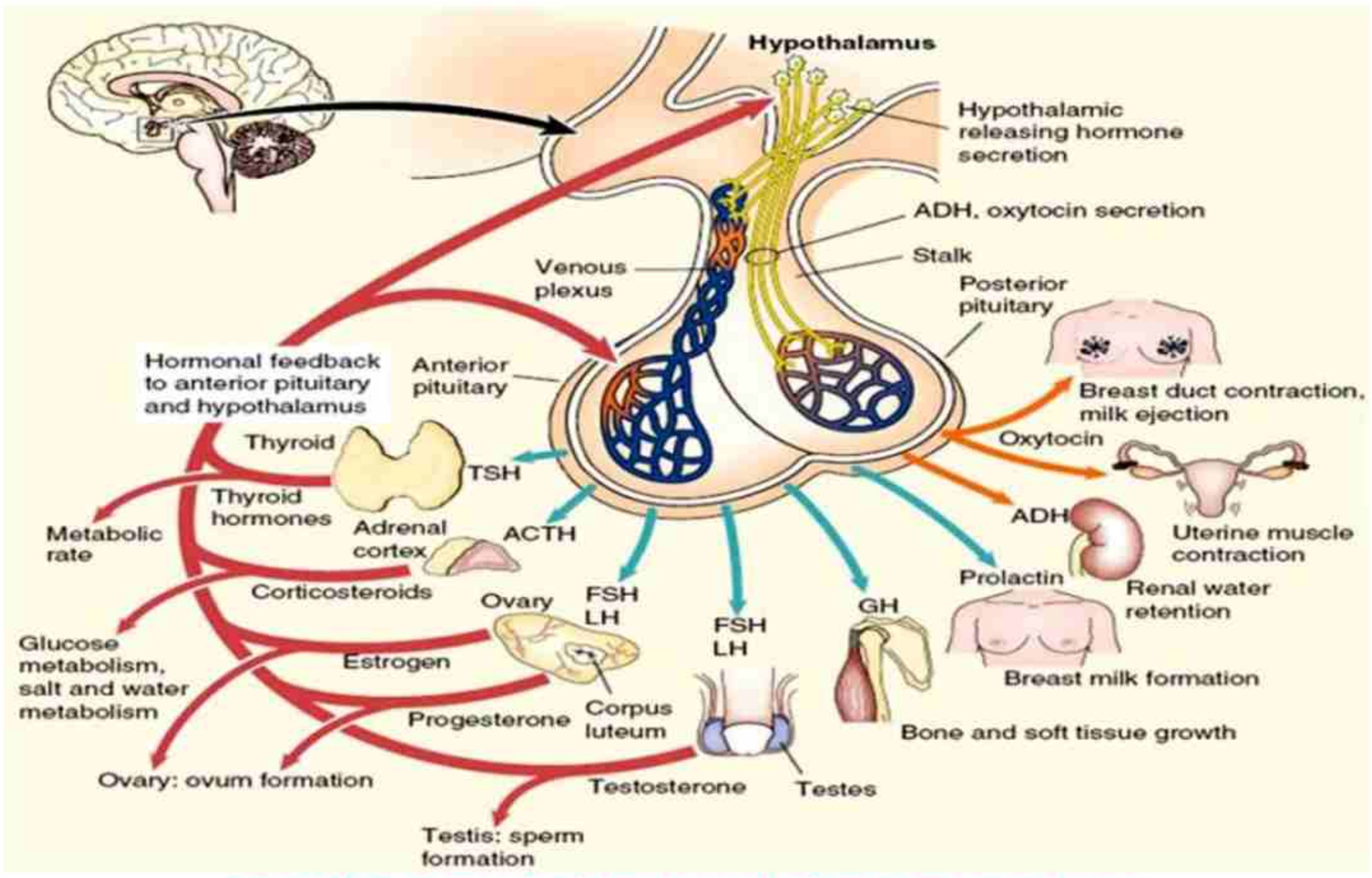


Fig.18.3 Hypothalamus and pituitary response

Table 18.1 Releasing and inhibiting hormones of hypothalamus

Hormone from the hypothalamus	→	Anterior pituitary
Thyrotropin releasing hormone (TRH)		Stimulate the release of thyroid stimulating hormone (TSH)
Corticotropin releasing hormone (CRH)		Stimulate the release of adrenocorticotropin hormone (ACTH)
Gonadotropin releasing hormone (GnRH)		Stimulate the release of LH and FSH
Growth hormone releasing hormone (GHRH)		Stimulate the release of Growth hormone (GH)
Growth hormone inhibiting hormone (GHIH)		Inhibits the secretion of Growth hormone
Prolactin inhibiting hormone (PIH)		Inhibits the secretion of prolactin
Melanocyte inhibiting hormone (MIH)		Inhibits the secretion of MSH

18.2. 2 Pituitary gland

The pituitary gland also known as the **hypophysis**, is a pea-sized gland that dangles from the hypothalamus by a stalk anatomically, the pituitary gland consists of two distinct lobes or parts, one of which appears glandular and is called the anterior pituitary lobe or **adenohypophysis**. The other portion appears fibrous and is called the posterior pituitary lobe or **neurohypophysis**.

Anterior Pituitary (Adenohypophysis)

The anterior pituitary is an independent endocrine gland. It produces at least seven essential hormones, many of which stimulate growth of their target organs, as well as production and secretions of other hormones from additional endocrine glands. Therefore, several hormones of the anterior pituitary are collectively termed as **tropic hormones** or **tropins**. Tropic hormones act on other endocrine glands to stimulate secretion of hormones produced by the target gland.

- **Adrenocorticotropic hormone (ACTH):** Stimulates the adrenal cortex to produce corticosteroids.

- **Melanocyte stimulating hormone (MSH):** Stimulate the synthesis and dispersion of melanin pigment in the skin.
- **Growth hormone (GH) OR Somatotropic hormone (STH):** The growth of muscles, bone and other tissues.
- **Prolactin:** Stimulate the mammary glands to produce milk.
- **Thyroid Stimulating hormone (TSH):** Stimulates thyroid gland to produce thyroxin.
- **Luteinizing hormone (LH):** Stimulate gonads (testes/ovaries) for production of steroid hormone estrogen and progesterone from ovaries and testosterone from testes.
- **Follicle stimulating hormone (FSH):** Stimulate development of ovarian follicles in females. In males it is required for the development of sperm. FSH and LH are called gonadotropins (GnTH) because they stimulate the activities of the male and female gonads.

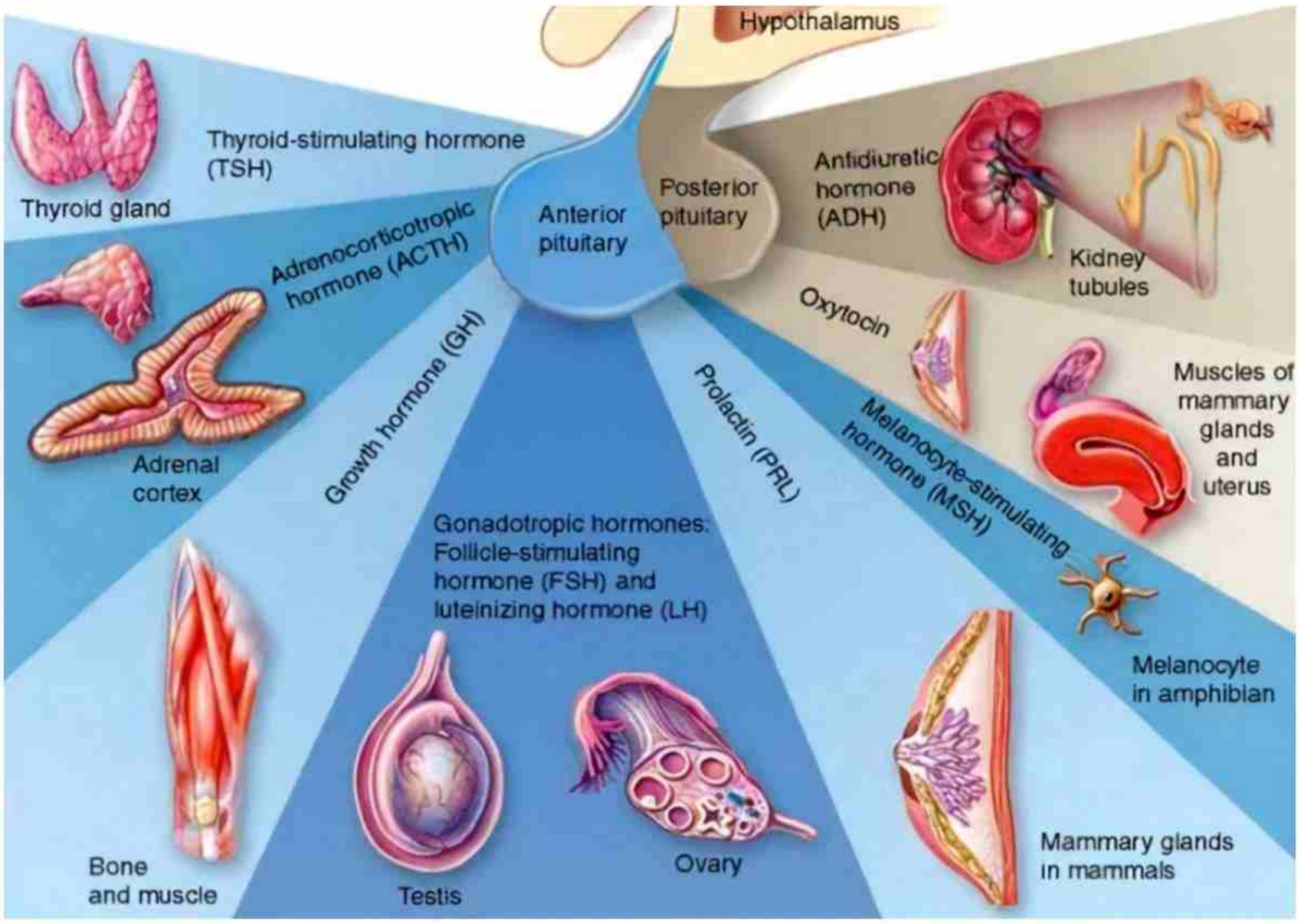


Fig.18.4 Pituitary gland

Posterior Pituitary gland (Neurohypophysis)

The posterior pituitary contains the ending of two types of neurosecretory cells whose cell bodies are found in the hypothalamus. The hormones released from here are actually stored secretion of hypothalamus, Antidiuretic hormone (ADH) and oxytocin. **Antidiuretic hormone** which literally means **"hormone that prevents urination"** helps prevent dehydration. ADH causes more water to be reabsorbed from the urine and retained in the body, by increasing the permeability to water of the collecting ducts of nephrons in the kidney. **Oxytocin** has two primary physiological effects: it stimulates uterine contractions during labour and stimulates breast tissue contractions to promote lactation after childbirth.

Additionally serving as a chemical messenger in the brain, it plays a significant part in social interaction and human behaviour.

18.2.3 Thyroid gland

In human thyroid gland is located at the base of neck in front of tracheae (windpipe). It is comprised of two lobes (bilobed) and the **isthmus** that binds them together. Thyroid gland produces three major hormones. **Tri-iodothyronine (T3)**, **Tetra-iodothyronine (T4)** or **thyroxin** and **calcitonin**. Thyroxin or T4 contains four atoms of iodine, it is secreted in greater amount but is less potent than T3, which has only three atoms of iodine. Thyroxin influences most of the cells in the body elevating their metabolic rate its effects include increasing oxygen consumption and heart rate and stimulating the synthesis of enzymes that breakdown glucose and provide energy.

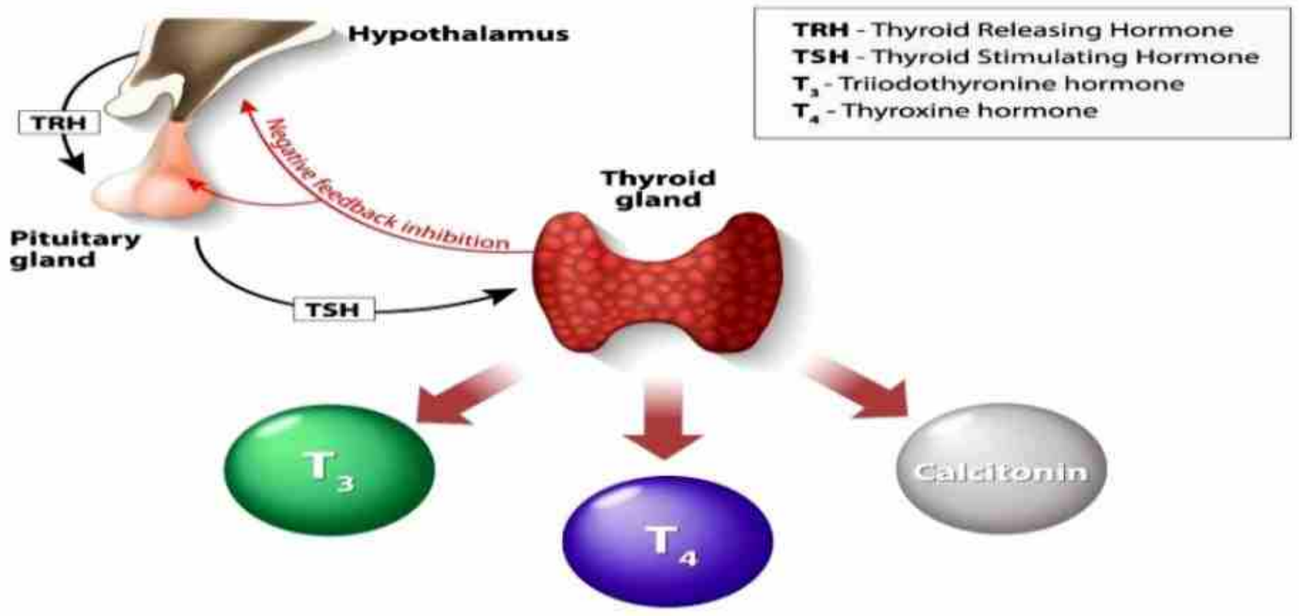


Fig.18.5 Thyroid gland

In adults metabolic rate involved in regulating body temperature and exposure to cold, for example, greatly increases thyroid hormone production level of thyroxin in the blood maintained by feedback loops. Thyroxin release is stimulated by **thyroid stimulating hormone** (TSH) from the anterior pituitary, which in turn is stimulated by releasing hormone from the hypothalamus **thyroid releasing hormone** (TRH). Excessive secretion of thyroid hormone known as **hyperthyroidism** produces such symptoms as profuse sweating, weight loss, heat intolerance, irritability and high blood pressure. Low secretion of thyroid hormone known as **hypothyroidism** produces symptoms such as weight gain, lethargy and cold intolerance in adults. Children born with hypothyroidism are stunted in their growth and suffer severe intellectual disability, a condition called **cretinism**. Another condition associated with a shortage of thyroid hormones is an enlargement of thyroid called **goiter**, often caused by a deficiency of iodine in the diet. **Calcitonin** a peptide hormone that plays role in maintaining proper levels of calcium (Ca^{++}) in the blood. When blood Calcium concentration rises too high, calcitonin stimulates the uptake of calcium into bones, thus lowering its concentration in the blood.

18.2.4 Parathyroid gland

The parathyroid glands are four small glands attached to the back of thyroid gland. The hormone produced by the parathyroid gland is a peptide hormone called **parathormone** or **parathyroid hormone** (PTH). It is synthesized and released in response to falling levels of calcium in the blood. This decline cannot be allowed to continue uncorrected because a significant fall in the blood calcium level can cause severe muscle spasms.

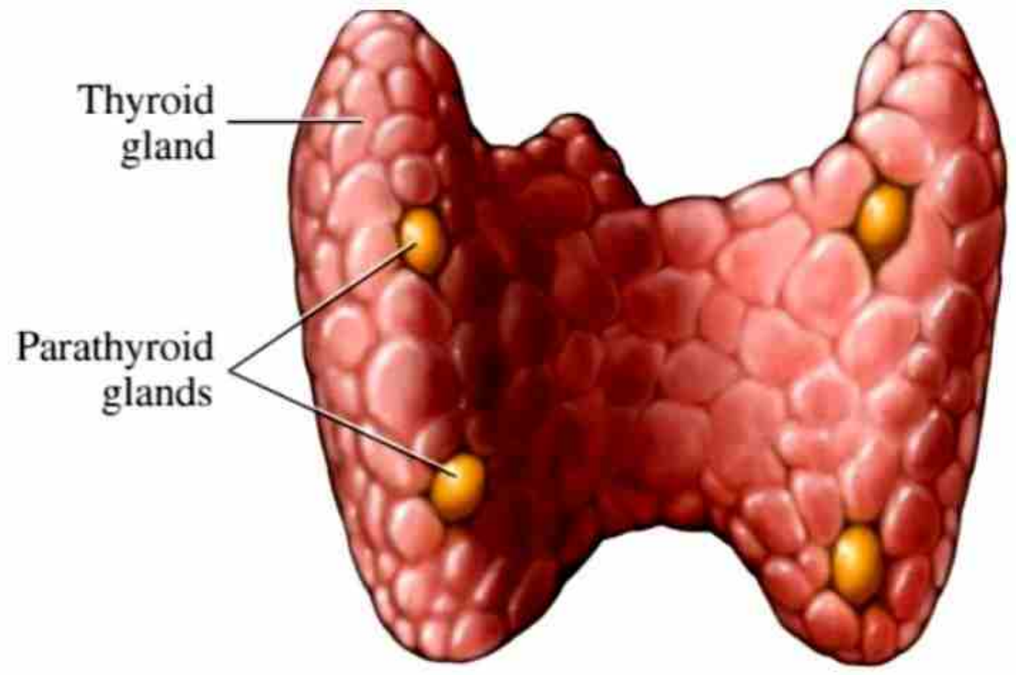


Fig.18.6 Parathyroid gland

A normal blood calcium level is important for the functioning of muscles, including the heart, and for proper functioning of the nervous and endocrine system. PTH stimulates osteoclasts (one of bone cells) in bone to dissolve the calcium phosphate crystal of the bone matrix and release calcium into the blood. It also stimulates kidneys to reabsorb calcium from the urine and leads to the activation of Vitamin-D, needed for the absorption of calcium from food in the intestine.

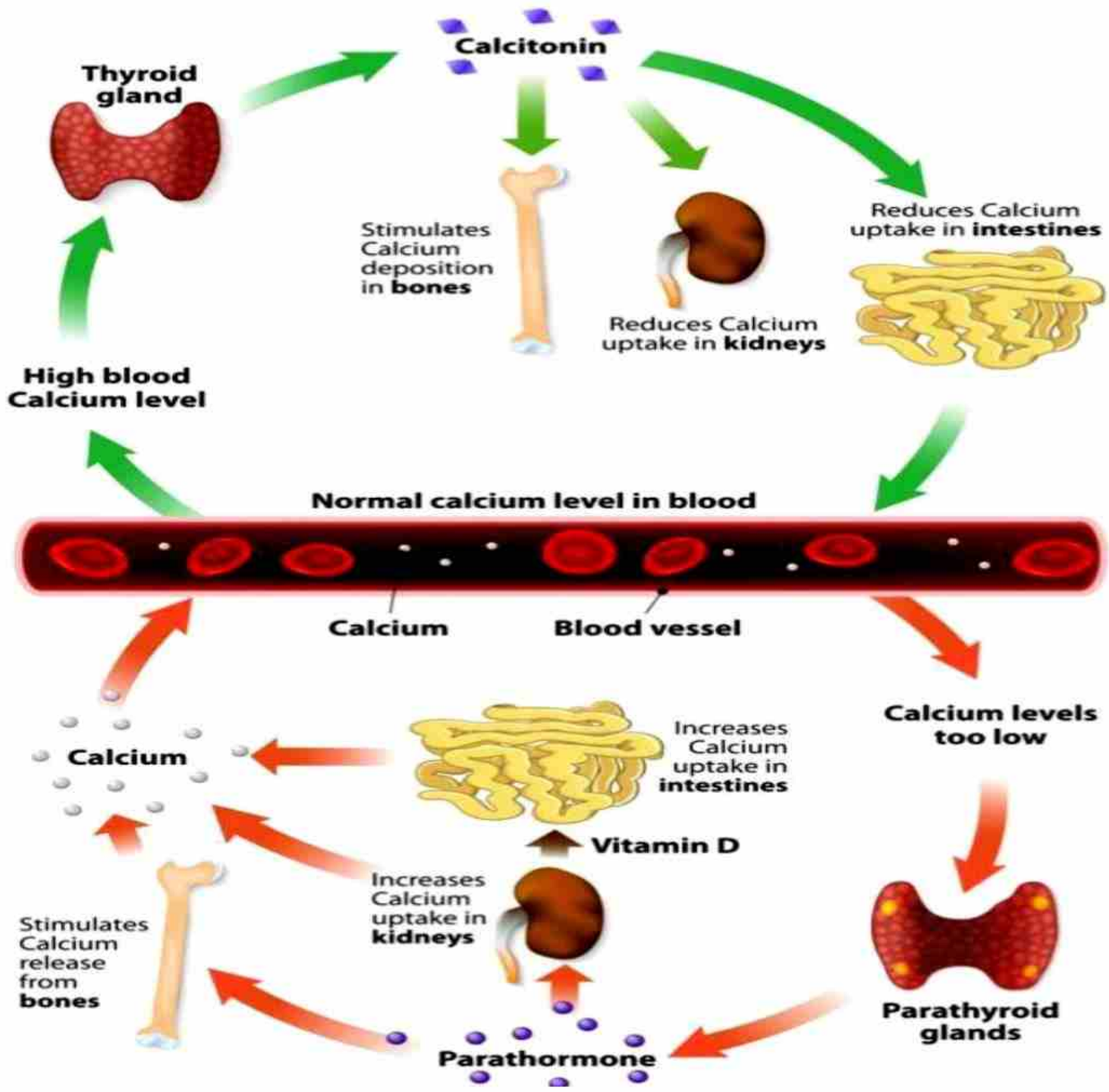


Fig. 18.7 Calcitonin and PTH relationship

18.2.5 Pancreas

The pancreas is located adjacent to the stomach. It performs both endocrine and exocrine functions. Endocrine cells makeup only 2% of the weight of the pancreas, rest of the organ is exocrine tissues

that produce bicarbonate ions and a variety of digestive enzymes that carried to the small intestine via the pancreatic duct. In 1869 a German medical student named Paul Langerhans described some unusual clusters of cells scattered throughout the pancreas, these clusters came to be called **Islets of Langerhans**. Cluster of endocrine cells that secrete two hormones directly into the circulatory system. Each islet has a population of **alpha cells**, which secrete the peptide hormone **glucagon**, and a population of **beta cells**, which secrete the peptide hormone **insulin**. Insulin and glucagon are antagonistic hormones that regulate the concentration of glucose in the blood. When blood glucose rises (for example, after a meal), insulin is released. Insulin causes most of the cells of the body to take up glucose and either metabolizes it for energy or convert it to fat or glycogen for storage. By far the most important storage organ for glycogen is the liver.

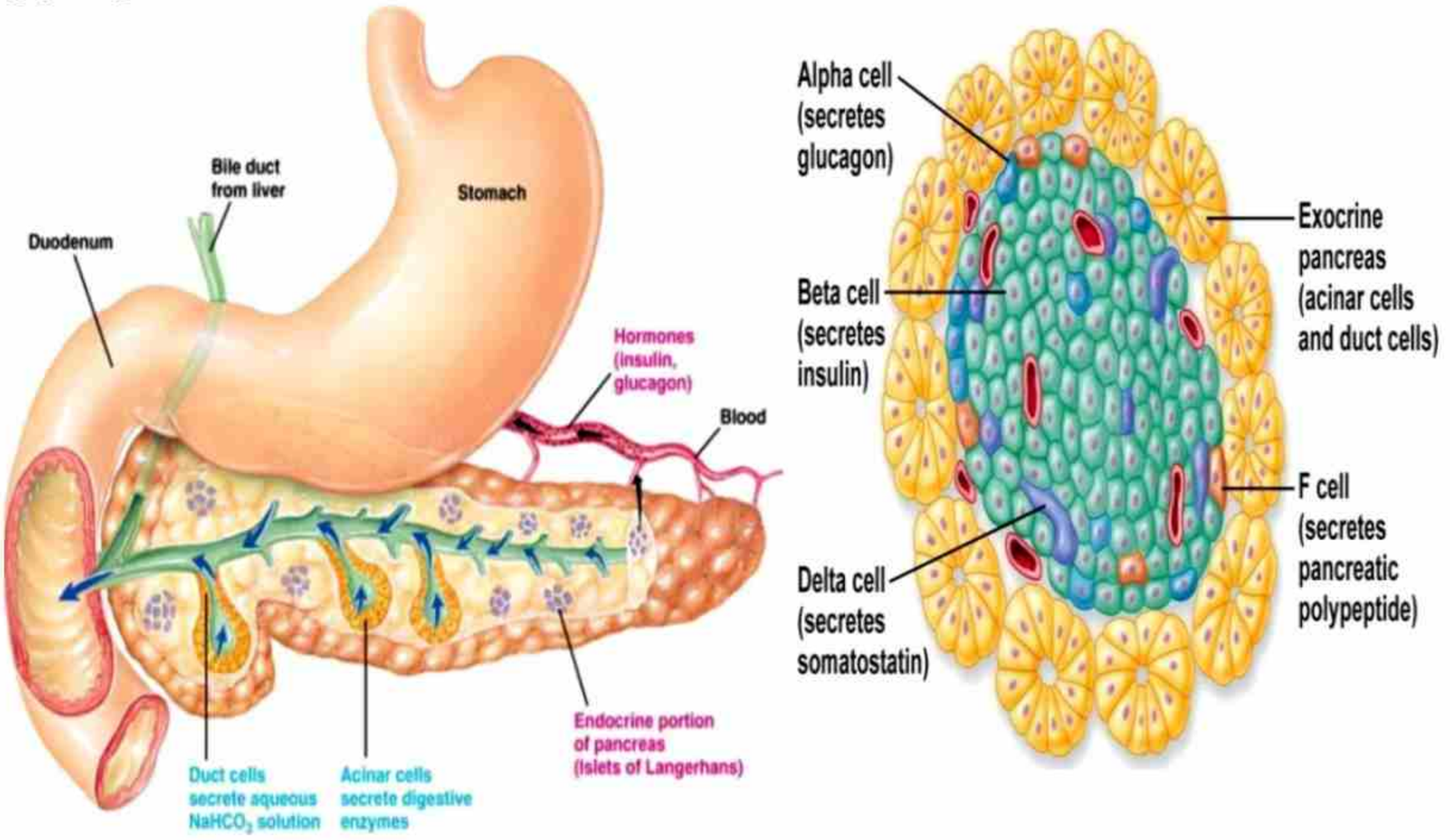


Fig.18.8 Pancreas and pancreatic cells

When blood glucose level drops (for example, after a person skips breakfast). Glucagon is released. It activates a liver enzyme that breakdown glycogen releasing glucose into the blood. It also promotes lipid breakdown, releasing fatty acids that are metabolized

for energy. Defect in insulin production, release or reception by target cells result in **diabetes mellitus**, a condition in which blood glucose levels are high and fluctuate wildly with sugar intake.

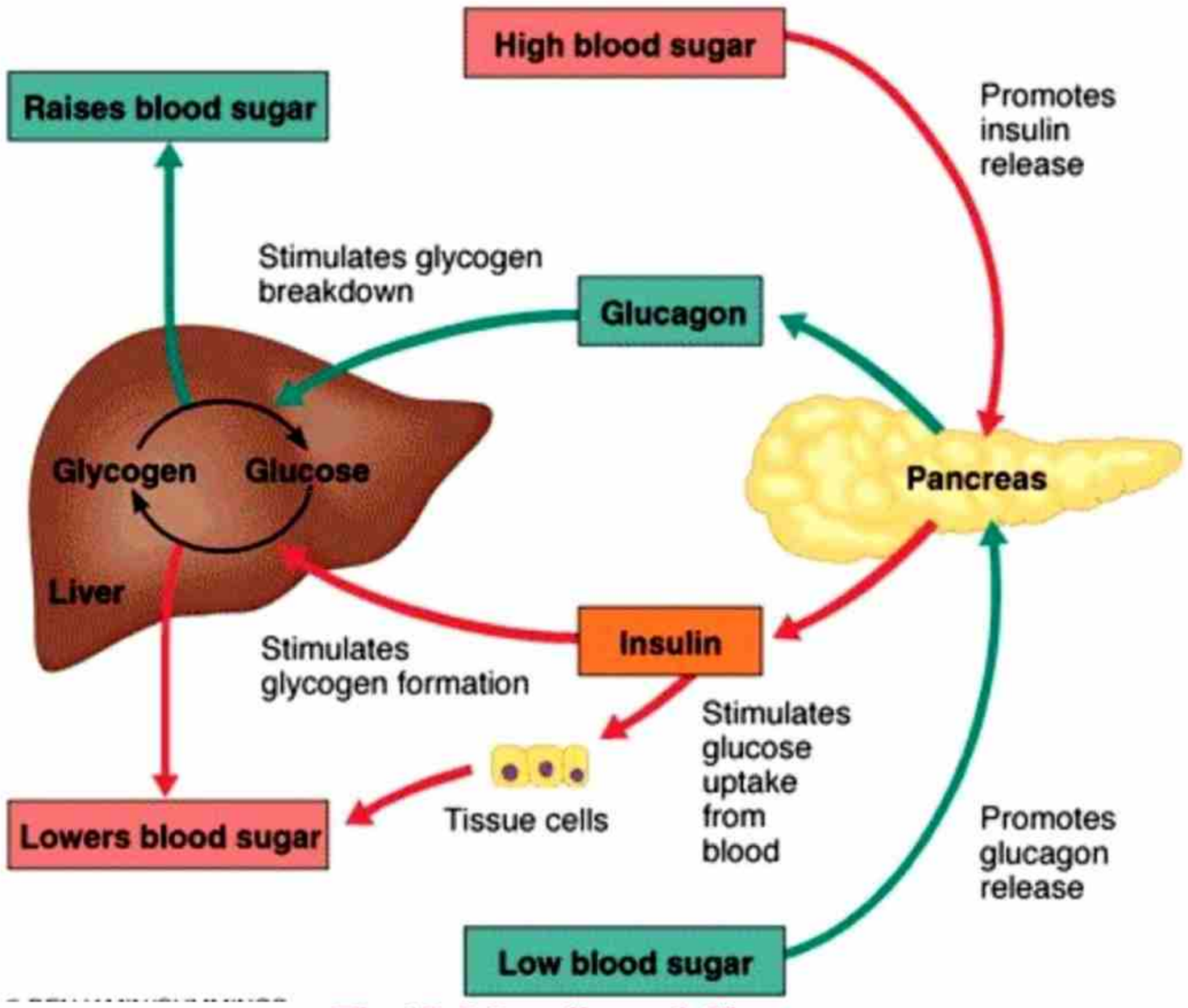


Fig.18.9 Insulin and Glucagon

The lack of functional insulin in diabetics causes the body to relay much more heavily on fats as an energy source, leading to high circulating level of lipids, including cholesterol. Severe diabetes causes fat deposits in the blood vessels, resulting in high blood pressure and heart disease. Fatty deposition in small vessels can also cause damage the retina of the eye, leading to blindness and the kidneys, leading to kidney failure.

Diabetes type-I: It is an autoimmune disorder i.e. the immune system attacks and destroys its own beta (β) cells, so that little or no insulin is produced, usually caused by body producing antibodies against β cells in islets of Langerhans. It is treated by using insulin injections to control blood sugar level.

Diabetes type-II: It is associated with genetic history, obesity, stress, lack of exercise and old age. In type II insulin is produced but the body cells (Target cells) do not respond to insulin, it can be controlled by adopting a low carbohydrate diet.

18.2.6 Adrenal gland

The adrenal glands are located just above each kidney. Each adrenal gland is composed to an inner portion, the **adrenal medulla** and an outer portion the **adrenal cortex**.

Adrenal medulla

The adrenal medulla (central part) produces two hormones **epinephrine** (adrenaline) and **nor-epinephrine** (nor-adrenaline) in response to stress. The actions of these hormones trigger "alarm" responses similar to those elicited by the sympathetic nervous system helping to prepare the body for extreme efforts among the effect of these hormones are an increased heart rate, increased blood pressure, dilation of bronchioles, elevation in blood glucose reduced blood flow to the skin and digestive organs and increased blood flow to the heart and muscles. The adrenal medulla is activated by the sympathetic nervous system which prepares the body to respond to emergencies.

Adrenal cortex

The hormones from the adrenal cortex are all steroids and are referred to collectively as corticosteroids. Many corticosteroids have been isolated from the adrenal cortex, the three main types are **glucocorticoids** such as cortisol, and the **mineralocorticoids** such as aldosterone and **Androgen**. Glucocorticoids or cortisol stimulates the breakdown of muscle protein into amino acids which are carried by the blood to

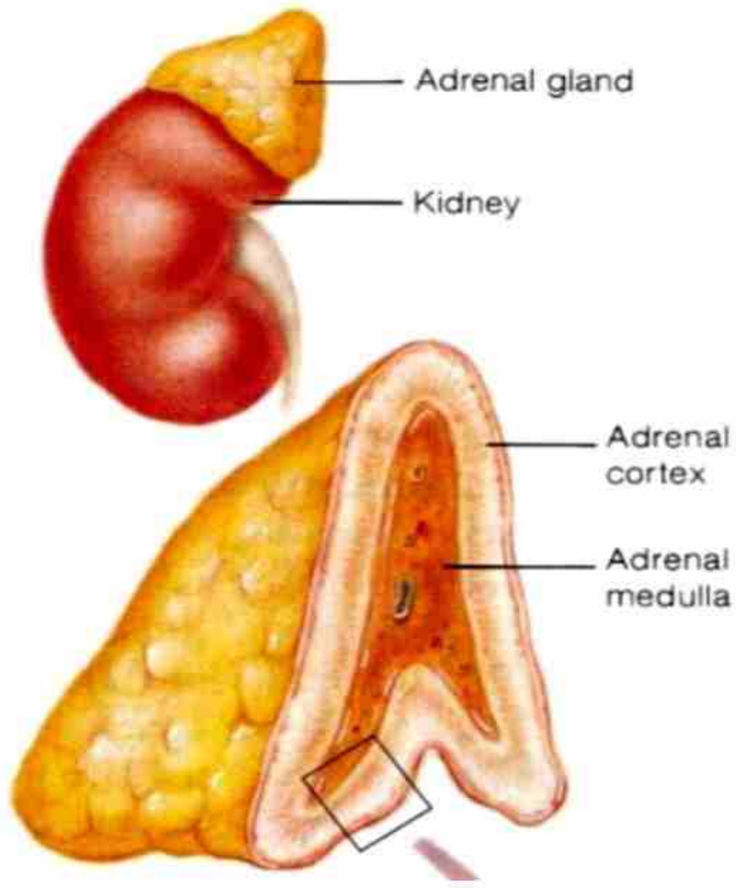


Fig.18.10 Adrenal gland

the liver. They also stimulate the liver to produce the enzymes needed for **gluconeogenesis** i.e. convert amino acids into glucose. Glucocorticoid release is stimulated by ACTH from anterior pituitary.

Cortico-releasing hormone (CRH), which is produced by the hypothalamus in response to stressful events including trauma, infection, or exposure to severe temperatures, in turn stimulates ACTH release. The glucocorticoid acts somewhat similarly to glucagon in that it stimulates the synthesis of glucose while encouraging the utilization of lipids rather than glucose for energy production. You may have observed that a variety of hormones, including thyroxin, insulin, glucagon, epinephrine, and glucocorticoids, are involved in the metabolism of glucose. This is likely due to the brain's need for certain nutrients during metabolism. While the majority of bodily cells can use both carbohydrates and fats and proteins to make energy, brain cells can only use glucose. Thus blood glucose levels cannot be allowed to fall too low, or brain cells rapidly starve leading to unconsciousness and death. Over secretion of cortisol cause **Cushing's syndrome** (Hypercortisolism). Symptoms of Cushing's syndrome are high blood pressure, weight gain, muscle wasting, weakened bones and mood swings. Low secretions of adrenal cortex hormone cause **Addison's disease**. Lack of cortisol results in a drop of glucose and high susceptibility to any kind of stress due to insufficient energy supply even a mild infection can cause death.

Aldosterone the other major corticosteroid is classified as a **mineralocorticoid** because it helps to regulate mineral balance. A primary action of aldosterone is to stimulate the kidneys to reabsorb sodium (Na^+) from the urine. Na^+ is needed to maintain blood volume and blood pressure. During low blood sodium level, the kidneys secrete an enzyme, the renin, which converts a plasma protein angiotensinogen to angiotensin-I. The latter is converted into angiotensin in the lungs, which stimulates adrenal cortex to release aldosterone this is called **Renin angiotensin-aldosterone system (RAAS)**. It affects the blood pressure in two ways, the angiotensin constricts the arteries and the aldosterone causes increased absorption of sodium.

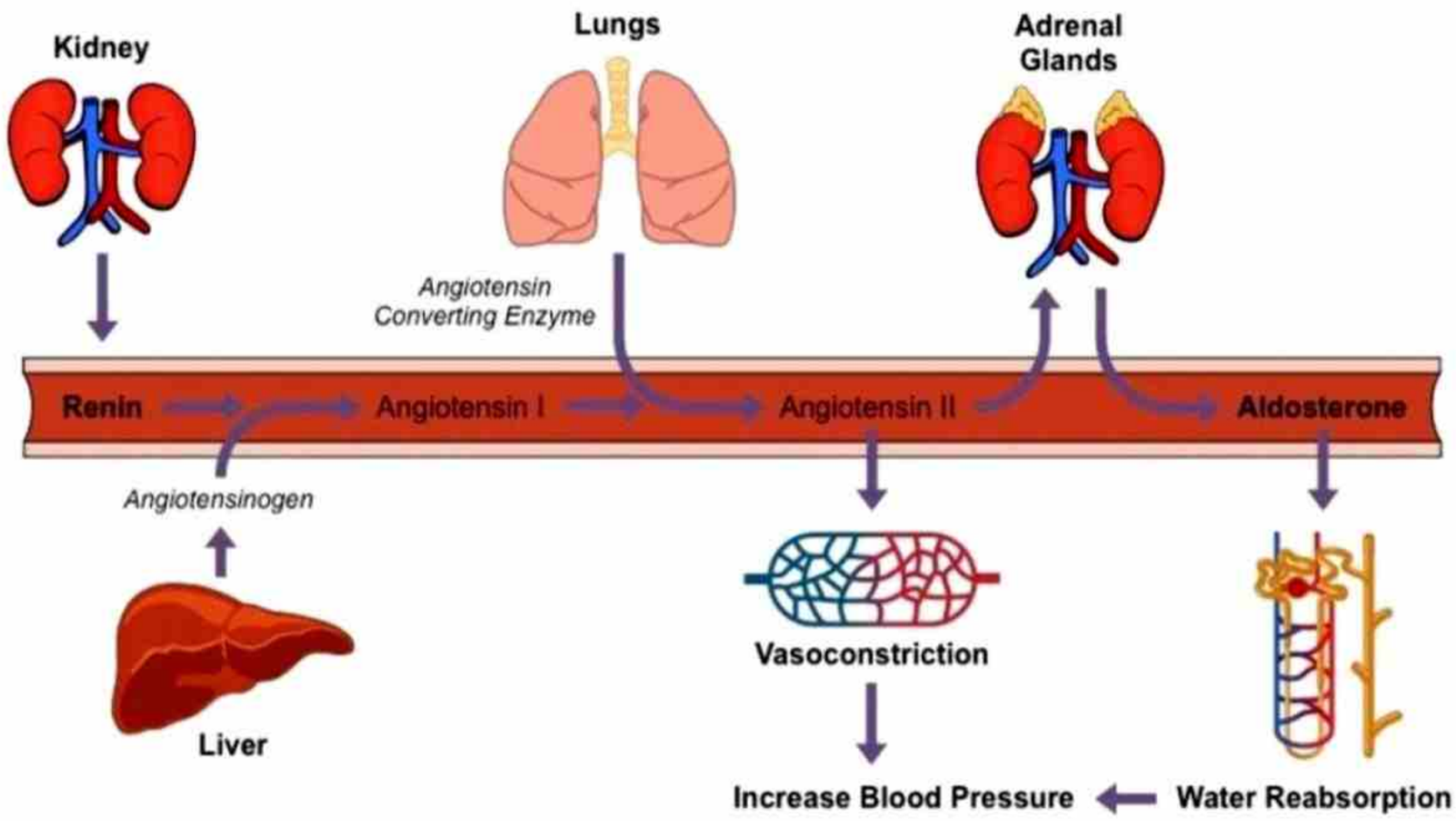


Fig.18.11 Renin- Angiotensin-Aldosterone system (RAAS)

A third group of corticosteroid are sex hormone mainly **androgen** similar to testosterone present in both male and female bodies. During adolescence level of androgen increases in both male and females, promote secondary sex characters in human male.

Extra Reading Material

Stress kicks the endocrine system into high gear

In response to stress, the endocrine system quickly secretes various hormones at higher-than-normal levels in order to help the body mobilize more energy and adapt to new circumstances. For example, the pituitary-adrenal axis starts releasing adrenaline to increase the volume of blood pumped out by the heart and the blood flowing to the skeletal muscles. And during acute physical stress, the pituitary gland may also ramp up the secretion of the growth hormone, which enhances metabolic activity. But prolonged or frequent stressful events can lead to a number of endocrine disorders, including Graves's disease, gonadal dysfunction and obesity.

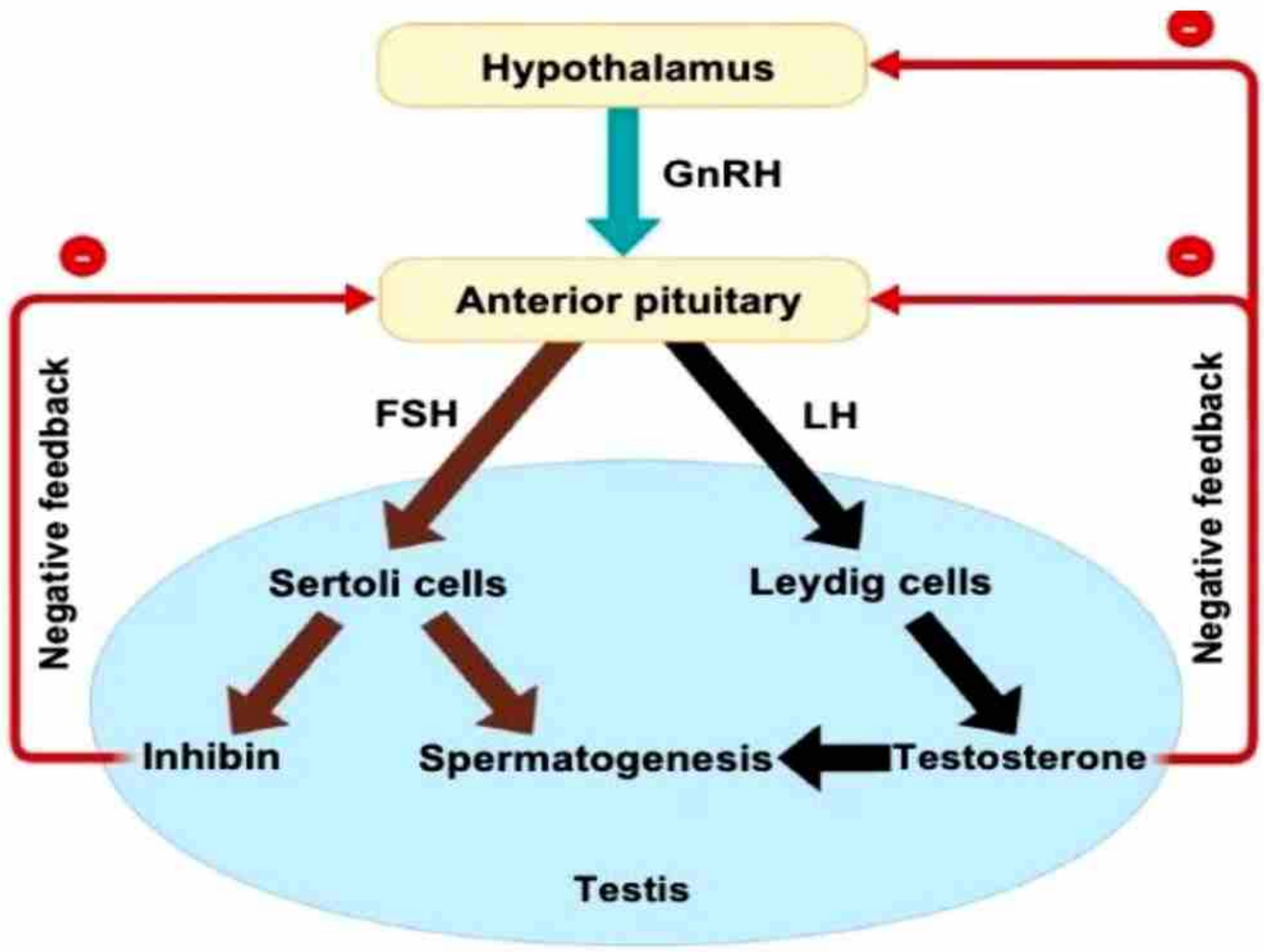
18.2.7 Gonads

The gonads produce and secrete three major categories of steroid hormones, a testosterone, estrogen and progesterone. All

three types are found in both males and females but in different proportions.

Testes

The testes are male gonads produce both sperm and male sex hormones. The anterior pituitary gland secretes gonadotropins, follicle stimulating hormone (FSH) and Luteinizing hormone (LH). FSH stimulates **sertoli cells** of testes to facilitate sperm development and LH stimulates **Leydig cells** of testes to release **testosterone**. Leydig cells of testes located in the interstitial tissues between the seminiferous tubules (site of sperm production) begin to secrete testosterone. It is produced early in the development of an embryo determine that fetus will develop as male rather than a female.



Testosterone produces both anabolic and androgenic effects in human males. Anabolic effects of testosterone include muscle mass, muscle strength, increased bone density, bone strength, linear growth and bone maturation. Androgenic effects of testosterone include maturation of sex organs, formation of scrotum in fetus, deepening of voice and growth of facial and axillary hairs.

Ovaries

The ovaries are female gonads, lie in the abdominal cavity produce both egg (ova) and female sex hormones. Ovaries secrete two lipophilic hormones **estrogen** and **progesterone**.

Estrogen contributes to the development and function of the female reproductive organs and promotes secondary sex characters which include development of breasts, fats distribution in hips, legs and breast, armpit and pubic hairs and **menarche** (start of menstrual cycle). Change in estrogen levels is encountered in various phases and involvement in female reproductive life and period of low estrogen are associated with mood swings, depression, headaches, and irregular periods and sleep problems.

Progesterone hormone of ovary helps in regulating menstruation and maintaining pregnancy in human females.

Extra Reading Material

Estrogen has about 400 functions in a woman's body. Such as regulate body temperature, improves blood flow, increases concentration, decreases wrinkling, risk of colon cancer, Parkinson's disease and Alzheimer's disease etc.

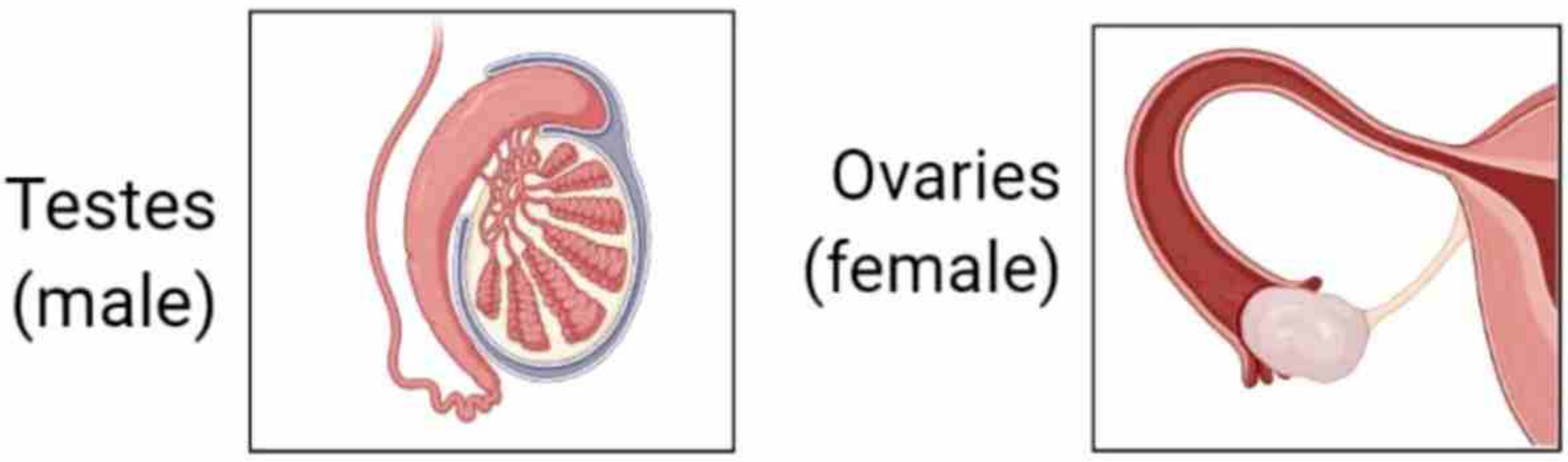


Fig.18.12. Gonads

18.2.7. Other endocrine tissues.

A variety of hormones produce from tissues within the body like digestive tract, kidney, heart and placenta. **Gastrin** a peptide hormone responsible for enhancing mucosal growth, gastric motility and secretion of hydrochloric acid (HCL) from walls of stomach.

Secretin a peptide hormone from duodenum regulates environment of stomach, pancreas and liver maintain pH to a more neutral to the basic state of the duodenum.

Cholecystokinin a peptide hormone from duodenum that stimulates gall bladder to contract and stimulates pancreas to release digestive enzymes. Some hormones are produce in kidney such as angiotensin and erythropoietin. **Angiotensin** regulates blood pressure. **Erythropoietin** stimulates red blood cell synthesis in bone marrow. Human heart also produce hormone like **atrial natriuretic hormone**. It increases salt and water excretion to reduce blood pressure. **Prostaglandins** are lipophilic hormone from every tissue of the body involved in dealing with inflammation, blood flow and protection from injury. Placenta an endocrine tissue release variety of hormones during pregnancy like **human chorionic gonadotropin (HCG)** and **progesterone**. Human brain releases endorphins hormone involved in pain relief.

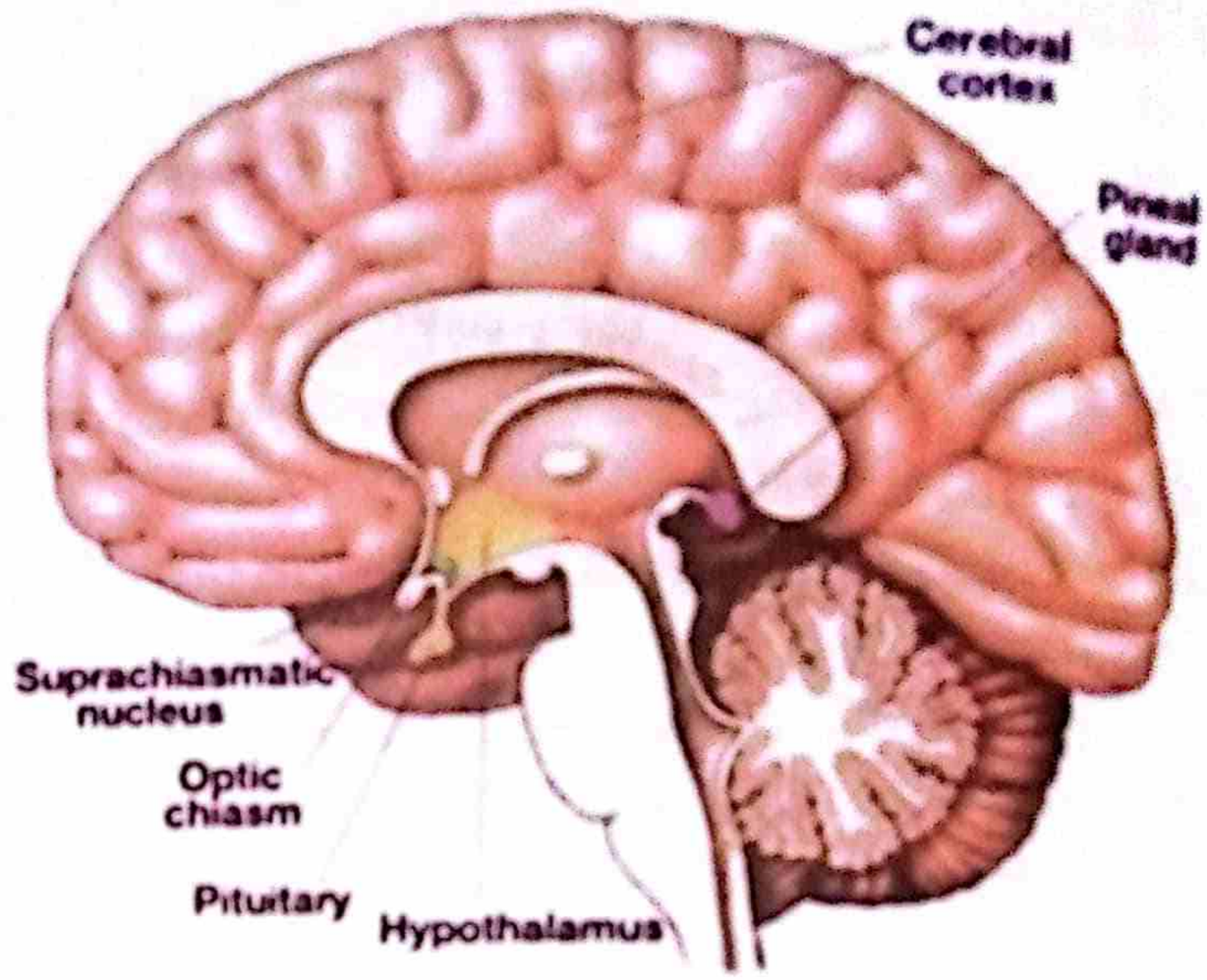


Fig.18.13 Pineal gland

18.3 FEEDBACK MECHANISM

Chemical co-ordination or most of bodily functions are regulated by a series of complex feedback mechanism. These mechanism works like a thermostat that responds to temperature

Extra Reading Material

The pineal gland evolved from medial light-sensitive eye (sometimes called a "Third Eye" although it could not form images). It is located between the two hemispheres of the brain. Just above and behind the brainstem. Named for its resemblance to a pine cone, the pineal is smaller than a pea. In 1646, the Philosopher Rene Descartes described it as the seat of "the rational soul". It secretes melatonin a modified amino acid hormone that regulates circadian rhythms.

changes by telling a furnace to turn on and off. Endocrine gland reacts to changes in hormonal level in the blood in much the same way that a thermostat reacts to temperature changes. If there are not enough hormones circulating in the blood, the gland makes more, increasing blood hormonal level. If there is too much hormone, the glands stop producing it leading to lower blood hormone levels. There are two mechanisms exist to maintain blood hormonal level positive and negative feedback mechanism.

18.3.1 Positive feedback mechanism

Positive feedback mechanism is rare in endocrine system, only few hormones are regulated by positive feedback. A positive feedback mechanism in endocrine system is when release of a hormone initiates action that leads to an additional release of that hormone. **Oxytocin** is one of the few hormones regulated by a positive feedback mechanism. In both childbirth and breastfeeding, oxytocin is released and causes additional release of oxytocin. During childbirth, release of oxytocin results in uterine contractions, and uterine contractions causes additional oxytocin to be released. During breastfeeding, oxytocin is released which allows for milk ejection. Milk ejection causes more oxytocin to be released.

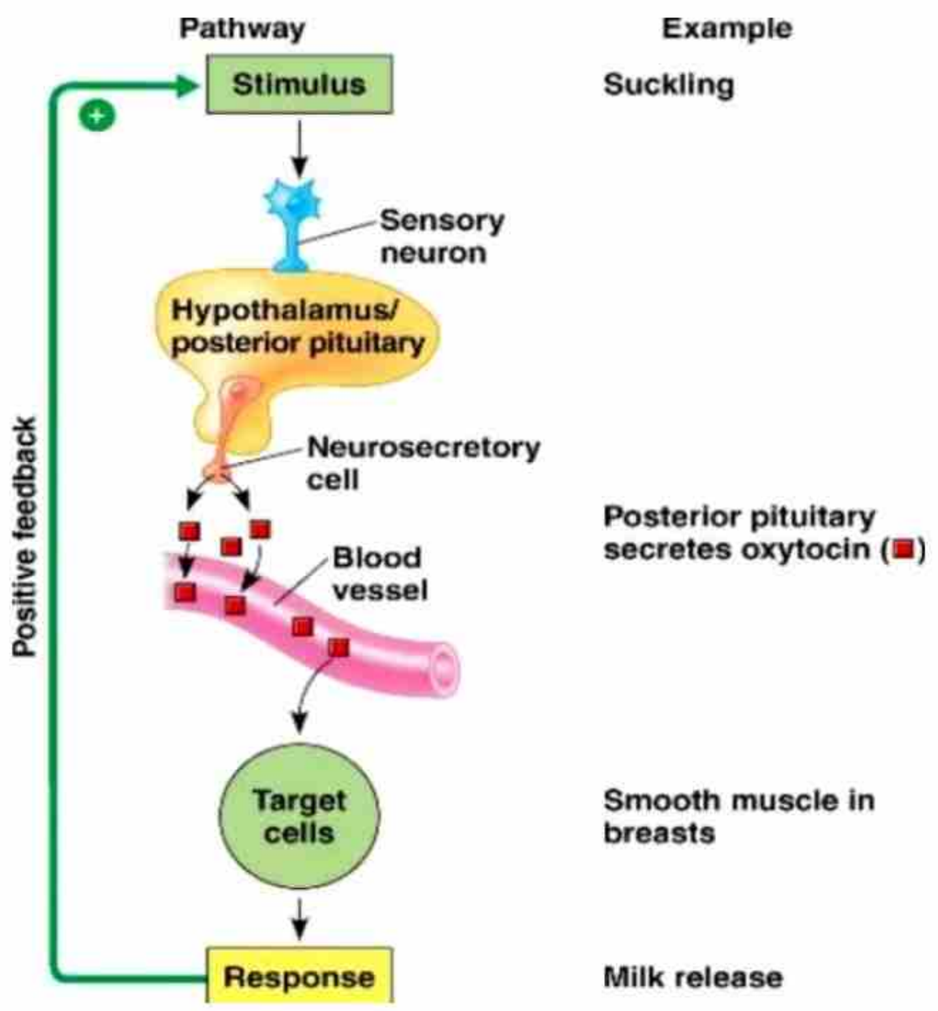


Fig.18.14. Positive feedback

18.3.2 Negative feedback mechanism

A negative feedback mechanism is one way that the endocrine system tries to keep homeostasis (stability) in the body. If an endocrine gland senses that there is too much of one hormone in the body, it will initiate changes to decrease production of that hormone,

and if there's not enough of the hormone, the body will increase production of that hormone.

The control of blood sugar (glucose) by **insulin** is a good example of a negative feedback mechanism. When blood glucose rises, receptors in the blood vessels sense a change. In turn the control center stimulates pancreas to secrete insulin into the blood effectively lowering blood glucose levels. Once blood glucose level reaches homeostasis, the pancreas stops releasing insulin.

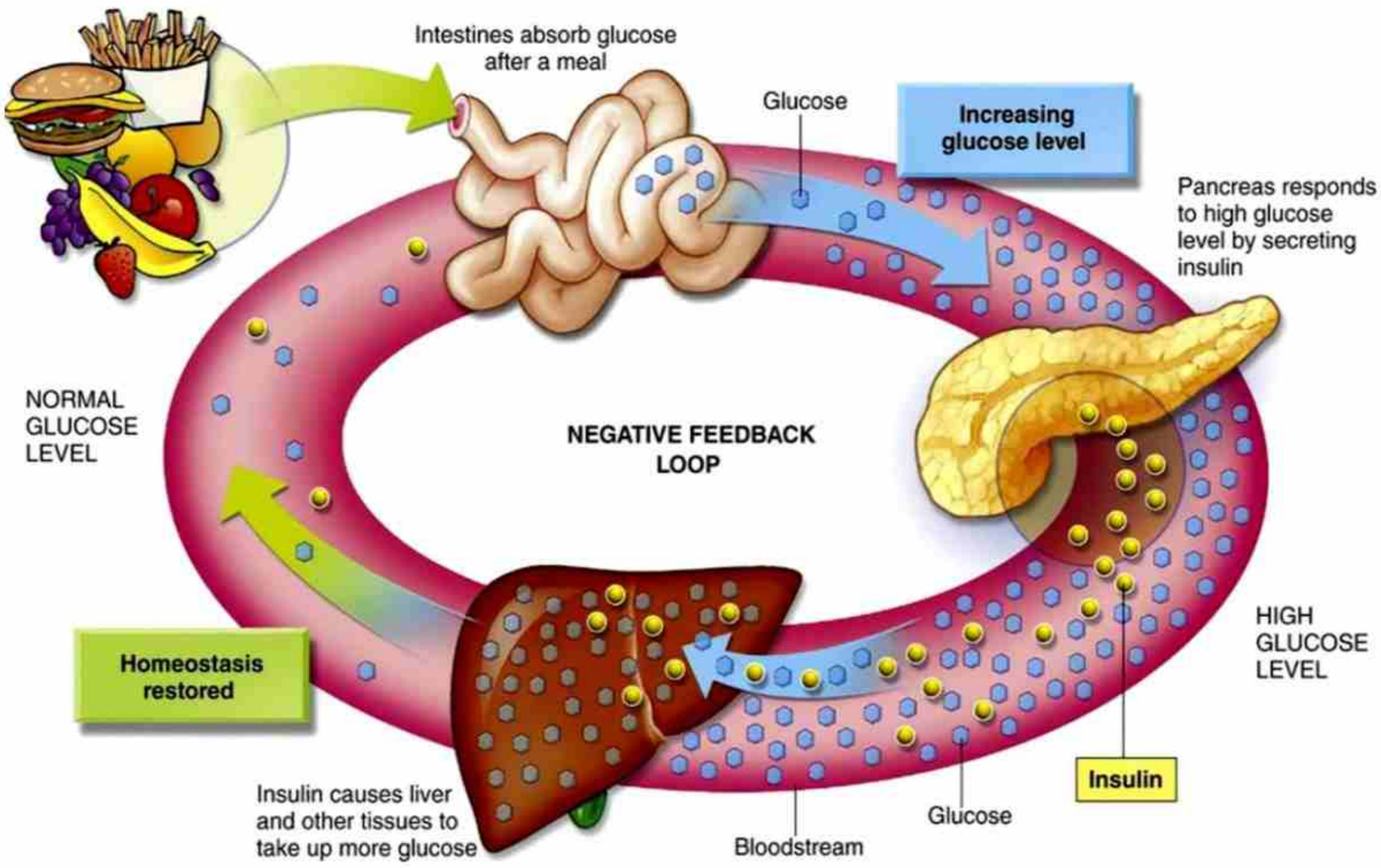


Fig.18.15. Negative feed back

SUMMARY

- Cell-to-cell communication is crucial to the control of movement, growth, reproduction, and the maintenance of homeostasis.
- A hormone is a chemical messenger that is secreted by specialized tissues called glands.
- Short chain amino acid hormones are called peptide hormones and Long chain amino acid hormones are called protein hormones.
- Hormones specificity is determined by receptors on target cells.
- Hormones may be categorized as hydrophilic and lipophilic.
- Hypothalamus is a part of the brain that contains clusters of specialized cells called neurosecretory cells.
- Thyroid gland is located at the base of neck in front of tracheae.
- Isthmus binds the two lobes of thyroid gland.
- Thyroid gland produce three major hormones T3, T4 and calcitonin.
- Parathyroid glands are four small glands attached to the back of thyroid gland.
- Pancreas is located adjacent to the stomach; it performs both endocrine and exocrine functions.
- Defect in insulin production release or reception by target cells result in diabetes mellitus.
- Lack of functional insulin in diabetes causes the body to relay much more heavily on fats as an energy source, leading to high circulating level of cholesterol.
- Adrenal glands are located just above each kidney. Each adrenal gland is composed to an inner portion, the adrenal medulla and an outer portion the adrenal cortex.
- Adrenal medulla produces two hormones epinephrine and nor epinephrine in response to stress.
- Hormones from the adrenal cortex are all steroids and are referred to collectively as corticosteroids.
- Testes are male gonads produce both sperm and male sex hormones.
- Testosterone produces both anabolic and androgenic effects in human males.

- Ovaries are female gonads produce both egg and female sex hormones.
- Placenta an endocrine tissue release variety of hormones during pregnancy like HCG and progesterone.

EXERCISE

1. Encircle the correct choice.

i) Which of the following statements about hormones is incorrect?
(a) They are produced by endocrine glands.
(b) They are modified amino acids, peptides or steroid molecules.
(c) They are carried by the circulatory system.
(d) They are used to communicate between different organisms.

ii) Oxytocin and ADH are produced by the _____ and stored in the ____.
(a) Hypothalamus; Neurohypophysis
(b) Adenohypophysis; Kidneys
(c) Adrenal cortex; Adrenal medulla
(d) Posterior pituitary; Anterior pituitary

iii) Tropic hormones from the anterior pituitary directly affect the release of which of the following?
(a) Parathyroid hormone (b) Calcitonin
(c) Epinephrine (d) Thyroxine

iv) Which of the following endocrine disorders is /are not correctly matched with the malfunctioning gland?
(a) Diabetes → Pancreas (b) Giantism → Pituitary
(c) Goiter → Adrenal medulla (d) Tetany → Parathyroid

v) Which hormone exerts antagonistic action to PTH?
(a) Thyroxin (b) Calcitonin
(c) Growth hormone (d) Epinephrine

vi) Which of the following are synthesized from the amino acid tyrosine?
(a) Epinephrine (b) Catecholamines
(c) Thyroxin (d) All of the following

vii) If the adrenal cortex were removed, which group of hormones would be most affected?
(a) Steroid (b) Peptide
(c) Tropic (d) Amino acid derived

viii) Which of the following hormones is (are) secreted by the adrenal gland in response to stress and promote(s) the synthesis of glucose from non-carbohydrate substrates?
(a) Glucagon (b) Glucocorticoids
(c) Epinephrine (d) Thyroxin

ix) Which of the following stimulates the contraction of uterine muscle?
(a) Oxytocin (b) Thyroxin
(c) Growth hormone (d) Insulin

x) A distinctive feature of the mechanism of action of thyroid hormones and steroid hormones is that
(a) These hormones are regulated by feedback loop
(b) These hormones bind with specific receptor protein on the plasma membrane of target cells.
(c) These hormones bind to receptors inside cells
(d) Target cells react more rapidly to these hormones than to local regulators.

2. Write short answers of the following questions:

i) Why hydrophilic hormones need secondary messengers?
ii) Why hormones are called chemical messengers?
iii) Why posterior pituitary is called neurohypophysis?
iv) Enlist hormones of anterior pituitary?
v) Why pancreas is called as exocrine and endocrine gland?
vi) Why secretions of adrenal cortex are called corticosteroids?
vii) Differentiate between following
(a) Hypothyroidism and Hyperthyroidism
(b) Insulin and glucagon
(c) Calcitonin and Parathyroid hormone
(d) Lipophilic and hydrophilic hormones
viii) Define following terms
(a) Hormones (b) Goiter (c) Thymosin
(d) GnTH (e) Atrial natriuretic hormone (f) Erythropoietin

3. Write detailed answers of the following questions:

i) Define hormone? Describes hormone action with the help of suitable diagram.

ii) Explain pituitary gland their lobes and hormones of pituitary glands.

iii) Explain position and physiology of adrenal gland.

iv) Describe hormones and their functions of other endocrine tissues.

v) Describe mechanism of positive feedback.

Chapter 19

ANIMAL BEHAVIOUR

Major Concept

In this Unit you will learn:

- The Nature of Behaviour
- Innate Behaviour
- Learning Behaviour
- Social Behaviour

The Living organisms are different from non-living things because they have capacity to response to change in the environment. The response of the organism is adaptive that is, it enhances the probability of an organism to survive and reproduce. One of the most important ways of adapting to environmental change is behaviour. Behaviour means the response of an organism to stimuli. Usually, the behaviour of an organism is inherited but it can be modified by experience.

19.1THE NATURE OF BEHAVIOUR

19.1.1 Behaviour of Organisms in Response to Stimuli

All those responses to stimuli involved in the integrated functioning of the entire organism are called **behaviour**. In simple words, what an organism does, and how it acts after being stimuli is called behaviour. An organism has ability to response to stimuli may vary from relatively simple action as an odour of food. In this sense, a bacterial cell behaves by moving toward higher concentrations of sugar. On the other hand, the complex sexual behavioral patterns of territory defense and mating are seen in fishes, birds and mammals. In other words, what a human, animal or any other organism does after being exposed to stimuli is part of its behaviour. The study of animal behaviour is called **Ethology** (Gr. *ethiologica*, depicting character).

19.1.2 Relationship between stimuli and behaviour

The **stimulus** is a detectable change (physical or chemical) happens in the environment that causes an organism to response. The sensory cells (receptors) of an organism located in many places on or in the body which detect different changes receive form the environment and convert into signals (nerve impulses). The organism then processed or interprets the signals received from the sensory cells resulting in a response or being ignored.

Interpretation and response to stimuli

The receptors send signals through nerve cells to CNS (Central Nervous System). In CNS the signals are interpreted on the basis of stimuli. For example, thermoreceptors in the skin of baby detect heat, if the heat interpreted as dangerously high, the baby will jerk

away from the source of heat through a fast process called **reflex action** without involvement of the brain. On the other hand, the chemoreceptors in the nose of dog detect odour coming from food. The signal reaches the brain which interprets that some is good to eat. The dog then responds by salivating and perhaps begging for treat.

Different ways of responses to stimuli

The response of an organism to the stimuli can be positive, negative or ignored. A **positive** response is that in which one wants more or is attracted to the stimulus. For example a person becomes happy after hearing a good news is a positive response. A **negative** response is that in which one wants to avoid the stimulus. For example, a dog hides when you want to give it a bath is a negative response. The **ignored** reaction is that in which an organism decides to ignore the stimulus. For examples, you pay no attention to slight changes in the room's temperature.

19.1.3 Relationship between Heredity and Behaviour

The behaviour of an organism depends on neural and hormonal mechanisms such as sensory cells, nerve cells and CNS. Therefore, Genes are associated with behaviour because they control the development of all physiological systems such as the nervous system. Genes also produce proteins which are important in the behaviour response, including turning on a gene for a specific hormone or its receptor or affecting the growth of nerve cells and its activity.

When the classical methods were experimentally demonstrated the genetic basis of behaviour among animals including inbreeding and artificial selection. The animals show vary in the expression of certain behaviour because of variation in their genes. For example, all dogs belong to same species, after artificial selection different breeds have different behaviour such as variation in the hunting skills among breeds due to variation in their genes.

19.1.4 Biological Rhythms

Biological rhythms are cyclic physiological patterns of activities in an organism that are in response to periodic

environmental changes. The internal mechanism or device that controls the physiological activities in the living organism independent from external stimuli is termed as **biological clock**.

The activity of most organisms is synchronized with the daylight or night (darkness) cycle, with most organism their pattern of activity to a specific portion of the day or 24 hours called a day-night rhythms or **circadian rhythms**. The animals that are not active throughout 24 hours of a day, such as butterflies, birds including mammals which are most active during the day light are called **diurnal animals**. Other animals that are active at night (darkness) such as cockroaches, owls and bats are called **nocturnal animals**. There are still some species of the animals such as mosquitoes that are active in the early morning (dawn) or early in evening (dusk) are called **crepuscular animals.** Some animals have annual rhythms called **annual cycle** or circannual **rhythms**, including bird migration, reproductive cycles in many insects, fishes, birds and mammals and hibernation of animals.

There are two types of animal behaviour i.e. **innate behaviour** and **Learning behaviour**

19.2 INNATE BEHVIOUR (INBORN OR INSTINCTIVE BEHAVIOUR)

19.2.1. Innate (inborn) behaviour

The behaviour of an organism that is performed in response to stimulus at the time of birth without prior experience is called **innate behaviour or inborn behaviour**. Innate behaviour is inherited behaviour performed by the animals in a very similar way by all the members of species. For example, a human newborn baby instinctively grasps objects placed on his palm. Innate behaviours are important in the survival of specially those animals that have short life span and poorly developed nervous system. There are two types of innate behaviours i.e. orientation and non-orientation behaviours.

Orientation behaviours

The behaviour in which an organism moves or changes its direction in response to a source of stimuli is called **orientation behaviour**.

19.2.2. Taxis (Plural: Taxes)

Taxis is a directional movement toward or away from the particular stimulus (e.g. light, heat), if the response is movement toward the stimulus, it is a **positive taxis** and response is movement away from stimulus, it is a **negative taxis**. Moth shows positive taxis by moving toward the light and cockroach shows negative taxis by moving away from light. With respect to type of stimuli, a taxis might be classified as **phototaxis**, response to light ray, **chemotaxis** response to chemical substance, **thigmotaxis** response to contact, **hydrotaxis** response to moisture and so on.

Kinesis (Plural, kineses)

Kinesis is a simple form of non-orientation movement that be can be slow or fast. In this behaviour the animal alters its rate of movement according to intensity of the stimulus. For example, **woodlice** (Fig. 19.1) move rapidly over the dry environment, and slowdown at high humid environments.

Fig 19.1 Woodlice

Non-Orientation behaviours

In these behaviours the animals do not show movement toward particular directions in response to stimuli. These are more complex behaviours than orientation. These include, reflexes, instincts and motivations etc.

19.2.3. Reflexes

Reflex behaviour is the simplest form of response to stimulation. It describes the rapid automatic response of the body or part of the body to simple stimuli. A stimulus below the knee provokes the spinal cord which relays it through the motor nerve to extensor muscle, causing them to contract causing a kicking action. In the bright light, the pupil will contract, blinking of your eyes, withdrawing your hand from a hot object are also examples of reflexes. Sometimes, the whole body of animals may be involved in the reflex response. Withdrawal response of invertebrates such as polychaetes worms and various mollusks involve the whole body,

when triggered by nerve fibers that carry very fast messages to all muscles, so that they contract suddenly and simultaneously.

19.2.4. Instincts

The **Instinct** or **instinctive** (innate or inborn behaviour) is an inherited behaviour pattern that does not require learning or practice. These are complex behaviour patterns that are genetically programmed, which develop along with the developing nervous system and can evolve gradually over the generations, so it is also called **fixed action pattern**. In this behaviour the whole body of the animal is involved and displays its own characteristics, following behaviours are instinctive or inborn patterns of behaviour.

Migration of Salmon Fish

In fish, the migration of the salmon is remarkable. Salmon spends their life in two different habitats i.e. river and ocean. In the freshwater, the female deposits her eggs and male deposits his sperms over eggs, this process is called **Spawning**. Young spends early life in the fresh water and then leave the freshwater, moving thousands of kilometers into the open ocean. In the ocean, salmon lives six months to seven years, where they continue to feed and grow and after two or three years transform into **smolt** (stag of sexual maturity). During breeding season smolts stop feeding and then start their journey approximately hundreds miles back to exact stream for spawning where they hatched. The journey from oceanic feeding grounds to freshwater spawning grounds, risking death from exhaustion or predation, a small percentage of salmon reach their spawning ground. This migration of salmon is an instinct or innate behaviour as they do it to perfection without having prior experience. (Figure 19.2)

Fig 19.2 Salmon Fish

Dances of bees

Honey Bees have one of the interesting behaviour of communication systems to signal other bees of hive the distance and direction of the food. Bees (scout) leave hive and forage for food when they return back at their hive, other bees gather around and detect the odour of nectar source the scout has discovered. The scout performs a dance on the wall of hive, which indicates the distance and often direction of food. Scout performs two types of dance round dance and waggle dance. If the source of food is less than 90 meters away from the hive, the bees perform a **round dance** (Fig. 19.3 a.). If the source of food is farther 90 meters away, the scout bee performs a **waggle dance** (Fig. 19.3 b.) indicating both direction and distance. The dance is repeated many times and using the sun as compass and speed of the dance indicate the distance of food source from the hive, they can communicate about food up to 2 kilometers away. This type of communication among bees is instinct or inborn, bees born with this ability to understand this type of behaviour.

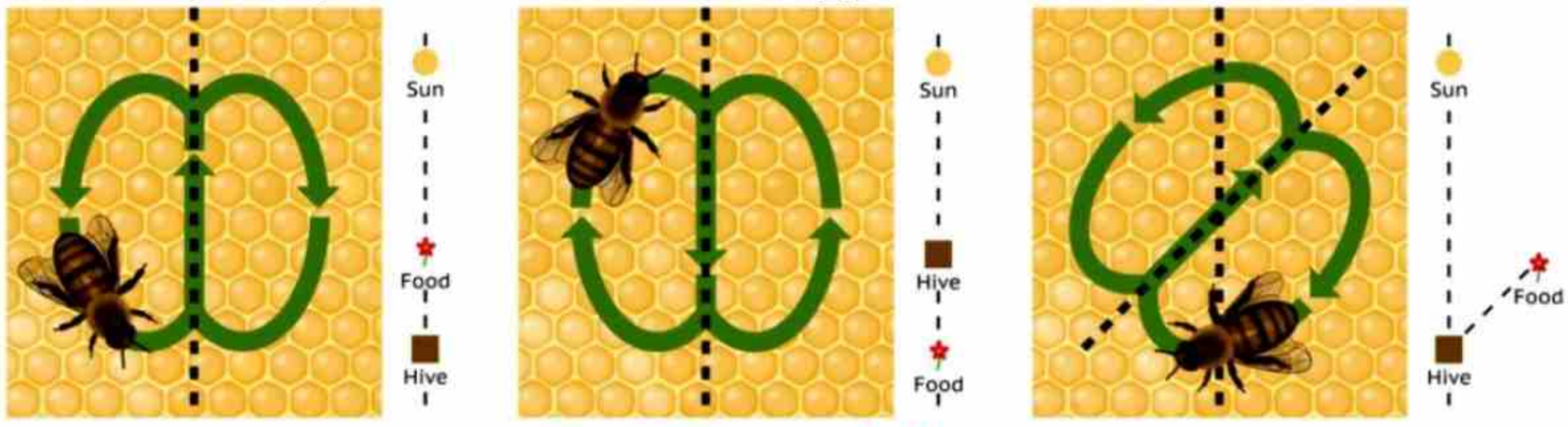


Fig. 19.3a waggle dance

Fig. 19.3 b Round dance

Nest building by birds

All birds have different strategies to build nests for their eggs deposition, the long tailed **tailor-birds** have ability to build a hanging nest. A young long tailed tailor-bird to acquire a mate builds nest for their eggs laying. This bird builds nest between hanging leaves with twigs and grass. The tailor bird has not learned nest building by older birds and had no prior experience in such a task, however it builds a nest by its instinct behaviour. (Figure 19.4)

Fig 19.4
Tailer Bird woven Hanging nest

Building of spider's orb web

The circular or orb web is spun by common spiders all over the world. The orb web is built of silk threads which are secreted by special **silk glands** present in the abdomen. A scleroprotein secretion emitted as a liquid hardens on contact with air to form the silk. Spider applies the main rule contains a set of sub rules for measuring angles and walking set distances up certain threads. By following the program of elementary rules the spider can build a complex structure without having a plan for it in her head. The orb web of spider is the outcome of highly complex and instinct or inborn behaviour patterns. (Figure 19.5)

Fig 19.5
Spider's Orb Web

Courtship behaviour of stickleback Fish

The **three-spined stickleback** fish have ritualized courtship, aggressive and parental behaviour. Sexually mature male develops a bright throat and red belly called nuptial colouration. During the breeding season, territorial male builds nest and becomes aggressive and dominant to protect from the other males. The female with

prominent silver belly approach to the male's territory, the male leads female to the nest and shows the entrance of the nest. Once the female is inside the nest the male stimulates spawning by pods the base of her tail. After spawning, the female leaves the nest and the male enters and fertilizes the eggs. The male stays close to the nest to look after the offspring, fanning the eggs and protecting the newly hatched fish for several days. This mating behaviour of the stickle-back is instinct or inborn without prior experience (Fig. 19.6).

Fig 19.6 Three-spined stickleback fish (Male and female)

19.3. LEARNING BEHAVIOUR

Learning is a process in which the animals modify their behaviour as a result of specific experience. This modification is adaptive, because it allows an animal to not only change its response to fit a given situation, but also to improve its response to subsequent, similar environmental changes. Learning behaviour is not controlled by genes like innate behaviour but it is achieved by the experience from the environment. Learning behaviour is more prominent in those animals that have a comparatively long life span and well developed nervous system.

19.3.1. Distinguish between learning and innate behaviour

Innate behaviour	Learning behaviour
Innate behaviour is inherited come with the someone's birth	Learning behaviour is acquired by knowledge/experience from society
It is reflex action of organism when exposed to stimulus	It is learned or acquired behaviour which is based on knowledge or experience
It is permanent, cannot be modified and remains same in the next generation	It can be modified by the experience and does not remain same in the next generation.
It contributes in the survival and proper functioning of organism	It improves the behavioral traits in an organism to fit in a given situation
It is more common in those animals having short life span	It is more common in those animals having long life span
In this behaviour animal requires no time to adapt them	In this behaviour animals requires more time to adapt them
Leg moving upward by newborn baby is the example of innate behaviour	Playing cricket is the example of learning behaviour

19.3.2. Habituation

Habituation is the simplest form of learning, in which the animals learn not to respond or ignore to a repeated, irrelevant stimulus. The animals learn that repeated harmless stimuli from humans or other animals then ignore the stimuli and behave accordingly. Habituation occurs at the level of the brain and may involve more complex stimuli; the stimulus is still perceived, but the animal has simply "decided" to no longer pay attention.

Fig 19.7 Wild squirrel (Habituation)

For example the wild squirrels commonly inhabits the park. If a person wants to take a picture of a squirrel it will move away from the people due to fear of danger. After this happens many times the squirrel will learn that it is not dangerous to him. This process repeats over time and squirrel will be less afraid. Eventually, the squirrel will completely lose its fear and will not respond to a stimulus. This happens due to habituation behaviour and when the people give them feed then the squirrel will approach the human without any fear (Fig. 19.7).

19.3.3. Imprinting

Imprinting is a type of learning in which a young one fixes its attention on the first moving object or another animal then follows soon after birth or hatching. It refers to a particular form of learning that occurs during a usually very short sensitive period early in the life of an individual. Once the animals learn, this information is firmly fixed and may be used later in life in identifying mates, in forming flocks, and in other social interactions. Imprinting was first observed in birds when chicks, ducklings, and goslings followed the first moving object they saw after hatching.

The classic experiment was done by **Konrad Lorenz** in the 1930s. He used the greylag goose (*Anser anser*) to demonstrate imprinting. Lorenz found that by substituting himself for the mother during this critical period, he could induce young geese to imprint on him. When incubator-hatched goslings spent their first few hours with Lorenz, rather than with their mother, they steadfastly followed Lorenz and showed no recognition of their mother or other adults of their species. Even as adults, the birds continued to prefer the company of Lorenz and other humans to that of geese. Lorenz demonstrated that the most important imprinting stimulus for greylag geese was movement of an object (normally the parent bird) away from the hatchlings. (Figure 19.8)

Fig 19.8
Konrad lorenz with greylag goose

19.3.4. Differentiate habituation and imprinting as reversible and irreversible learned behaviour

Habituation is a reversible. For example a snail crawling on a sheet of glass retracts into shell when glass is tapped. After pause, it emerges and continue moving. A second tap causes retraction again but it emerges more quickly. Ultimately, tapping has no effect and snail ceases to respond. It is reversible learning behaviour because after some time this habituation will vanished and snail again will show same response. Imprinting is learning that is limited to as specific time period in animals life and that is irreversible i.e. it remains throughout life.

19.3.5. Classic Conditioning

The animal learns the same response for two different stimuli, which are presented together to the animal is called **classic conditioning**. The most famous experiment of classical conditioning was developed by **Ivan Petrovich Pavlov**. He presented food to the dog and rang the bell simultaneously. After a while, the dog began to salivate at the sound of the bell, whether or not food was available. To begin with, consider a normal stimulus, such as the odor of food; this is likely to elicit salivation in dogs. Food (or its odor) is a highly relevant stimulus; a bell, of course, is not and means nothing to a dog unless something happens that causes the animal to associate the bell with food. In this situation, as classical conditioning begins, the odor is termed the unconditioned stimulus (UCS) and the bell becomes a conditioned stimulus (CS) which produces the conditioned response of salivation. When Pavlov rang the bell (a neutral stimulus-NS) at the same time he presented food (a UCS) and did so repeatedly and consistently, the dog formed an association between the bell and food. (Figure 19.9)

Fig 19.9 Pavlov's Experiment

19.3.6. Instrumental conditioning (Trial and error learning)

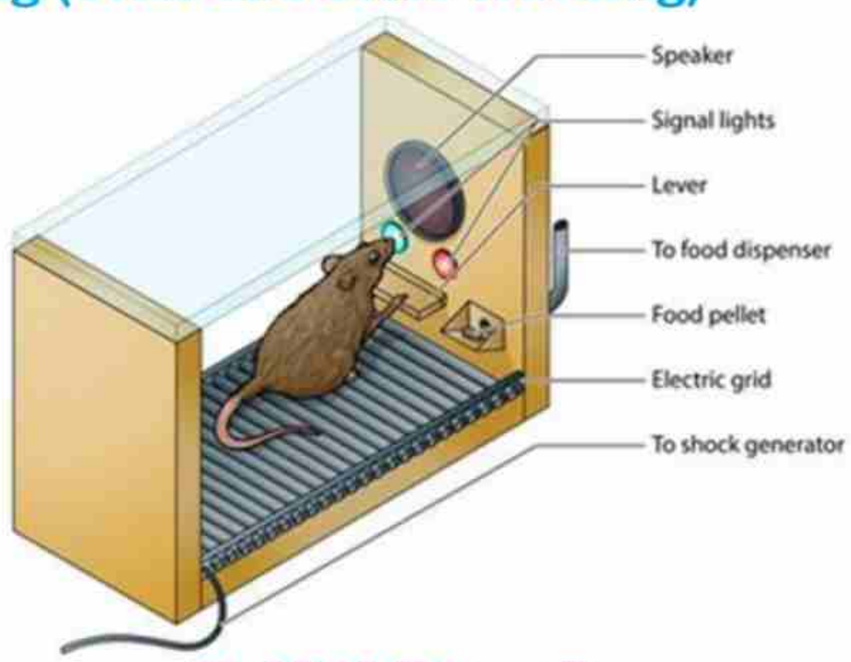


Fig 19.10 Skinner Box

The animal learns while carrying out certain searching actions such as walking and moving about. When the animal finds food during these activities, the food reinforces the behaviour and the animal associates the reward with the behaviour is called operant learning. A classic example of instrument conditioning is that in a 'Skinner box' developed by well-known psychologist **B.F Skinner** (1904-1990). When, he placed rat in the box, the rat began to explore. It moves all about the box and by accident or eventually presses a lever and is rewarded with a food pellet. Because food rewards are provided each time the rat presses the lever, the rat associates the reward with behaviour. Through repetition, the rat learns to press the lever right away to receive the reward. In this type of learning, the animal is instrumental in providing its own reinforcement. Finally, the rat learns to press the lever to obtain food. (Figure 19.10)

19.3.7. Latent Learning

Fig 19.11 Latent Learning

Sometimes animals seem to learn without any obvious immediate reward. For instance, an animal can learn important characteristics of its environment during unrewarded explorations and then use this information later. If food or another reward is provided, the animals suddenly respond quickly to it by previous learning, but remain latent or hidden until an obvious reinforcement is provided called Latent learning. The

American psychologist **K.L. Lashley** used a maze, a rat was put in the maze. The rat explores the maze in order to find the exit. Eventually, the rat found the way to exit but it also learned the location of food in the maze. The rat was not hungry at that time so it did not pay attention to the food. Then the same rat was put in the maze when it felt hungry. The rat, because of its previous experience, found the food quickly than a rat has been put without previous exploratory experience. (Figure 19.11)

19.3.8. Insight Learning

In the insight learning animals use cognitive process, practice or judgment to solve the problem, it is based on trial and error without prior experience. German psychologist **Wolfgang Kohler** in the 1920s performed an experiment on the behaviour of chimpanzees. Kohler placed chimpanzees in a cage, provided several sticks and boxes and hung a bunch of bananas that were out of reach. The chimpanzees first looked at the bananas and tried to reach but they could not reach, after that they thought and observed to solve this problem to reach the bananas. In the first they placed the sticks into another stick to make a long stick that could be used to knock down the hanging bananas. The chimpanzees would also solve the problem by stacking the boxes on top of each other, which allowed them to climb up to the top of the stack of boxes and reach the bananas. This type of learning based on observation Kohler called insight learning. (Figure 19.12)

Fig 19.12 Insight learning

19.4. SOCIAL LEARNING

The interaction between two or more individuals of the same species living together is called social behaviour. The animals live together have its benefits, it can help an animal avoid predators, find food and rear offspring.

19.4.1. Aggregation and Animal Societies

Aggregation is a simple group of animals that may be together due to feeding, drinking or mating but do not interact behaviorally. Fruit flies hovering on a piece of rotting fruit, huge flocks of birds of many species living on trees together, groups of zebra, school of fish are examples of aggregations.

The living organisms are often organized into groups. The group of animals of the same species living together that have cooperative social relationships is called social group or **society**. Social or mutual behaviour is the key characteristic of the society. These are relatively permanent unions of individuals held together by mutual attraction of its members. The basis of social life is the interaction of individual members who exchange food, water, body care and sexual favor

19.4.2. Hostile and helpful intraspecific interaction.

Hostile and helpful interaction seen in many social insects, the best known interaction is observed in the honey bees. In the hive, there are three different castes i.e. workers, drones and queen. In the hostile interaction, the workers become old and unable to perform their duties, furthermore than these workers are killed by other workers. On the other hand, in helpful interaction all castes work together like workers collect nectar and convert into honey, drones are specific to provide defense mechanisms and fertilize the eggs and queen lay eggs.

19.4.3. Agonistic Behaviour

In the society of animals, conflicts arise due to limited resources, such as food, mates or territory; these conflicts are settled by the **agonistic behaviour.** In this behaviour, one animal is aggressive or attacks another animal including threats, rituals and sometimes combat that determine which competitor gains access to the resources. In many species, males show their aggressiveness in the form of signals that warn other males of an intention to defend an area or territory. Agonistic behaviour is important in the maintenance of territories and dominance hierarchies.

19.4.4. Territory

A **territory** is an area or home which is fixed by animals. The size of the territory varies with the species, it is typically used for feeding, mating, rearing young, or combinations of these activities. A territorial animal uses agonistic behaviour to defend their territory against other individuals. For example, a male actively defends his territory against other males so he can attract a female and court her without interference from other males. Once the territory is established through agonistic behaviour then other individuals will not enter in their territory because they will understand through aggressive behaviour that this is an occupied area of other animals. Territorial behaviour is seen in animals as diverse as worms, insects, fish, birds and mammals.

Territorial behaviour in Gorillas

Gorillas are non-territorial social mammals that live in groups (called Troops). Troops consist of 1-4 old and strong males called silverback, some immature males called black backs and several adult and young females. The adult male silverback is usually dominant in the troop and has exclusive breeding rights to the females. The adolescent female transfers from troop to another before reproducing age (about 8 years). The rank of female in the troop is determined by the order of recruits in the troop. Late arrivals in the family do not receive the benefit of high ranking females because having offspring remain close to the silverback male for protection. On the other hand, adolescent male split from his family due to lack of breeding opportunities. Usually, he remains alone until he forms his own family. Silverback is typically more aggressive than other group members because the troop's safety is his responsibility. He does exhibit territorial behaviour by standing upright on their two

Fig 19.13 Mountain Gorilla

legs and profoundly their chest in order to intimate whatever threat he has given. He is dominant over his family, makes all troop's decisions, is responsible for all calls, receives the dominant portion of food and can terminate troublesome behaviour with just a look. (Figure 19.13)

Territorial behaviour in Baboons

The Old World monkeys lack a prehensile tail, and their nostrils open downward. They include mandrills, macaques, rhesus monkeys, and baboons. Many species of old work monkeys are arboreal, but some are ground dwellers such as baboons that live in a troop in their territory. Baboons are dimorphic, the males are larger than the females. They threaten other family members of the troop with their long, sharp teeth (Canines).

Fig 19.14 Baboon

One or more male baboons become dominant by frightening other males. However, the dominant males pay costs for their dominance. Being dominant, it is their responsibility to fight predators and may get hurt and so forth. Baboons travel within a territory, foraging for food the whole day and sleeping in trees at night. Dominant males decide where and when the troop will move. If the troop is threatened, dominant males protect the troop as it retreats and attacks intruders when necessary. Vocalization and displays, rather than outright fighting, may be sufficient to defend a territory. (Figure 19.14)

19.4.5. Dominance hierarchy

A dominance hierarchy describes situations in which animals organized a rank that determine the resources such as access to food, mating, and grooming services of other members in their social group. Individuals at the top of hierarchies often have first access to more food, more mating opportunities, and safer territories than

individuals at the lower end of hierarchies. This relationship between individuals in a group as a result of aggressive behaviors and the response to aggressive behaviors. When aggression occurs in group-living species, and individuals interact with each other many times it can be measured dominance hierarchies.

Pecking order of chicken

Pecking order in chickens is a good example of a dominance hierarchy. When several hens unfamiliar with one another are placed together, they response by fighting, chasing and pecking among themselves until established a clear pecking order. The alpha, or top-ranked, hen in the pecking order is dominant, she is not pecked by any other hens and can usually drive off all the others by threats rather than actual pecking. The alpha hen also has first access to resources such as food, water, and roosting sites. The beta, or second-ranked, hen similarly subdues all others except the alpha, and so on down the line to the omega, or lowest, animal. Once the hierarchy is set, peaceful coexistence is possible and occasionally fights will occur if a hen tries to move up in the order. (Figure 19.15)

Fig 19.15 Chicken exibiting peck order

19.4.6. Altruism (L.: alter, the other)

Many social behaviours are selfish, in which they behave for their own benefits. Behaviours that increase the survival and reproductive success regardless of how much the behaviour may harm others. On the other hand, altruism is a behaviour performed by animals without regard of self-interest. Animals sacrifice some of their own reproductive potential to benefit other members of its society. Altruism behaviour is often found in the social animals. In insect societies, especially, reproduction is limited to only one pair, the queen and her mate.

Altruism in the organization of honeybee society

Honeybees are social insects that live together in an organized group or colony. A colony of honeybee consists of three types of castes i.e. the queen, the workers and the drones. These castes perform specific functions in the colony. The **queen** lays fertilized and unfertilized eggs from which other bees develop. New queen also develops from the fertilized egg, the larva of the queen feeds on the special food called (**Royal jelly**). The old queen and new developed queen may both be present in the hive for some time. Then, the new queen to emerge may be killed by the other members of the colony and assume the same rule or may create a swarm and leave the colony to establish the new hive. On the other hand, the old queen and swarm of females and drones leave to establish a new hive or accidentally killed, lost, or removed from the hive. The **drones** are male bees that develop form the unfertilized eggs. The main function of the drones is to fertilize the queen during her mating flight. But unfortunately they die after mating. The **workers** are sterile females (non-reproductive) developed from the fertilized eggs. The workers are relatively small in size but the greater number in the colony. The workers perform all the labor of the hive such as cleaning and polishing the hive, building beeswax combs, forage for nectar, care for the queen and guard the entrance. Even though sterile female workers spend their lives feeding and looking after their other members of the colony, they are prevented producing offspring. (Figure 19.16)

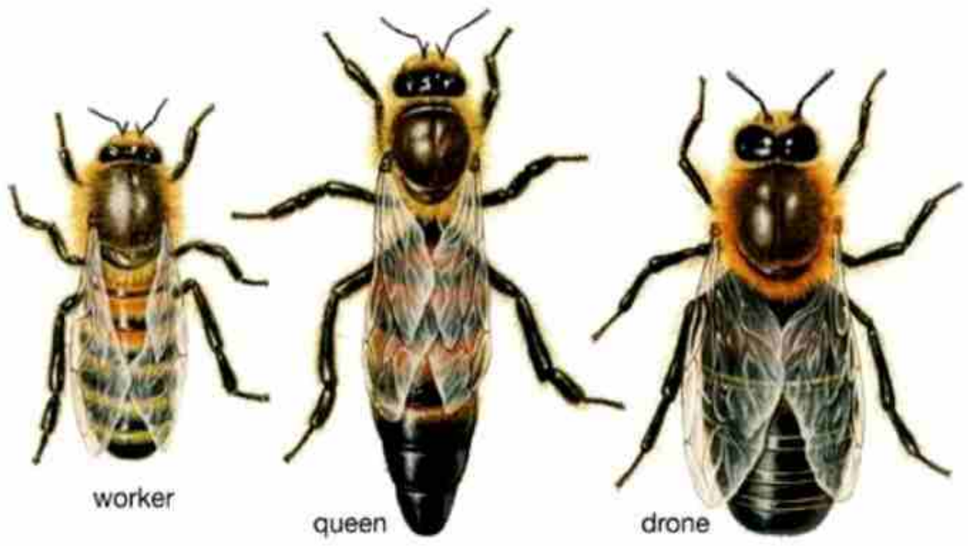


Fig 19.16 Honeybee (Apis mellifera)

SUMMARY

- All the activities performed by animals in response to stimuli called behaviour.
- The scientific study of animal behaviour is called Ethology.
- The stimulus is any detectable change (physical or chemical) in the environment of an organism. The behaviour of animals is depend upon the nerve impulse, hormones and physiological mechanisms.
- The internal mechanisms by which internal phenomenon occur without external stimuli is called the biological clock.
- Innate behaviour may be defined as the behaviour of an organism performed at the time of birth in response to stimuli without prior experience, it is inherited behaviour.
- Kinesis (plural, kineses; from the Greek word for "movement") is a simple form of orientation, in which the animal's response is proportional to the intensity of stimulation.
- Taxis is a directional movement toward or away from the particular stimulus (e.g. light, heat), if the response is movement toward the stimulus.
- The Instinct or instinctive (innate or inborn behaviour) is an inherited behaviour pattern that does not require learning or practice.
- Learning behaviour is a change in the behaviour of animals resulting from the experience.
- In habituation, the animals stop or ignore the response to an irrelevant stimulus.
- Imprinting is a type of learning behaviour in which animals fix their attention on the first moving object after birth and thereafter follows that object.
- An animal can learn important characteristics of its environment during unrewarded explorations and then use this information later is called latent learning.
- In insight learning, animals use cognitive process, practice or judgement to solve the problem, it is based on trial and error without prior experience.

EXERCISE

1. Encircle the correct choice.

i) The decrease in response to repeated or continuous stimulation is called
(a) Insight (b) Habituation
(c) Maturation (d) Instinct

ii) The cyclic physiological patterns of activities in an organism that are in response to periodic environmental changes is called
(a) Biological Clock (b) Biological rhythms
(c) Circadian rhythms (d) All of Above

iii) A directional movement of an organism toward or away from the particular stimulus is called
(a) Kinesis (b) Taxis
(c) Reflex (d) Fixed Action Pattern

iv) Simplest form of learning, in which the animals learn not to respond or ignore to a repeated, irrelevant stimulus.
(a) Imprinting (b) Kinesis
(c) Habituation (d) Fixed Action Pattern

v) Which one of the following is not an instinct behaviour?
(a) Migration of Salmon Fish (b) Dances of bees
(c) Territorial behaviour in Gorillas (d) Nest building by birds

vi) Wolfgang Kohler in 1920s performed the experiment on the behaviour of
(a) Rats (b) Chimpanzees
(c) Graylag Goose (d) Dog

vii) Workers (honey bee) are
(a) Fertile Females (b) Fertile Male
(c) Sterile Female (d) Sterile Male

viii) Agonistic behaviour is the type of
(a) Innate Behaviour (b) Learning behaviour
(c) Social Behaviour (d) Instinctive behaviour

ix) Migration of Salmon Fish is the example of
(a) Orientation behaviour (b) Learning behaviour
(c) Social Behaviour (d) Instinctive behaviour

x) Skinner box was used for
(a) Classic Conditioning (b) Operant Learning
(c) Latent Learning (d) Insight Learning

2. Write short answer of the following questions:

i) Define stimuli. How organisms respond to different stimuli?
ii) What is reflex? Give three examples of reflexes in vertebrates.
iii) What is the relationship between heredity and behaviour?
iv) Define biological rhythms. How are biological rhythms important to man?
v) What do you know about taxis? Give examples of positive taxis and negative taxis.
vi) What is the difference between innate behaviour and learning behaviour?
vii) How do bees communicate about food sources?
viii) How do old word monkeys defend their territory?

3. Write detailed answers of the following questions

i) Define innate behaviour in term of reflexes shown by vertebrates and invertebrates
ii) Describe the construction of an intricate web by a spider as instinct behaviour.
iii) What is imprinting? Describe the imprinting in young ducks. How is it adaptive?
iv) Describe the agonistic behaviour and relate it with the maintenance of social order in terms of territories and dominance hierarchies.

REPRODUCTION

Chapter 20

Major Concept

In this Unit you will learn:

- Human Reproductive System
- Disorders of Reproductive System
- Sexually Transmitted Diseases

We know that living things come from other living things and only life beget life. The older ones are called parents and the newly formed are called **progeny**. The process by which living things produce more of their own kind is called **reproduction**. Reproduction is not only vital for the life of an organism itself but it is much more important for the continuity of its race. It is the process of continuation of life with a fresh start. It performs yet another important function of transmission of genetic information from one generation to the next.

Through natural selection, over millions of years, a variety of ways evolved in which organisms reproduce their own kinds. There are, however two main ways. Asexual reproduction which requires only one parent and sexual reproduction which requires two parents.

Asexual reproduction is the primitive method of reproduction by which a new organism is formed from just one parent without the participation of mate, gamete or fertilization. The offspring produced by this method are the exact copies and thus identical to their parents and no variations are seen because all the offspring are genetically identical to their parents.

Sexual reproduction involves sex cells, the gametes. A male gamete, the sperm, fused with a female gamete, the ovum, to form zygote which undergoes development and a new individual is formed. Sexual reproduction leads to genetic diversity and adaptability. Alternatively, asexual reproduction allows a single parent to generate genetically identical or similar offspring without specialized reproductive cells. The reproductive process involves stages such as gametogenesis, mating, fertilization, embryonic development, and the birth or hatching of new individuals. Hormones, cellular differentiation, and morphological changes regulate these events.

20.1 HUMAN REPRODUCTIVE SYSTEM:

The human reproductive system is a complex network of organs and tissues that work together to facilitate reproduction. Human beings are **unisexual** or **dioecious** or **heterophrodite**, they are either male or female having testes and ovaries respectively in body, each with distinct structures and functions that contribute to the reproductive process. The male reproductive system generates and delivers sperm to the female reproductive system, while the

female reproductive system produces and prepares eggs for fertilization and provides support for fetal development during pregnancy.

20.1.2 Male reproductive system

The male reproductive system consists of internal and external genitalia, internal genitalia includes, the paired gonads (organs that produce sex cells), the testes (singular, testis) where sperms are produced, and accessory structures that store the sperm, produce secretions that activate and nourish them. The penis and scrotum are the external genitalia.

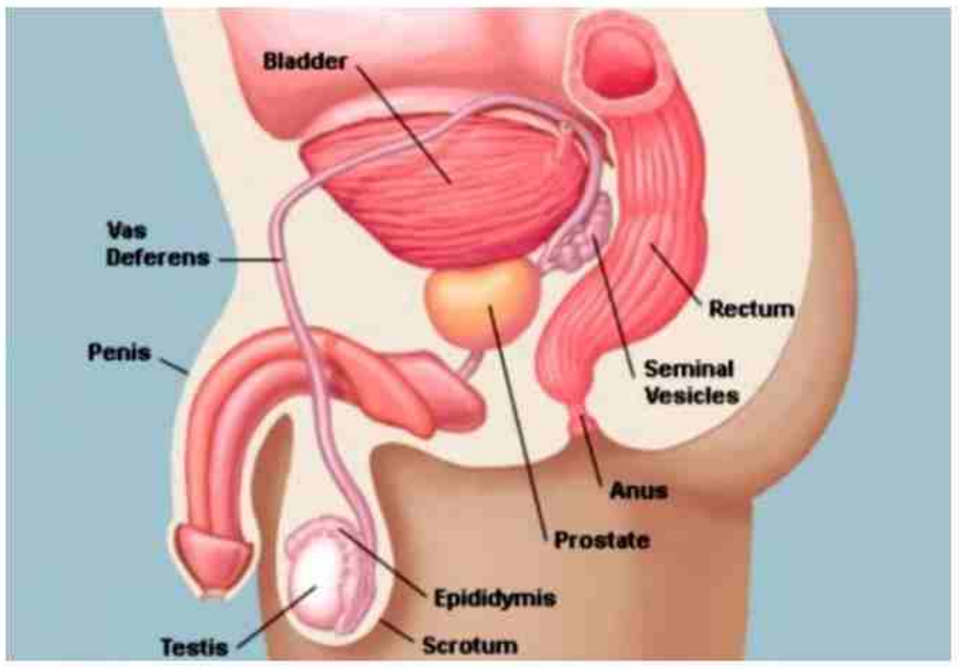


Fig. 20.1
Human male reproductive system

Gonads (testes)

The testes produce both sperm and male sex hormones. Though they develop inside the abdomen but come to lie, before birth in scrotum a pouch of skin located outside of the abdomen between the thighs. Since the sperms are unable to develop at body temperature. The scrotum maintains the testes at around 34°C, slightly lower than the body temperature (37 °C).

The **testis** is composed of lobules, which contain tightly coiled seminiferous tubules,

Fig. 20.2 Anatomy of testis

which make up most of each testis. The sertoli cells in the tubules responsible for the production of sperm, process of sperm production is called **spermatogenesis**.

Accessory ducts

Sperm cells move towards the **epididymis** through the **rete testis** after being produced in the seminiferous tubules. The epididymis and rete testis are connected by a network of tubes known as the **efferent ducts**. Sperm cells are kept in the epididymis until they are ready for ejaculation and are fully developed. **Ductus deferens** or **vas deferens** is a thick-walled tube that carries sperm from the epididymis, where the sperm are stored before being released during ejaculation. Each ductus deferens has an ampulla, which is an expanded part that serves as a reservoir. **Ejaculatory duct** one of two hollow tubes created by joining the excretory duct of a **seminal vesicle** and the ampulla of a ductus deferens. The ducts serve to combine the sperm deposited in the ampulla with the fluids generated by the seminal vesicles and transfer these substances to the prostate. They enter into the urethra about halfway through the prostate gland. The urethra also called **urinogenital duct** is a common tube for the urinary and reproductive discharge.

> Testicular cancer is the most common type of cancer in young men between the ages of 15 and 34, but it has a high cure rate with early treatment.

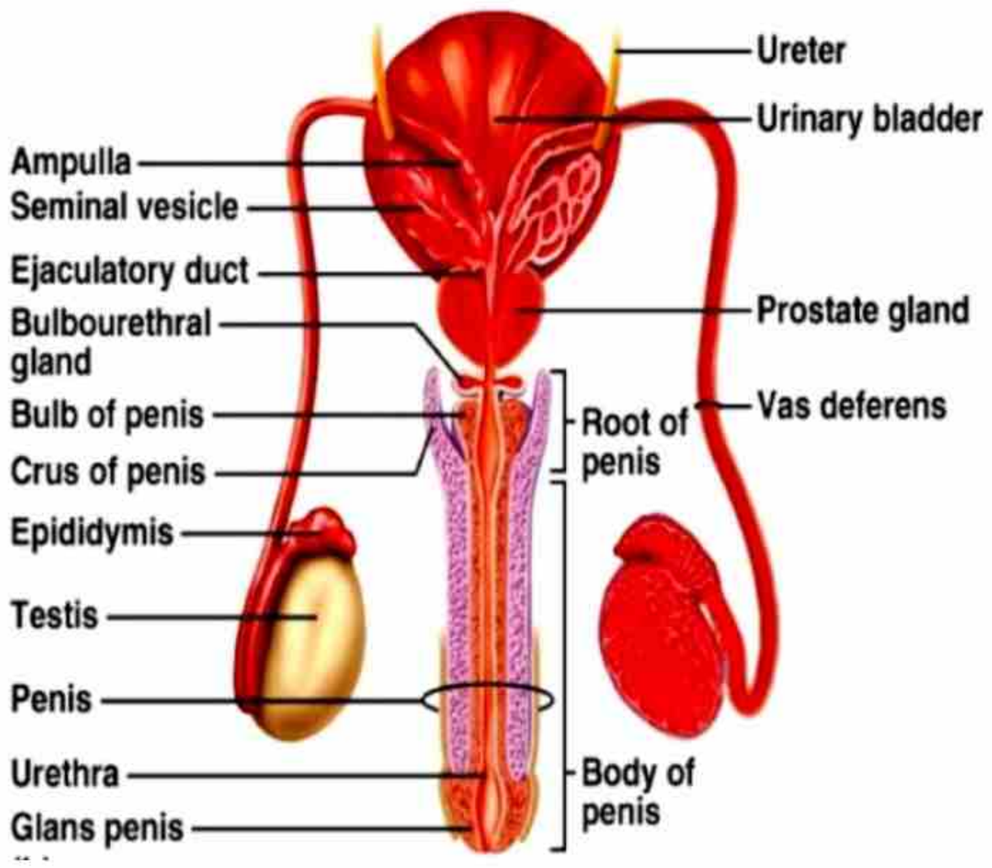


Fig. 20.3 Human male duct system

Penis: The male external genitalia and copulatory organ consists of **Glans** or head or tip of penis, the glans is very sensitive and contains the opening of the urethra. In some men, a fold of skin that called the

foreskin may cover the glans. **Shaft** Contains layers of erectile tissues. **Root** is where the penis attaches to the pelvic area. **Scrotum:** The male external genitalia, like penis. It protects the testes and keeps them at a temperature several degrees below the normal body temperature.

Three sets of accessory glands (the seminal vesicles, prostate and bulbourethral glands). A pair of **seminal vesicles** contributes about 60% of total volume of semen. The **prostate gland** is the largest of the semen-producing glands. It secretes its products directly into the urethra. The **bulbourethral glands** are a pair of small glands along the urethra below the prostate. Before ejaculation they secrete clear mucus that neutralizes any acidic urine remaining in the urethra.

> Each ejaculation of human male averages between 2 and 5 ml. Normally it contains 200 to 300 million sperms

Table 20.1 Male Reproductive System and its Physiology

Organ	Function
Testes	Produce sperm and sex hormones
Epididymides	Sites of maturation and some storage of sperm
Vasa deferentia	Conduct and store sperm
Seminal vesicles	Add fluid to semen
Prostate gland	Add fluid to semen
Urethra	Conducts sperm (and urine)
Bulbourethral glands	Add fluid to semen

Spermatogenesis: The Process of Sperm production is called spermatogenesis. It takes place within the seminiferous tubules, found within the testes. Let's explore the stages of spermatogenesis and unravel the intricacies of this essential biological process.

The journey begins with undifferentiated germ cells called **spermatogonia (2n).** These cells undergo mitosis to produce identical daughter cells, ensuring a continuous supply of cells for future development. Spermatogonia, triggered by hormonal signals, transform into **primary spermatocytes (2n)**. During this phase,

each primary spermatocyte undergoes DNA replication, resulting in two identical sets of chromosomes.

Meiosis I: This critical phase involves the division of primary spermatocytes into **secondary spermatocytes (n)**. Meiosis I reduce the chromosome number by half, ensuring genetic diversity in the resulting sperm cells.

Meiosis II: Secondary spermatocytes undergo further division in meiosis II, yielding four haploid cells known as **spermatids (n)**. Each spermatid contains half the number of chromosomes as the original primary spermatocyte.

Spermatids undergo a dramatic transformation in **spermiogenesis**, as they morph into mature **sperm cells**. This intricate process involves the reshaping of the nucleus, the formation of the **acrosome** (containing enzymes crucial for fertilization), and the development of the flagellum, which enables sperm motility. Finally, the fully developed sperm cells, called spermatozoa, are released into the lumen of the seminiferous tubules. From there, they continue their journey through the epididymis, where they acquire the ability to swim and gain the necessay maturity for fertilization.

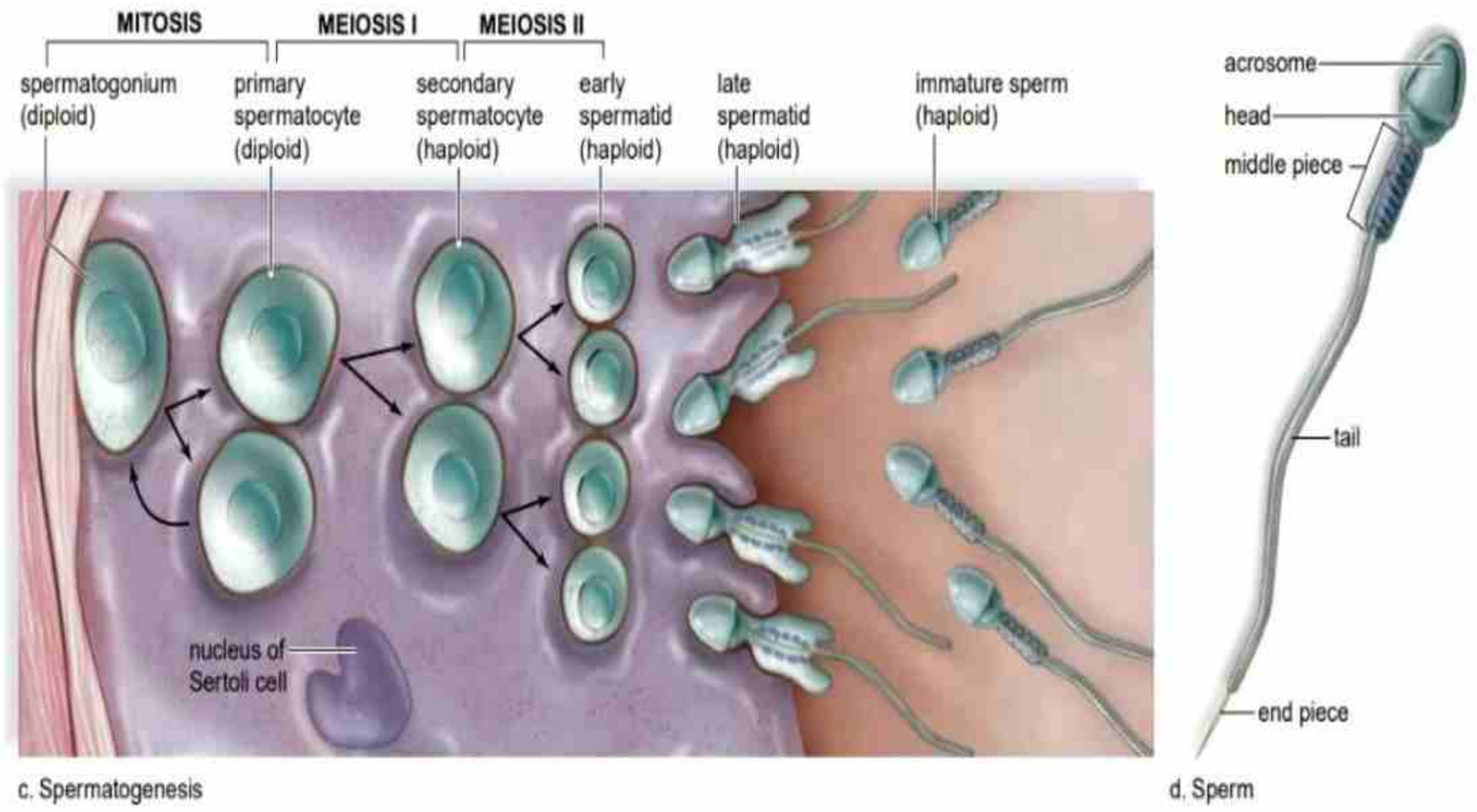


Fig. 20.4 Spermatogenesis

20.1.2 Hormonal Regulation in Males

Reproductive system of male maintains and regulates its functions through certain hormones. The main hormones involved in the male reproductive system are testosterone, follicle-stimulating hormone (**FSH**), luteinizing hormone (**LH**), inhibin and gonadotropin-releasing hormone (**GnRH**). Let's explore the hormonal role in the male reproductive system:

Testosterone: Testosterone is the primary male sex hormone produced by the testes. It plays a crucial role in the development and maintenance of male reproductive tissues, including the testes, prostate gland, and seminal vesicles. It is responsible for the development of male secondary sexual characteristics, such as facial and body hair growth, deepening of the voice, and muscle mass development. It also stimulates the production of sperm.

Follicle-Stimulating Hormone (FSH): FSH is produced by the pituitary gland and acts on the testes. In males, it promotes the development and maturation of sperm cells within the seminiferous tubules of the testes. It also stimulates the production of proteins necessary for sperm production.

Inhibin: A peptide hormone, release from sertoli cells of testes, which inhibits the secretion of follicle stimulating hormone.

Luteinizing Hormone (LH): LH is also produced by the pituitary gland and acts on the testes. In males, it stimulates the production of testosterone by the **Leydig cells** in the testes. It triggers the release of testosterone into the bloodstream.

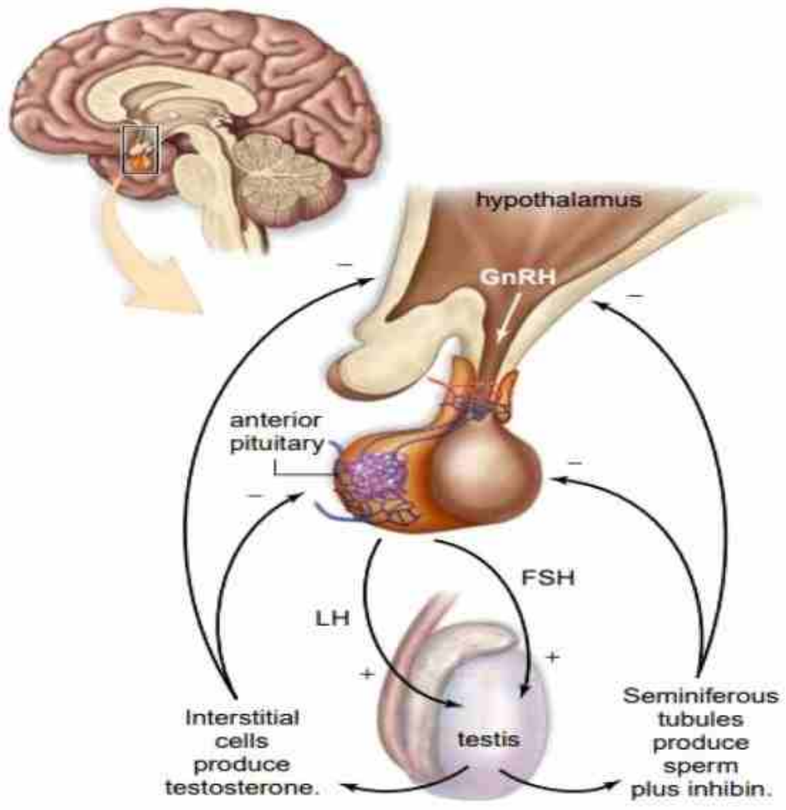


Fig. 20.5
Hormonal control of male reproductive system

Gonadotropin-Releasing Hormone (GnRH): GnRH is produced in the hypothalamus of the brain. It stimulates the release of FSH and LH from the pituitary gland. GnRH secretion is regulated by a negative feedback loop, where low levels of testosterone stimulate the release of GnRH, leading to increased production of FSH and LH, which in turn stimulates testosterone production. As testosterone levels rise, they inhibit the release of GnRH, resulting in a decrease in FSH and LH production.

20.1.3 Female reproductive system

The female reproductive system comprises four main parts: the ovaries, oviducts, uterus, and vagina.

Gonads (Ovaries)

The female ovaries lie in the abdominal cavity, flanking, and attached with a mesentery to, the uterus. Each ovary is enclosed in a tough protective capsule and contains many follicles. A follicle consists of one egg cell surrounded by one or more layers of follicle cells, which nourish and protect the developing egg cell. Each female ovary potentially contains 200,000 follicles. Formed before her birth, of these, only several hundred will release egg cells during the female reproductive years. Starting at puberty and continuing until menopause, usually one follicle matures and releases its egg cell during each menstrual cycle. The cells of the follicle produce female sex hormone called **estrogen**.

Oviducts (fallopian tube or uterine tube)

The female duct system begins with the **oviduct**. The open end of the oviduct is fringed with ciliated "fingers" called **fimbriae** that nearly surround the ovary. It has cilia on the inner epithelial linings they are where fertilization typically takes place and where the ovulated oocyte is received. The oviducts, which carry eggs from the ovary to the uterus, are each around 10 cm long.

Uterus

The uterus or womb is a muscular organ with an inverted pear form that lies between the bladder and the rectum. The uterus has three major regions: The **fundus**, the **body** and the **cervix**. The body,

the main portion of the uterus, starts below the level of the fallopian tubes and continues downward until the uterine walls and cavity start to narrow. The lowest section, the cervix, extends downward from the isthmus until it opens into the vagina. The uterine wall is composed of three layers which are endometrium, myometrium and perimetrium. The **endometrium** is the inner epithelial layer, along with its mucous membrane it is richly supplied with blood vessels. The **myometrium** is the middle muscular layer of the uterine wall. The **perimetrium** is the outermost thin layer covers the uterus. The **cervix** is a narrow opening provides passage between the vaginal cavity and the uterine cavity.

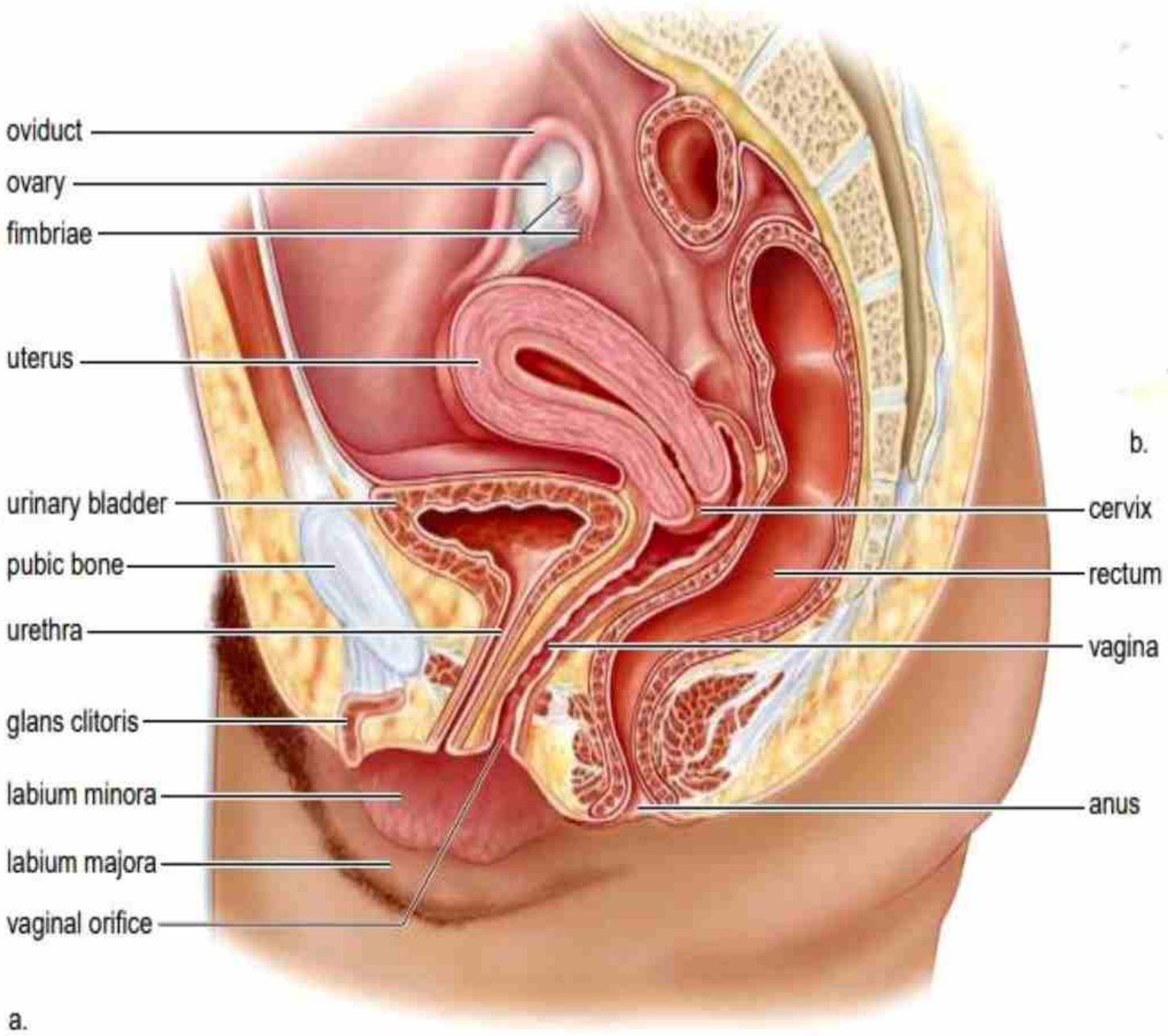


Fig. 20.6 Female reproductive system

Vagina

The **vagina** is muscular tube used for the reception of sperms and delivery of foetus so called **birth canal**.

Table 20.2 Female Reproductive system and its physiology

Organ	Function
Ovaries	Produce egg and sex hormones
Oviducts (fallopian tubes)	Conduct egg; location of fertilization
Uterus (womb)	Houses developing embryo & fetus
Vagina	Receives sperm & serves as birth canal
Ovaries	Produce egg and sex hormones
Oviducts	Conduct egg; location of fertilization

20.1.4 The Ovarian Cycle

Human females do not undergo a seasonal oestrous cycle as lower mammals do, instead one egg is released from an ovary once about every 28 days. This is often called **ovarian cycle**.

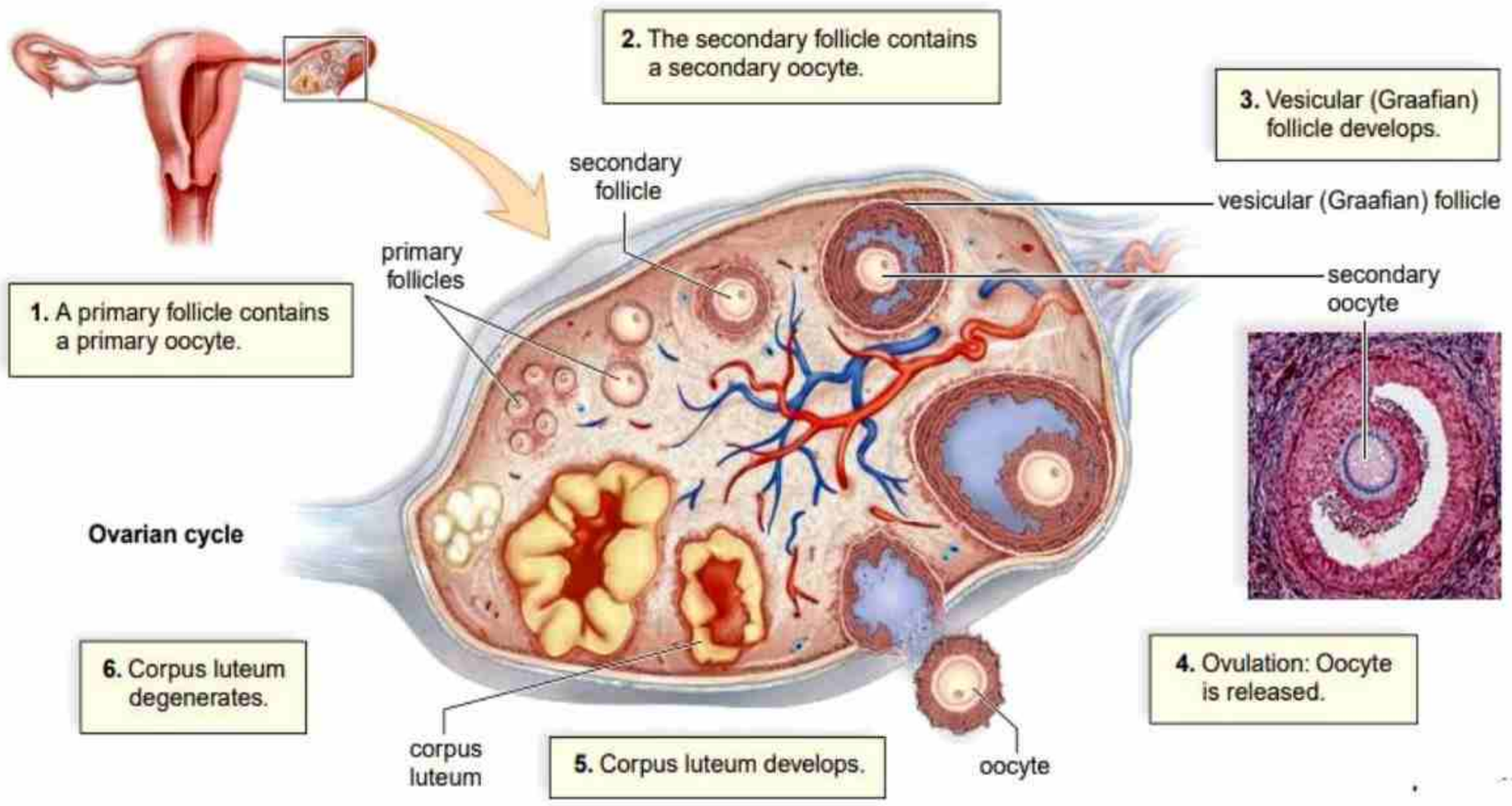


Fig. 20.7 Ovarian cycle

Ovarian cycle includes changes in ovarian follicles to secondary follicle and finally to a **vesicular** or **Graafian follicle**. It is under the regulation of follicle-stimulating hormone (**FSH**) and luteinizing hormone (**LH**) which are secreted by the anterior pituitary gland. The primary follicle is comprised of a primary oocyte that is enveloped by epithelial cells. On the other hand, the secondary follicle is characterized by the presence of follicular fluid pools that surround the oocyte. The vesicular follicle is characterized by the presence of a cavity that is filled with fluid, which gradually increases in size until the follicle wall protrudes outwardly on the surface of the ovary.

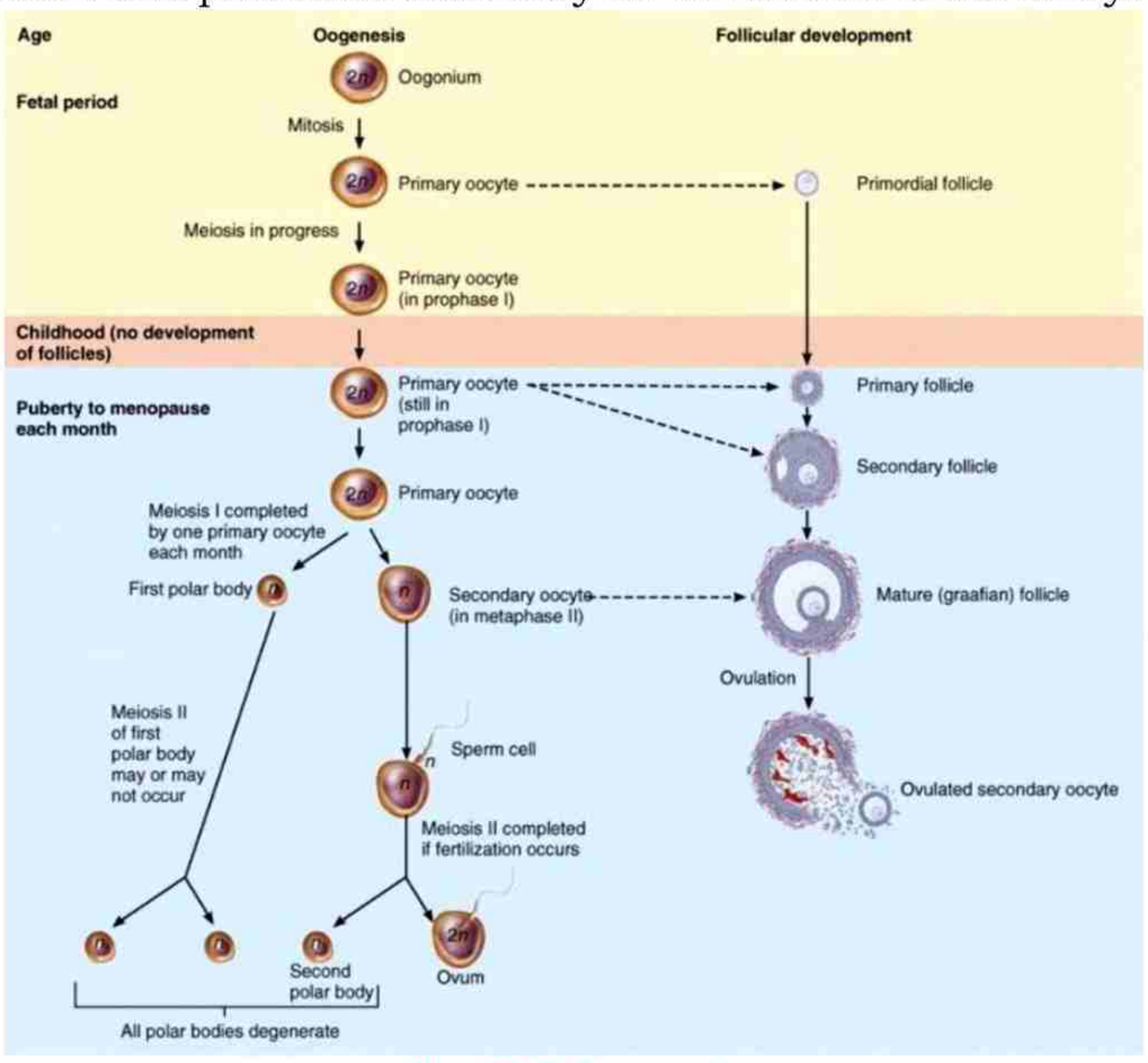


Fig. 20.8 Oogenesis

Oogenesis

It is a process of cell division by which ova (egg) are formed from germ cells present in the female gonads, the ovaries. Germs cells in ovary divide mitotically to form **oogonia** (2n) which develop into **primary oocyte** (2n). The latter undergo first meiotic division to

form two unequal cells, a larger **secondary oocyte** (n) and a smaller **polar body** (n). The expulsion of the secondary oocyte occurs simultaneously with ovulation, which is triggered by the rupture of the graafian follicle release of the secondary oocyte, the graafian follicle undergoes transformation into a glandular tissue known as the **corpus luteum**.

After ovulation, the secondary oocyte travels to the oviduct. If fertilization occurs, a sperm penetrates the secondary oocyte and triggers the completion of meiosis, resulting in the formation of **mature egg** and a second polar body. The egg contains 23 chromosomes. When the sperm (n) and egg (n) nuclei unite, they form a **zygote** (2n) with 46 chromosomes. However, if fertilization and pregnancy do not occur, the corpus luteum begins to degenerate.

The Uterine Cycle: The uterine cycle, influenced by the hormones estrogen and progesterone, involves a series of cyclic changes in the endometrium of the uterus. In the first phase (days 1-5), low hormone levels lead to the shedding of the endometrium, resulting in menstrual bleeding. From days 6-13, higher estrogen levels stimulate the growth of the endometrium in the proliferative phase. Ovulation typically occurs on day 14. From days 15-28, increased progesterone from the corpus luteum causes the endometrium to thicken and mature in the secretory phase, preparing for potential implantation. If pregnancy doesn't occur, hormone levels decrease, leading to the breakdown and shedding of the endometrium during menstruation.

Table 20.3 The Ovarian & Uterine Cycle Events

Ovarian Cycle	Events	Uterine Cycle	Events
Follicular phase— Days 1–13	FSH Follicle maturation Estrogen	Menstruation— Days 1–5	Endometrium breaks down
Ovulation— Day 14*	LH spike	Proliferative phase—Days 6–13	Endometrium rebuilds
Luteal phase— Days 15–28	LH Corpus luteum Progesterone	Secretory phase— Days 15–28	Endometrium thickens and glands are secretory

Menstrual cycle

The menstrual cycle is a complex physiological process that occurs in reproductive-aged individuals with uteruses. It involves a series of hormonal changes and physiological events that prepare the body for possible pregnancy. The cycle typically lasts around 28 days, although variations in cycle length are common.

The menstrual cycle is primarily regulated by four key hormones: follicle-stimulating hormone (FSH), luteinizing hormone (LH), estrogen, and progesterone.

Menstruation Phase (days 1-5)

Menstruation start with bleeding that is the discharge of blood and debris of discarded tissues of the uterus through vagina. Menstruation takes place when the body becomes aware chemically that no fertilization or pregnancy has occurred following the last ovulation. The progesterone secretion is stopped by corpus luteum and as a result, the soft spongy vascular lining of uterus called endometrium breaks off and starts flowing along with blood, out of vagina in the form of menstrual flow. The first day of menstrual flow is taken as the beginning of menstrual cycle. The stage lasts about five days and extends from day 1 to day 5.

Proliferative/pre-ovulatory phase (days 6-14)

During the initial days of the menstrual cycle, the increase in follicle stimulating hormone (FSH) leads to the stimulation of a few ovarian follicles. These follicles engage in a competitive process to establish dominance. Consequently, all the follicles, except for one, cease to grow and eventually disintegrate through a process known as follicle atresia. Meanwhile, a single dominant follicle in the ovary continues to mature and develops into a mature follicle (also known as a Graafian or vesicular follicle), where oogenesis takes place.

FSH also induces the Graafian follicle to produce estrogen, which plays a crucial role in regulating the blood supply to the inner lining of the uterus known as the endometrium. As a result, the endometrium becomes lush, thick, and well supplied with blood vessels. Ordinarily, cervical mucus is dense and adhesive, but increasing levels of estrogen cause it to become more fluid and transparent, forming pathways that assist the movement of sperm

through the cervix and into the uterus. Estrogen exerts negative feedback on FSH, resulting in a decrease in FSH levels as estrogen concentration rises. This decrease in FSH serves as a signal for the pituitary gland to release LH.

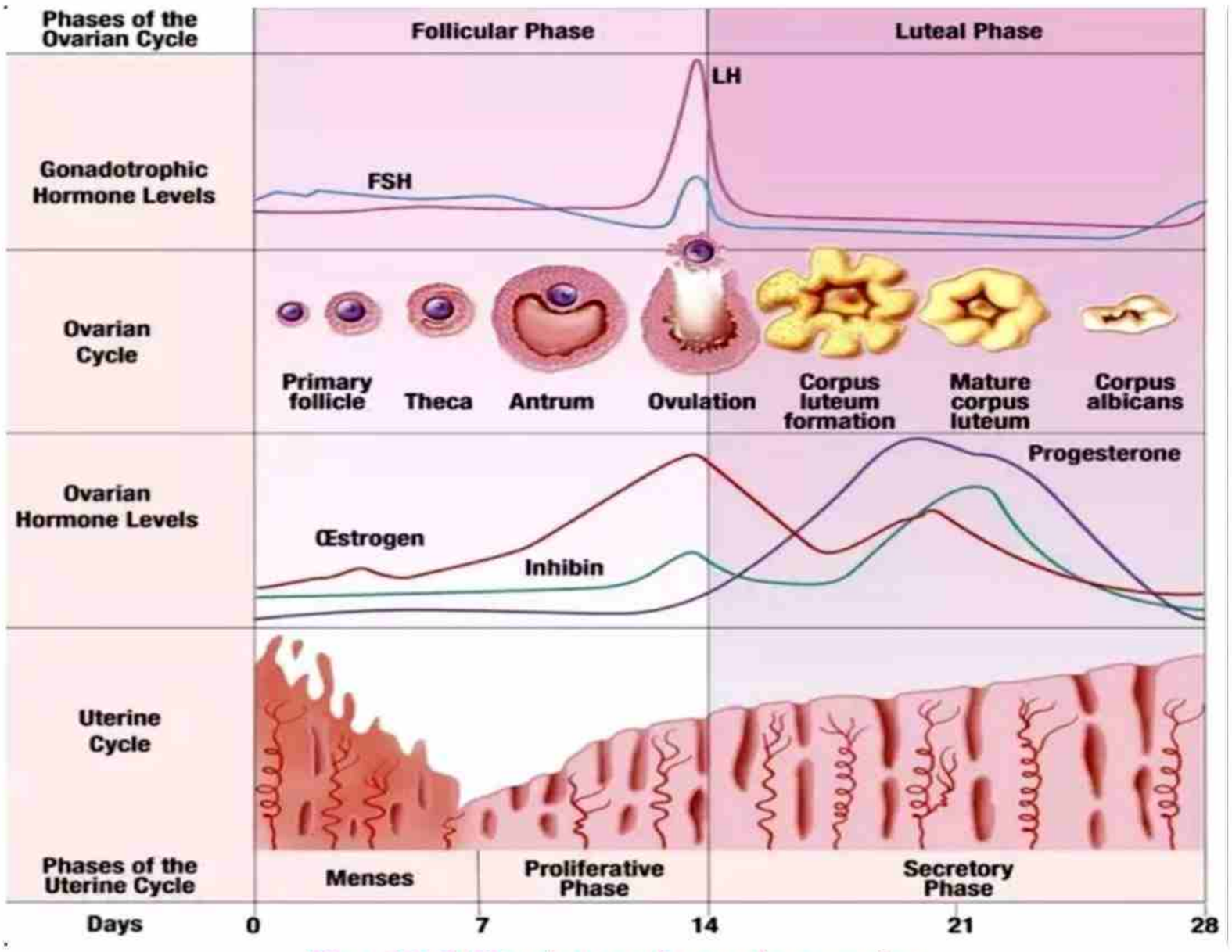


Fig. 20.9 Uterine and ovarian cycles

Towards the end of the proliferative stage, when LH is suddenly released from the anterior pituitary, it triggers the release of a developing egg from the mature follicle into the oviduct. This event, known as ovulation, typically occurs within a span of less than five minutes. Additionally, LH converts the ruptured follicle into a yellowish glandular mass known as the corpus luteum.

Secretory / Post ovulatory phase (days 15- 28)

The secretory phase, also known as the post-ovulatory phase, is the third phase of the menstrual cycle. It follows the proliferative phase (or follicular phase) and occurs after ovulation has taken place. The secretory phase is primarily regulated by the hormone

progesterone, which is produced by the corpus luteum, a temporary structure formed in the ovary after the release of an egg.

During this phase, the lining of the uterus (endometrium) thickens in preparation for a possible pregnancy. Progesterone promotes the growth and development of blood vessels and glands in the endometrium, making it a suitable environment for a fertilized egg to implant and develop into an embryo. The glands in the endometrium also produce nutrients that can support the early stages of pregnancy.

If fertilization and implantation do not occur, the corpus luteum begins to regress, leading to a decline in progesterone levels. This drop in hormone levels causes the endometrium to start breaking down, leading to the start of the menstrual period and the beginning of a new menstrual cycle.

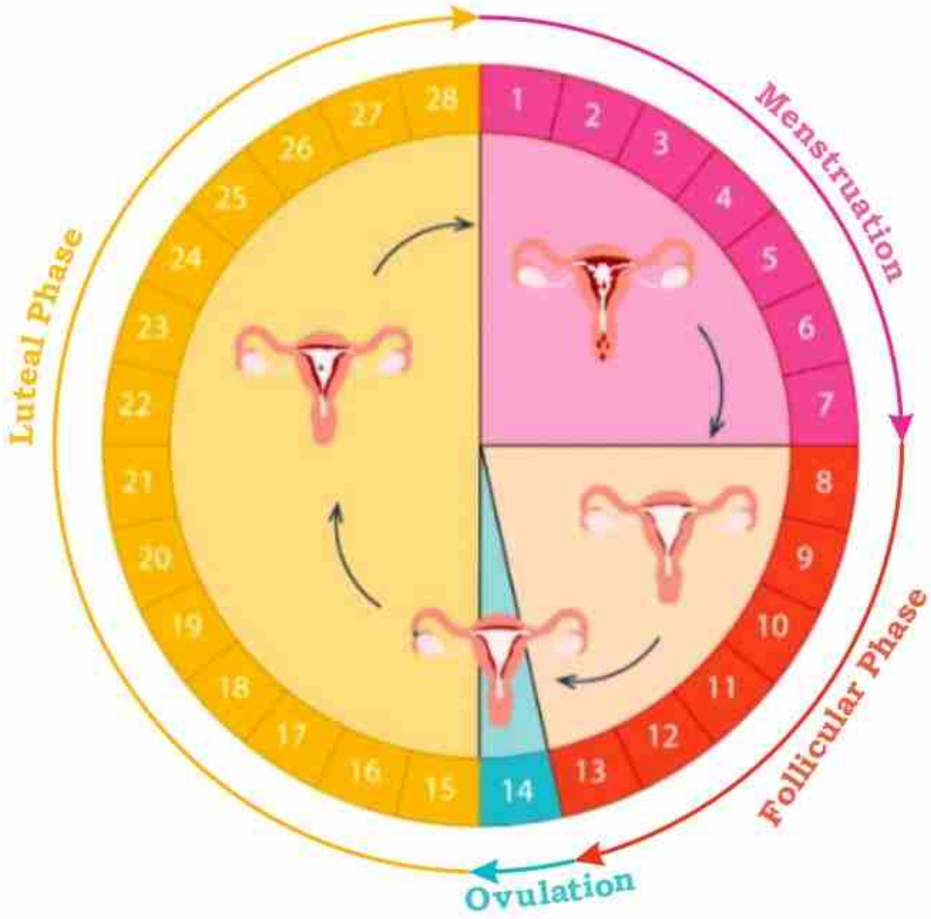


Fig. 20.10 Menstrual cycle

Fertilization and pregnancy:

After fertilization, the embryo undergoes development and migrates through the oviduct towards the uterus. The embryo then implants itself in the prepared endometrial lining of the uterus.

The placenta, which is formed by both maternal and embryonic tissues, serves as a discoid organ and facilitates the exchange of gases and nutrients between the fetal and maternal circulations. Initially, the corpus luteum, a temporary structure formed in the ovary after ovulation, is sustained by human chorionic gonadotropin (HCG) produced by the placenta. Later on, the placenta takes over the production of progesterone and estrogen.

Progesterone and estrogen have dual functions, inhibiting the activity of the anterior pituitary gland to prevent the maturation of new

follicles and sustaining the endometrial lining of the uterus, thus eliminating the need for the corpus luteum. During pregnancy, menstruation ceases to occur

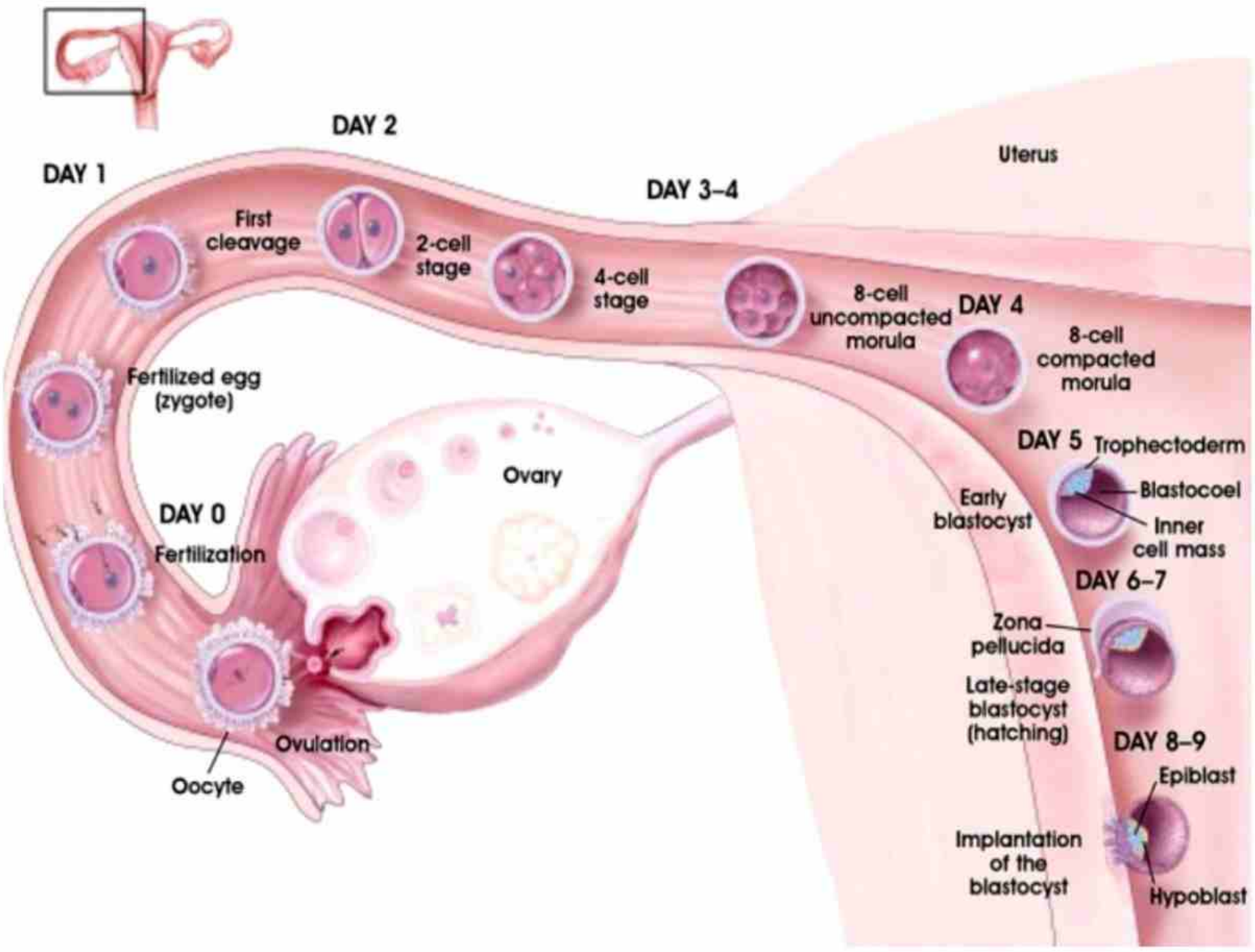


Fig. 20.11 Fertilization and implantation

Estrogen and progesterone

The hormones estrogen and progesterone play a crucial role in the proper development and functioning of the female reproductive system, as well as in the manifestation of secondary sexual characteristics. Estrogen is a vital hormone that plays a pivotal role in the development of female reproductive organs and is accountable for the manifestation of female body characteristics, including the distribution of body hair and fat, as well as breast development. The female body typically exhibits a curvaceous physique in comparison to the male body, primarily due to the increased deposition of

subcutaneous adipose tissue and a wider pelvic girdle. The hormone progesterone is a requisite factor in the process of breast development.

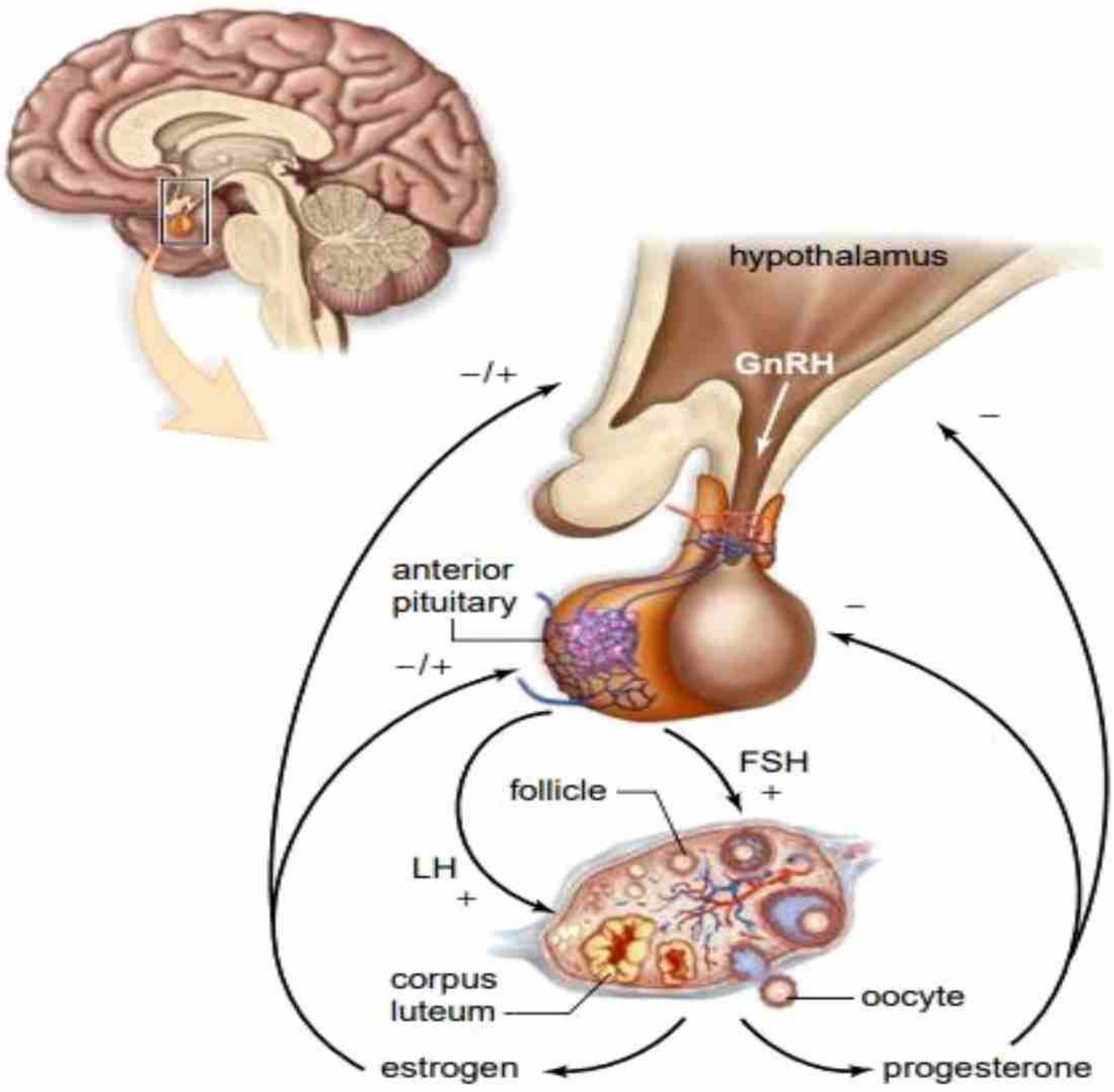


Fig. 20.12 Hormonal Control of Female Reproductive System

20.2 DISORDERS OF REPRODUCTIVE SYSTEM:

The human reproductive system is a complex network of organs and hormones that work together to ensure proper reproduction. However, various disorders can affect the functioning

of the male and female reproductive systems, leading to infertility, sexual dysfunction, and other health problems. These disorders can be caused by genetic, environmental, or lifestyle factors, and can affect people of all ages. As experts in the field of reproductive biology, it is important to understand the various disorders that can occur and their underlying causes, in order to develop effective treatments and preventative measures. In this chapter, we will explore the most common disorders of the male and female reproductive systems, including their symptoms, diagnosis, and treatment options.

Infertility

Infertility is the inability to conceive a child after one year of regular, unprotected sexual intercourse. It can affect both males and females.

20.2.1 Causes of Male Infertility

a) Abnormal Sperm Production or Function:

A microscopic examination of the semen is typically used to determine the sperm's **quantity**, **concentration**, **motility**, and **morphology** (form). The total amount of sperm in the ejaculate is known as the sperm count; counts can vary greatly, but numbers below 20 million are typically regarded as low. **Oligospermia** is the common name for low sperm count. A disease known as **azoospermia**, which results in a complete lack of spermatozoa in the ejaculate, can sometimes be the cause of male infertility.

b) Ejaculation Disorders:

Problems with ejaculation, such as retrograde ejaculation (semen entering the bladder instead of being expelled), or erectile dysfunction can result in infertility.

c) Obstruction:

Blockages in the male reproductive tract, such as congenital absence of the vas deferens or scarring from previous infections or surgeries, can prevent the transport of sperm.

d) Lifestyle Factors:

Certain lifestyle choices can contribute to male infertility, including excessive alcohol consumption, smoking, drug use, obesity, exposure to environmental toxins, or prolonged exposure to high temperatures (e.g., saunas or hot tubs).

20.2.2 Causes of Female Infertility:

a) Ovulation Disorders:

Irregular or absent ovulation can prevent the release of eggs necessary for fertilization. This can be caused by hormonal imbalances, polycystic ovary syndrome (PCOS), thyroid disorders, or premature ovarian failure.

b) Fallopian Tube Blockage:

Blockages or damage to the fallopian tubes can hinder the transport of eggs and sperm, making fertilization difficult or impossible. Common causes include pelvic inflammatory disease, endometriosis, or previous pelvic surgeries.

c) Uterine or Cervical Issues:

Abnormalities in the uterus or cervix can interfere with implantation of a fertilized egg or affect the passage of sperm. Conditions such as uterine fibroids, polyps, or cervical stenosis can contribute to infertility.

d) Endometriosis:

This condition occurs when the tissue lining the uterus grows outside of the uterus, often affecting the ovaries, fallopian tubes, and other pelvic organs. Endometriosis can cause inflammation, scarring, and structural abnormalities, leading to fertility problems.

e) Age-related Factors:

As women age, the quality and quantity of their eggs decline, making it more challenging to conceive. Advanced maternal age is associated with a higher risk of infertility and pregnancy complications

20.2.3 In Vitro Fertilization (IVF)

In vitro fertilization (IVF), also called test-tube conception, medical treatment in which mature egg cells are taken from a woman, fertilized with male sperm outside the body, and put into the uterus of the same or another woman for proper gestation.

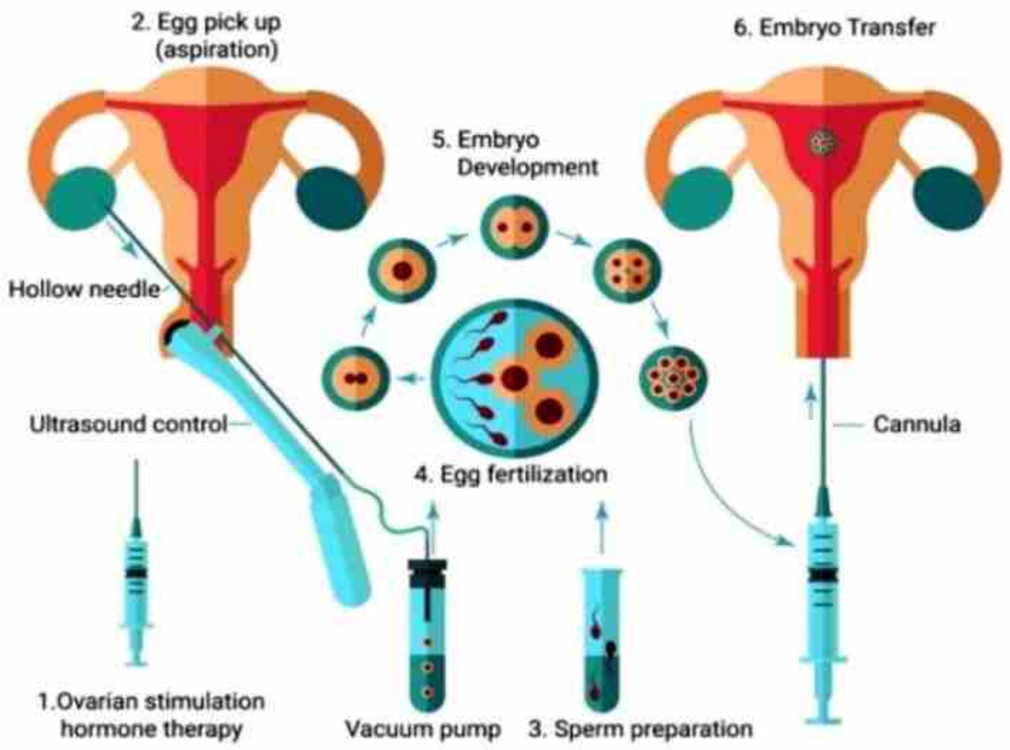


Fig. 20.13 In-vitro fertilization

20.2.4 Miscarriage

A **miscarriage** is the loss of a pregnancy before 20 weeks of gestation. Pregnancy loss occurs when the foetus stops developing. The pregnant tissue will eventually leave the body.

Causes of miscarriage

The embryo might place itself close to the cervix. In this situation, the placenta may partially or entirely cross the internal cervical opening as it expands. The area of the placenta over the cervical opening may tear, and bleeding may happen, when the uterus extends as the embryo and placenta continue to grow. Second, a haemorrhage caused by a normal position placenta can cause it to separate from the uterine wall. Both of these situations put the mother's life in danger and have the potential to cause miscarriage.

Miscarriage versus abortion

Abortion and miscarriage are two completely distinct events. Miscarriage can occur for a number of causes, including issues with the uterus or placenta. Contrarily, **abortion** is the deliberate termination of a pregnancy. It may be done for a number of reasons, including as an unintended pregnancy or a mother or child's health issues.

20.3 SEXUALLY TRANSMITTED DISEASES (STDS)

Sexually transmitted diseases are a group of ailments that may infect a healthy person during sexual contact with an infected person. A few of these are discussed below

20.3.1 Gonorrhea

Gonorrhea is a sexually transmitted disease, caused by the bacterium *Neisseria gonorrhoeae*. It primarily affects the reproductive system

Causes of Gonorrhea:

Gonorrhea is primarily transmitted through sexual contact, usually through genital and oral contact, with an infected person. The bacteria can infect the genital tract, mouth, throat, and rectum.

Symptoms of Gonorrhea:

- Painful or burning sensation during urination.
- Increased vaginal discharge in females and discharge
- Pain or swelling in the testicles (in males).
- Painful bowel movements or rectal itching.
- Sore throat or difficulty swallowing.

Treatment of Gonorrhea:

Gonorrhea can be effectively treated with antibiotics. However, due to increasing antibiotic resistance, it is crucial to follow the prescribed treatment regimen and complete the entire course of antibiotics as directed by a healthcare professional.

20.3.2 Syphilis:

Syphilis is a sexually transmitted disease caused by the bacterium *Treponema pallidum*. It is a serious health concern that can affect various organs and systems if left untreated.

Causes of Syphilis:

Syphilis is primarily transmitted through sexual contact, usually through genital and oral contact

Symptoms of Syphilis:

Syphilis progresses through distinct stages. The primary stage is characterized by the presence of a painless sore called a chancre at the infection site. In the secondary stage, a rash, along with flu-like symptoms, develops. The latent stage is symptom-free, but the infection can still be transmitted. If left untreated, syphilis can progress to the tertiary stage, which can cause severe complications affecting various organs, including the heart, brain, and bones. Symptoms during this stage can range from neurological problems to cardiovascular issues.

Treatment of Syphilis:

Syphilis can be effectively treated with antibiotics, The specific antibiotic and treatment duration depend on the stage and severity of the infection.

20.3.3 (AIDS)

Acquired immunodeficiency syndrome (AIDS) is caused by the **human immunodeficiency virus** (HIV), which attacks helper T cells, a type of lymphocyte.

Global Impact:

AIDS has had a profound impact on a global scale. Since the onset of the epidemic, millions of people worldwide have been infected with HIV, leading to substantial morbidity and mortality. It has disproportionately affected regions with limited access to healthcare, education, and resources, exacerbating social and economic disparities. Sub-Saharan Africa has been particularly affected, accounting for the majority of HIV infections and AIDS-related deaths globally. However, it is crucial to note that AIDS is a global concern, affecting people of all ages, genders, and geographical locations.

SUMMARY

- The male reproductive system includes structures like the testes, epididymis, vas deferens, prostate gland, and penis, each playing a specific role in sperm production, transportation, and ejaculation.
- Reproductive hormones in males, such as testosterone, FSH, and LH, regulate the development of reproductive organs, sperm production, and the manifestation of secondary sexual characteristics.
- The female reproductive system consists of the ovaries, fallopian tubes, uterus, cervix, and vagina, responsible for egg production, fertilization, implantation, and childbirth.
- Estrogen and progesterone are key hormones in females, regulating the menstrual cycle, the growth of the uterine lining, ovulation, and the preparation of the uterus for potential pregnancy.
- Infertility can occur in both males and females due to factors such as low sperm count, hormonal imbalances, ovulation disorders, and age-related factors.
- Miscarriage is the spontaneous loss of a pregnancy and can be caused by genetic abnormalities, hormonal imbalances, infections, or lifestyle factors.
- Miscarriage should not be confused with abortion, as miscarriage is a natural occurrence beyond the control of the individual, while abortion refers to the deliberate termination of a pregnancy based on personal, medical, or ethical reasons
- Gonorrhea and syphilis are bacterial STDs transmitted through sexual contact, causing symptoms like discharge, pain during urination, and genital sores.
- AIDS is a global STI caused by HIV, weakening the immune system and making individuals vulnerable to infections. It spreads through unprotected sex, sharing contaminated needles, and from mother to child during childbirth or breastfeeding.

EXERCISE

1. Encircle the correct choice.

i) Ovarian cycle includes changes in ovarian follicles to secondary follicle and finally to
(a) Graafian follicle (b) Primary follicle
(c) Vesicular follicle (d) Both “a” and “c”

ii) In males, FSH promotes the development and maturation of?
(a) Testosterone (b) Sperm cells
(c) Egg cells (d) Polar cells

iii) The menstrual cycle is primarily regulated by all of the following except:
(a) FSH (b) Estrogen
(c) Androgen (d) Progesterone

iv) FSH induces the Graafian follicle to produce
(a) LH (b) Estrogen
(c) Androgen (d) Progesterone

v) Key hormones in female reproductive system that regulates menstrual cycle.
I. Estrogen II. Progesterone III. Testosterone
(a) I only (b) II only
(c) I and II (d) III only

vi) What is the medical term for a miscarriage?
(a) Spontaneous abortion (b) Induced abortion
(c) Ectopic pregnancy (d) Both “a” and “b”

vii) Syphilis is a sexually transmitted disease caused by
(a) Bacteria (b) Virus
(c) Protozoan (d) Yeast

viii) Structure that protects the testes and keeps them at a temperature several degrees below the normal body temperature.
(a) Epididymis (b) Scrotum
(c) Penis (d) All of the above

ix) In-vitro fertilization (IVF) is a method used to:
(a) Treat infertility (b) Enhance hormones
(c) Prevent STDs (d) None of the above

x) Which of the following is a potential cause of female infertility?
(a) Polycystic ovary syndrome (PCOS) (b) Endometriosis
(c) Fallopian tube blockage (d) All of these

2. Write short answer of the following questions:

i) Why urethra in male is called urinogenital duct?
ii) Why hormonal system of female is better than male?
iii) Why testes descend down in human male foetus before birth?
iv) What are symptoms of gonorrhea?
v) Why inner uterine wall thicken during secretory phase?
vi) Enlist causes of male and female infertility.
vii) Differentiate between the following
(a) Testes and Ovaries
(b) Spermatogenesis and Oogenesis

3. Write detailed answers to the following questions.

i) Describe the structures of male reproductive system identifying their functions.
ii) Explain the principal reproductive hormones of human male and explain their role in the maintenance and functioning of reproductive system
iii) Explain the structures of female reproductive system and describe their functions.
iv) Describe phases of menstrual cycle.

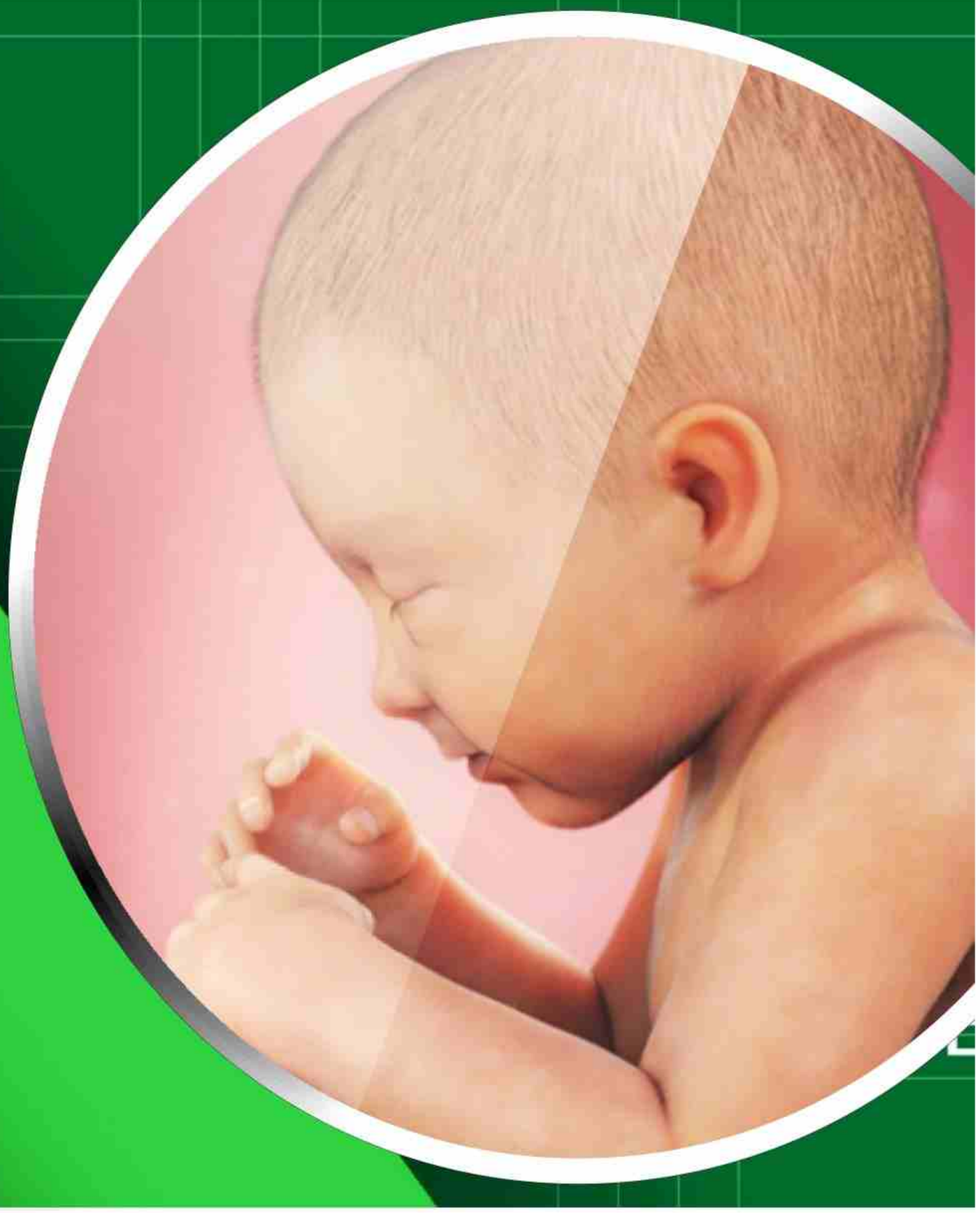
DEVELOPMENT AND AGING

Chapter 21

Major Concept

In this Unit you will learn:

- Human Embryonic Development
- Control of Development
- Pregnancy
- Disorders during embryonic Development
- Aging



Development refers to the process by which an organism grows and matures from a single cell into a complex multicellular organism with specialized tissues and organs. It involves a series of coordinated and sequential events that begin with fertilization and continue throughout the life of an organism. **Development** is a highly regulated process that is influenced by genetic and environmental factors, and it requires the precise coordination of numerous cellular and molecular processes.

In biology, growth and development are two distinct processes. **Growth** refers to an increase in size or number of cells, tissues, or organs, often resulting in an increase in overall mass. On the other hand, development refers to the process by which an organism changes from a simple to a more complex structure, acquiring new structures and functions. Development involves changes in gene expression, cell differentiation, and tissue organization that give rise to the diverse cell types and organs in an organism.

21.1.1 Fertilization and its site

Union of male and female gametes is called fertilization, this union results in the formation of single cell called zygote. Egg release from ovary in the form of secondary oocyte, which is covered with zona pellucida. Fertilization takes place in proximal part of oviduct. This process is facilitated by enzymes on the surface of the sperm cell, which break down the outer membrane of the egg.

Once a sperm cell has successfully penetrated the egg cell, zona pellucida of the egg undergoes changes that prevent any other sperm from entering. Once the sperm cell has entered the egg cell, the two cells fuse, and their nuclei combine to form a single, diploid nucleus. This marks the beginning of the development of a new individual. The zygote then undergoes a series of cell divisions and transformations as it travels down the fallopian tube towards the

uterus, where it will implant into the uterine lining and continue to develop.

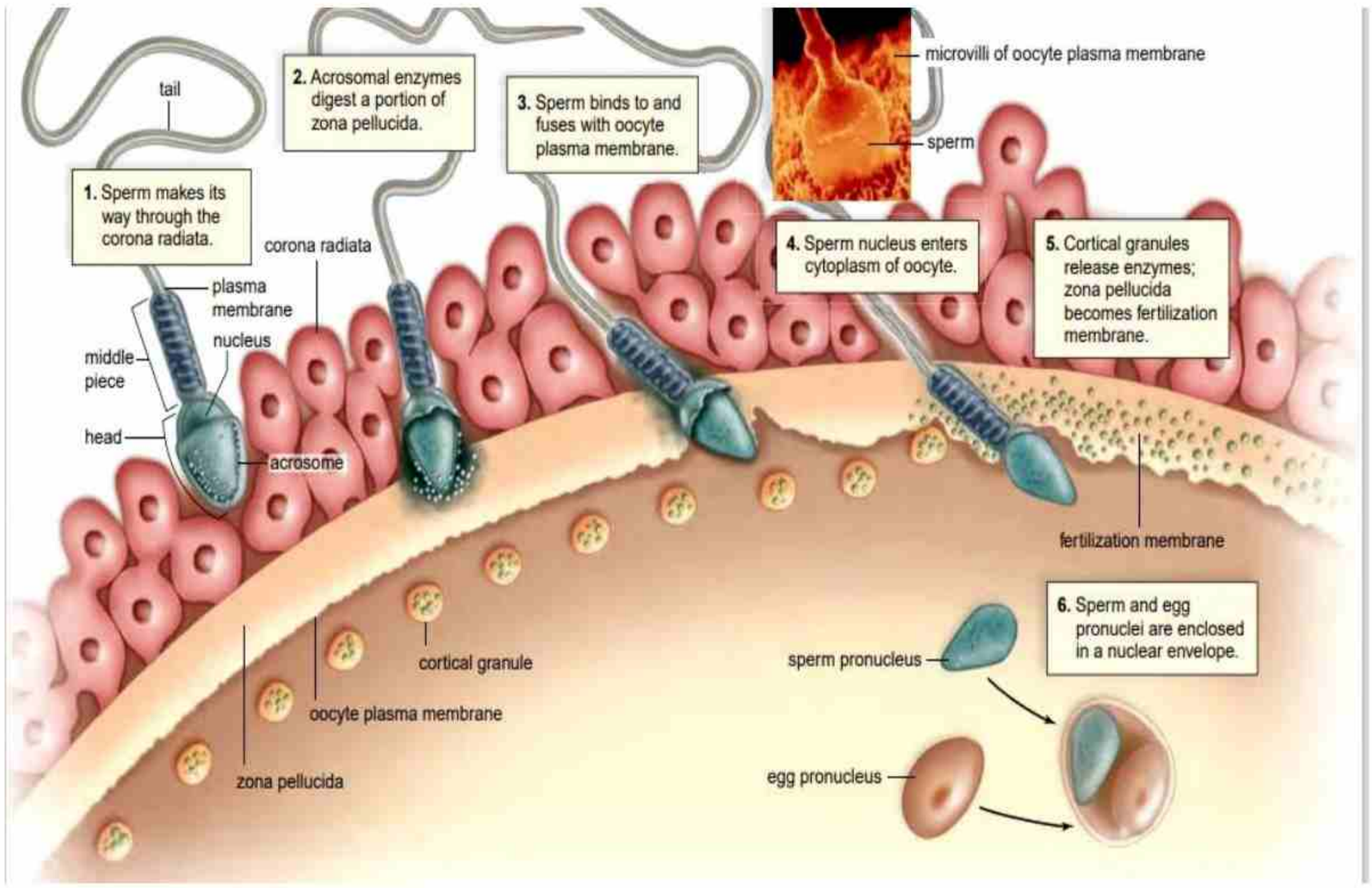


Fig. 21.1 Stages of Sperm entering an egg

21.1.2 Cleavage and egg types

Cleavage is the process of rapid cell division that occurs after fertilization, during which the zygote divides into smaller and smaller cells, each containing a copy of the genetic material from the original cell. The purpose of cleavage is to generate many cells that will eventually form the tissues and organs of the developing embryo. The amount of yolk present in the egg cell can significantly impact the cleavage process. In some animal species, such as birds and reptiles, the egg contains a large amount of yolk, which can make cleavage more difficult.

In eggs with moderate to little yolk, cleavage occurs throughout the whole egg, a pattern called **holoblastic cleavage**. However, in eggs with a large amount of yolk, with a small amount of clear cytoplasm concentrated at one pole called the **blastodisc**. Cleavage in

these eggs restricted to the blastodisc. The yolk is essentially an inert mass. This type of cleavage pattern is called **meroblastic cleavage**.

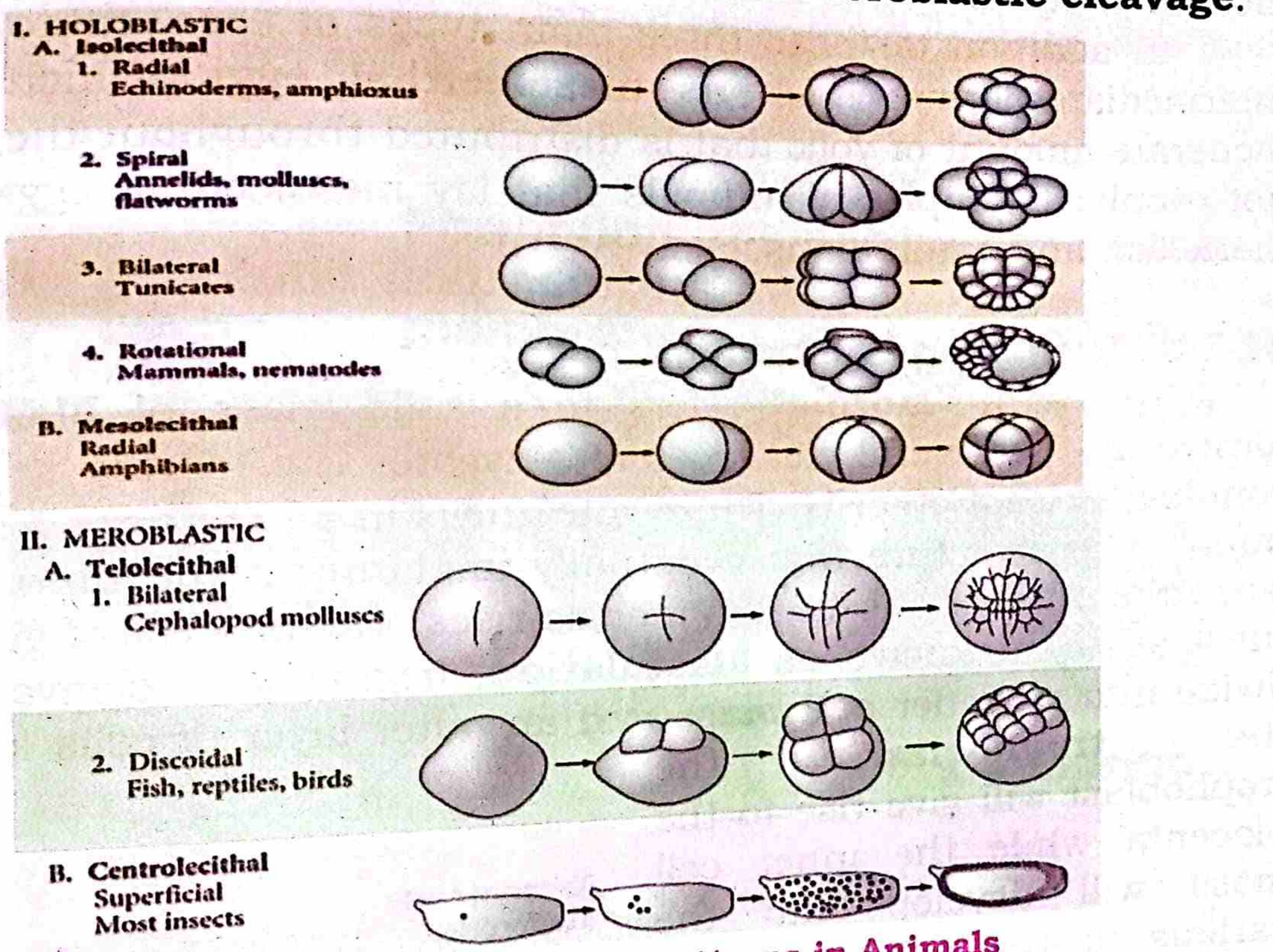


Fig. 21.2 Major Cleavage Patterns in Animals

Eggs can be classified into different types based on the amount and distribution of yolk present in them. The three main types of eggs are:

Telolecithal eggs: This type of eggs having large amount of yolk, which is concentrated at one end of the egg, creating a concentration gradient. Examples of animals that lay telolecithal eggs include birds, reptiles, and monotremes (egg-laying mammals).

Centrolecithal eggs: This type of eggs having large, centrally located yolk surrounded by a thin layer of cytoplasm. In these eggs, the nucleus and other organelles are located at the periphery of the egg, while the yolk is in the center. Examples of animals that lay centrolecithal eggs include insects and crustaceans.

Isolecithal eggs: This type of eggs having small amount of yolk that is evenly distributed throughout the cytoplasm of the egg. These eggs are common in animals that have a placenta, such as mammals, as the developing embryo receives nutrients from the mother rather

than from the yolk. Examples of animals that lay isolecithal eggs include many fish, amphibians, and some invertebrates.

In addition to these three main types of eggs, there are also intermediate forms, such as **mesolecithal eggs**, which have a moderate amount of yolk that is distributed throughout the egg, but not evenly. Examples of animals that lay mesolecithal eggs include many fish and amphibians.

21.1.3 Morula and Blastula

The term "**morula**" refers to a solid mass of **blastomeres** formed by the several cleavages of a zygote. The morula in humans contains at least 60 cells. The zygote grows in a **blastocyst**, a hollow, bubble-like structure that eventually implants in the uterine lining when the number of cells in a morula rises. The process of generating the blastocyst, known as **blastulation**, begins with cleavage. Cells divide into an inner **cell mass** and an outer layer of cells known as the **trophoblast**. The trophoblast will give rise to the placenta while the inner cell mass will develop into the various tissues and organs of the embryo, so inner mass cells are called **embryoblasts**, as division continues cells begin to move apart, so that spaces appear among cells in the center of mass. Cells keep pulling away from the central area, forming a fluid cavity called **segmentation cavity** or **blastocoel**.

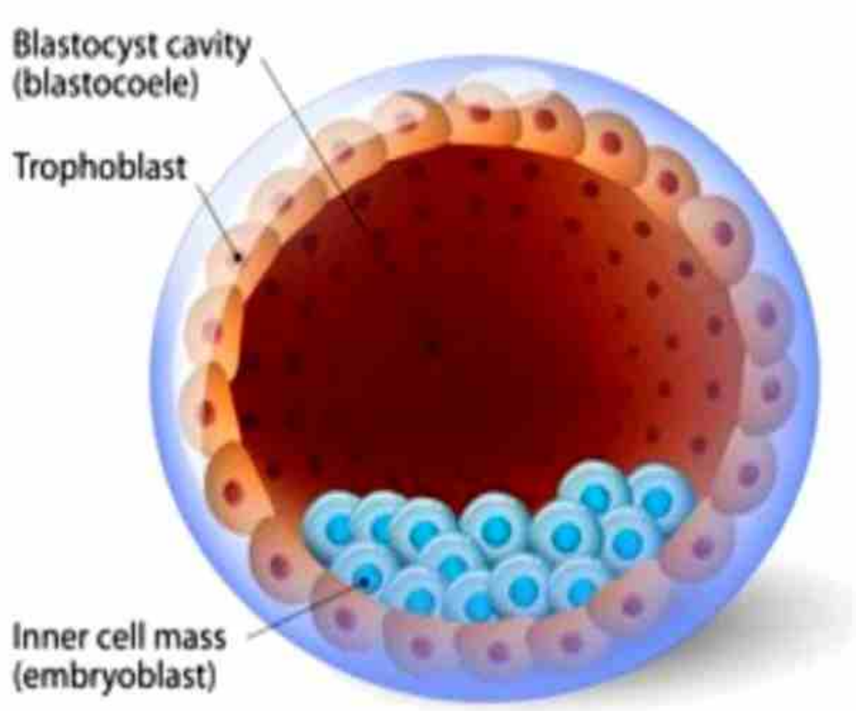


Fig. 21.3 Blastula

21.1.4 Events of Gastrulation

Gastrulation is a vital stage in human embryonic development, and it involves a series of complex cellular movements resulting in the formation of three germ layers: the **endoderm**, **mesoderm**, and **ectoderm**. These layers will develop into various organs and tissues such as the lining of the digestive tract, the heart, and the nervous

system. The process begins with the formation of the **primitive streak**, followed by the invagination of epiblast towards the midline. As the endoderm forms, a third layer of cells, the mesoderm, develops between the endoderm and ectoderm.

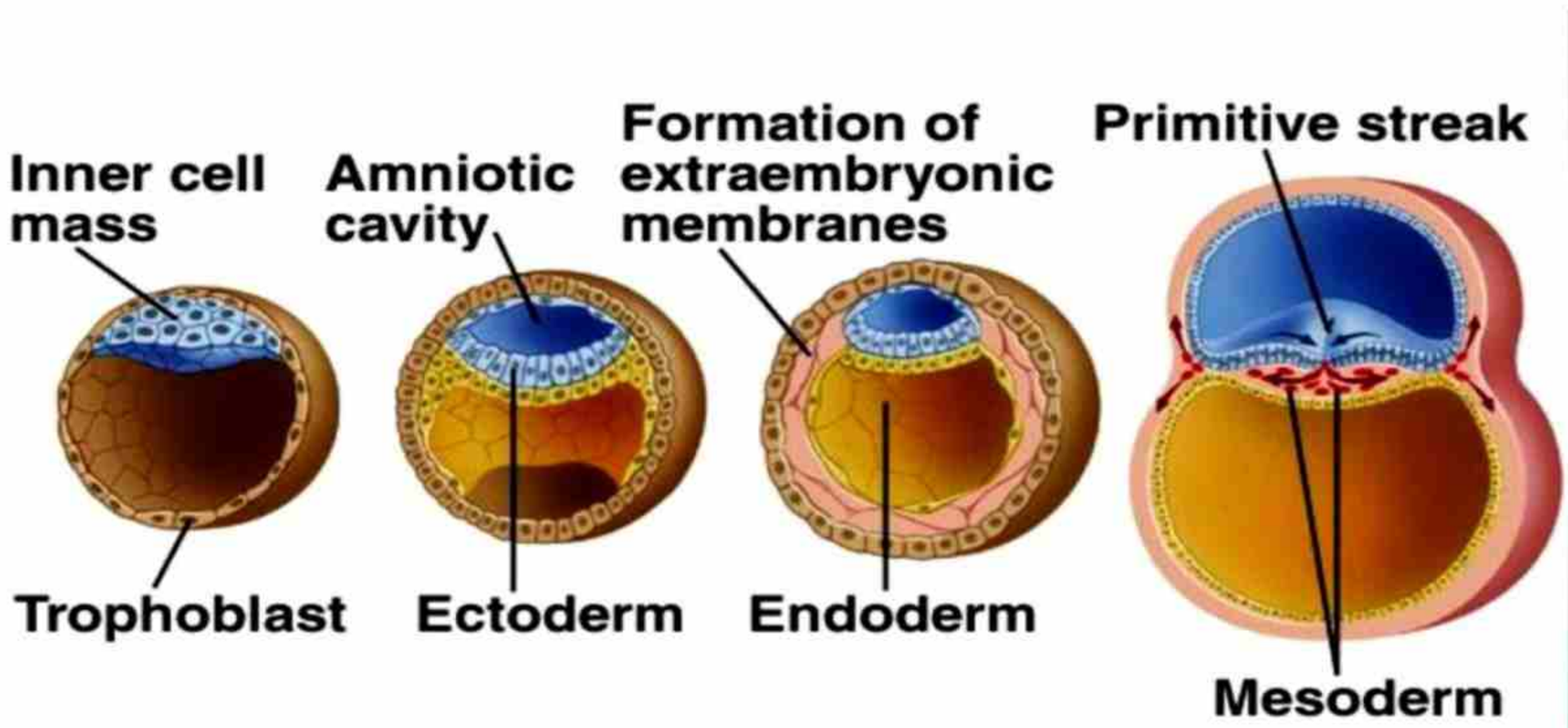


Fig. 21.4 Events of Gastrulation

During gastrulation, the inner cell mass creates **hypoblast cells** that line the **blastocoel**, resulting in the primitive yolk sac and a bi-layered embryonic disc made up of **epiblast** and **hypoblast**,

The epiblast splits into the **amniotic ectoderm** and the **embryonic epiblast**. The embryonic epiblast develops into the embryo (including ectoderm, endoderm, mesoderm, and germ cells), while the extra embryonic endoderm forms the **yolk sac**.

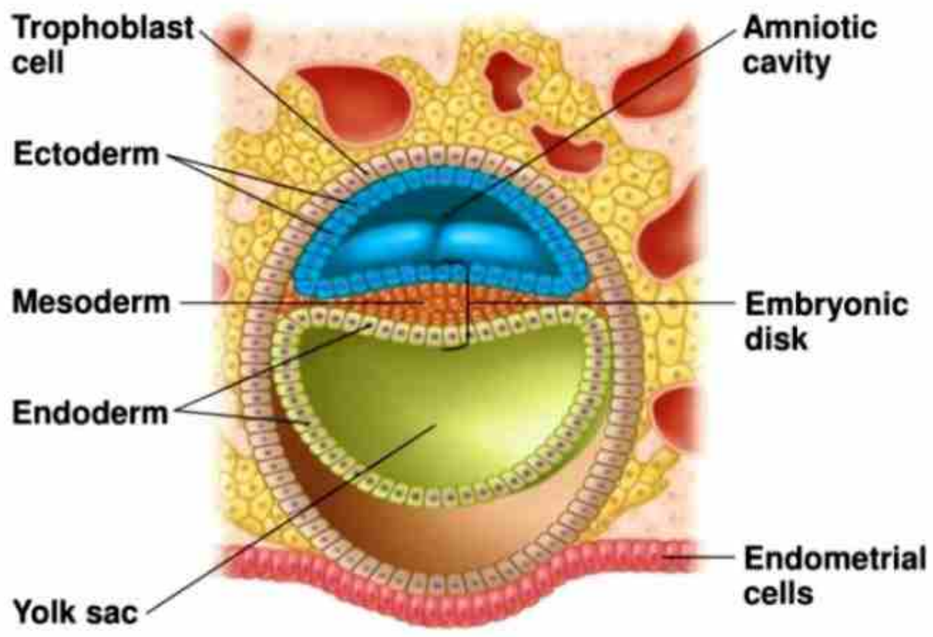


Fig. 21.5 Formation of Germ layers

The trophoblast develops through several stages, eventually becoming the **chorion**, the embryonically derived portion of the

placenta. Trophoblast cells also induce the mother's uterine cells to form the maternal portion of the placenta, **the decidua**. The decidua becomes rich in the blood vessels that will provide oxygen and nutrients to the embryo.

21.1.5 Fate of three germ layers

During human embryonic development, the three germ layers that form during gastrulation give rise to a wide variety of tissues and organs.

Table 21.1 Fate of Three Germ Layers

Germ Layer	Tissues and Organs
Ectoderm	Skin, teeth, eyes, nervous system (brain, spinal cord, nerves)
Mesoderm	Bones, muscles, heart, kidneys, blood vessels, reproductive system, dermis of skin
Endoderm	Lining of digestive tract (including esophagus, stomach, and intestines), lining of respiratory tract, liver, pancreas, bladder, thyroid gland

21.1.6 Events of Neurulation

Neurulation is the process by which the neural plate forms and eventually becomes the neural tube, which will give rise to the brain and spinal cord. During the third week of development, the ectoderm thickens along the midline, forming the **neural plate**. The neural plate then begins to invaginate or fold inwards, forming the **neural grooves** that runs along the midline of the embryo. As the neural plate continues to invaginate, the raised **neural folds** on either side of the neural groove start to elevate and approach each other until they eventually fuse together, forming the **neural tube**. As the neural tube is forming, some of the cells at the edge of the neural plate start to break away and migrate to form the **neural crest**.

The neural crest will eventually give rise to various cell types including cranial and spinal nerves, some components of the skull and face, and pigment cells. As the neural tube forms, it also undergoes **segmentation**, forming distinct regions that will give rise to different parts of the nervous system.

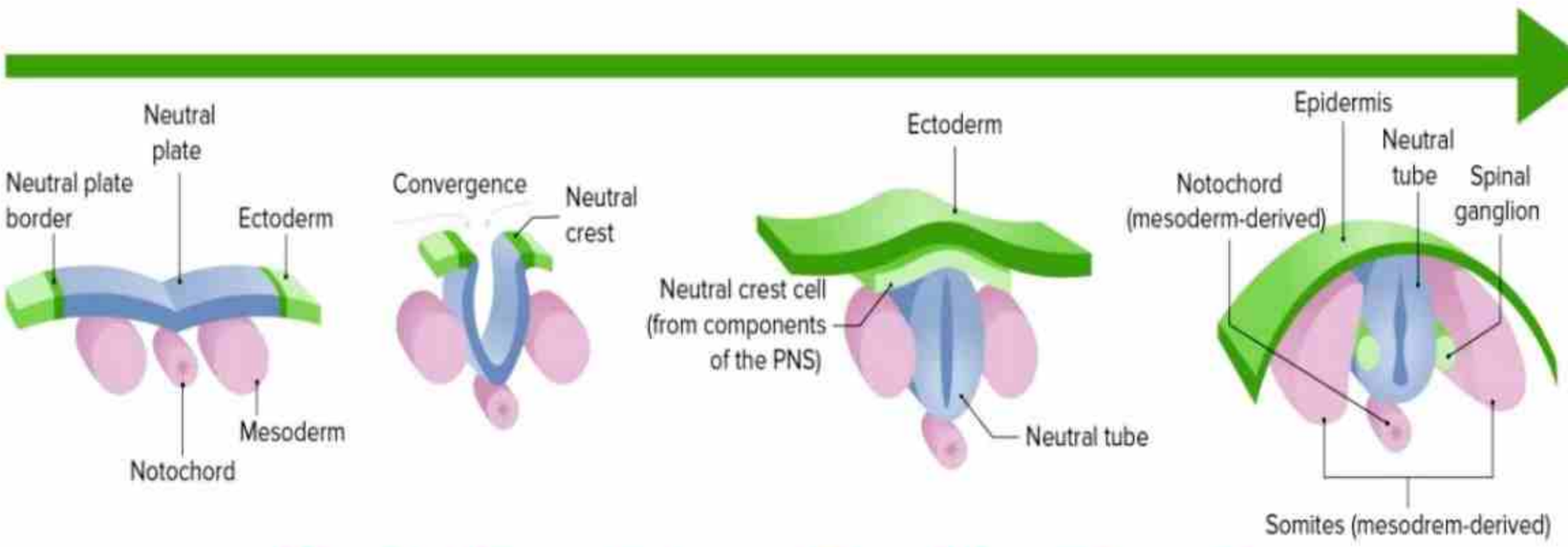


Fig. 21.6 Neural tube and Neural Crest Formation

For example, the anterior end of the neural tube will form the **brain** while the posterior end will form the **spinal cord**. The neural tube eventually closes at both ends, with the cranial (head) end closing first, followed by the caudal (tail) end.

21.1.7 Neural crest and neural crest cells

During embryonic development, the neural crest is a transient, highly migratory population of cells that arises from the neural plate and gives rise to a diverse array of cell types and tissues.

Table 21.2 Structures derived from neural crest cells

Structure	Description
Cranial nerve ganglia	Sensory and autonomic ganglia of the cranial nerves
Adrenal medulla	Chromaffin cells that make up the adrenal medulla, producing epinephrine and norepinephrine
Dorsal root ganglia	Sensory ganglia of the spinal nerves
Melanocytes	Pigment-producing cells responsible for skin, hair, and eye color
Skeletal and connective tissue	Cartilage, bones, and connective tissue of the face and skull, as well as some teeth
Smooth muscle	Smooth muscle cells of the cardiovascular system, including the aortic arch arteries
Schwann cells	Myelin sheath-forming cells around axons in the peripheral nervous system
Enteric nervous system	Nervous system controlling the function of the gastrointestinal tract

21.1.8 Organogenesis

Organogenesis is the process of organ formation in the developing embryo, which begins during the third week of human embryonic development and continues until the end of the eighth week. The three germ layers of the embryo the endoderm, mesoderm, and ectoderm give rise to the various organs and tissues of the body.

21.2 CONTROL OF DEVELOPMENT

The control of development involves the intricate interplay between genetic and environmental factors to determine how a fertilized egg transforms into a complex multicellular organism with distinct tissues and organs. Key processes in this control include pattern formation, where different regions of the embryo become specialized through regulated gene expression and signaling pathways. Another essential aspect is cell differentiation, where undifferentiated cells acquire specific identities through the influence of signaling molecules and transcription factors. Additionally, the environment, including factors like temperature, light, and nutrients, also influences gene expression and cell differentiation, thereby impacting the overall development of the organism.

21.2.1 Role of nucleus in development

During his studies in the late 1920s, Hammerling discovered that *Acetabularia*, a type of marine algae, had a single nucleus located in the base of the cell. He conducted an experiment in 1934 where he successfully transplanted the nucleus of one *Acetabularia* species, *Acetabularia crenulata*, onto the stem of another species, *Acetabularia mediterranea*, which had a different cap shape. The interesting finding was that the cap that grew in

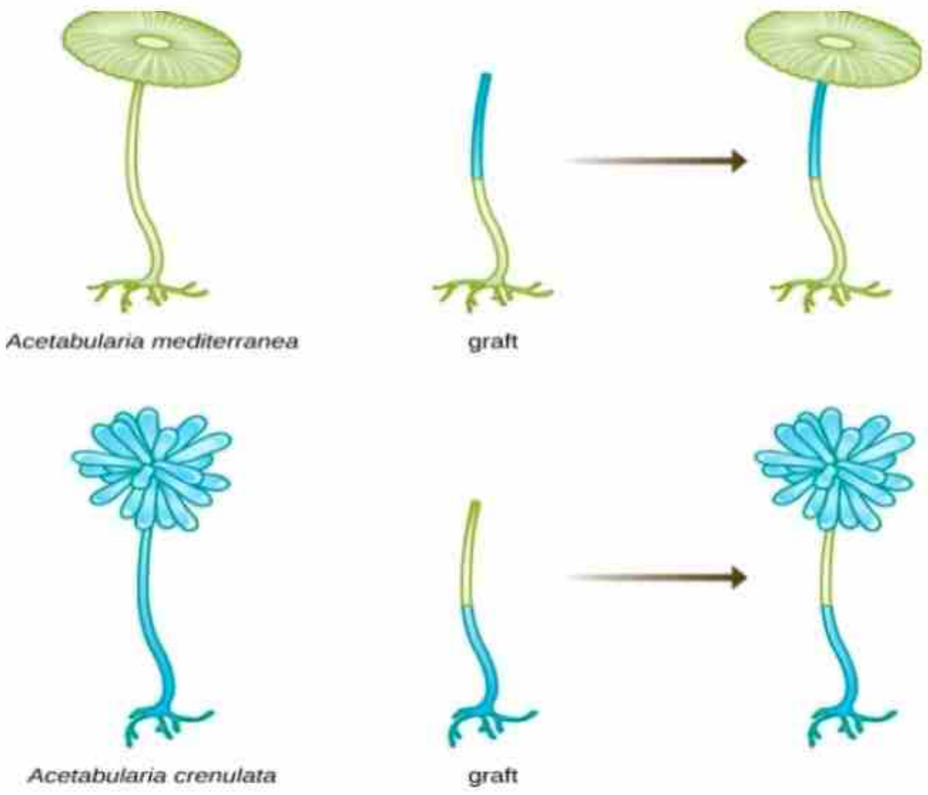


Fig. 21.7 Hammerling's experiments

the transplanted cell resembled that of A. *crenulata*. This indicated that the nucleus influenced the development of the cap by transmitting factors or substances to the cytoplasm. In simpler terms, the experiment showed that the nucleus controls the information that determines the shape of the cap.

21.2.2 Role of cytoplasm in development

The role of cytoplasm in controlling the process of development has been revealed through experiments on frog embryos. Before fertilization, the unfertilized frog egg has a pigmented upper cytoplasmic half and a yolky lower half. After fertilization, a gray crescent forms opposite to the point where the sperm nucleus enters the egg. This gray crescent is created when some pigments in the cytoplasm shift upward, leaving a crescent-shaped area.

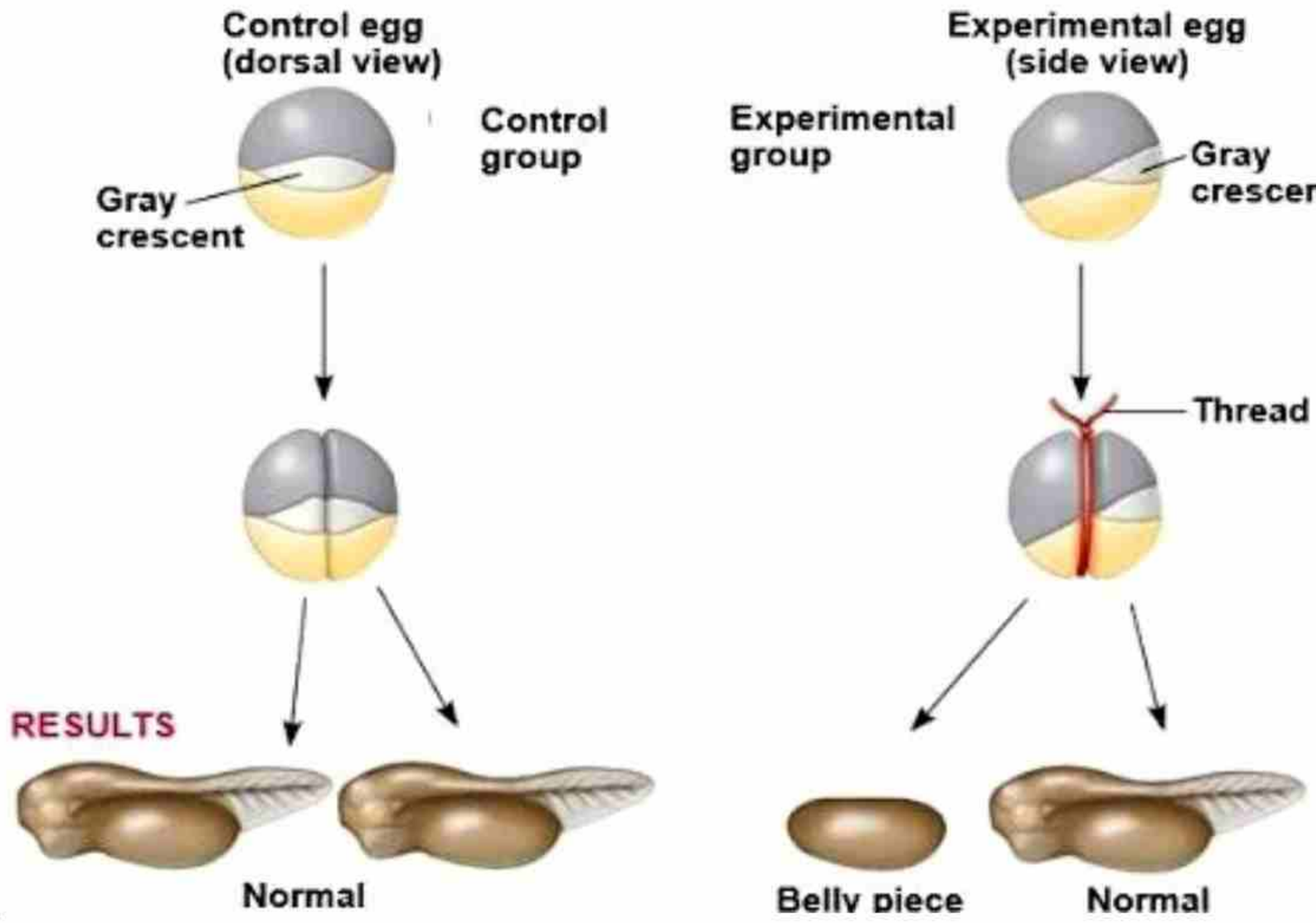


Fig.21.8 Distribution of gene regulating substance

During the first cleavage, the zygote divides vertically, and each daughter cell receives half of the crescent. Interestingly, if these daughter cells are separated carefully, each of them develops into a

normal tadpole larva. In an experiment conducted by Hans Spemann in 1930, he purposely altered the normal plane of the first cleavage. As a result, one of the daughter cells received the entire gray crescent, while the other did not receive any crescent. Both of these daughter cells were separated and allowed to develop. The daughter cell that received the entire gray crescent developed into a complete tadpole larva, while the non-crescent daughter cell failed to develop properly. This experiment highlighted that even though both daughter cells had the same genes, the presence or absence of the gray crescent in the cytoplasm had a significant effect on gene expression and subsequent development.

21.2.3 Embryonic Induction

Induction, the process by which one type of embryonic tissue influences the development of another, is a fundamental aspect of embryonic development. In frog embryos, the primary organizer, situated at the dorsal lip of the blastopore, is essential for proper development. The proximity to the primary organizer determines the fate of cells, with those closest becoming endoderm, those farther away becoming mesoderm, and the farthest becoming ectoderm. This suggests the presence of a molecular gradient that serves as a chemical signal for germ layer differentiation.

Renowned embryologist **Hans Spemann** and his colleague **Hilde Mangold** conducted a groundbreaking experiment in 1924 to study embryonic induction, specifically focusing on the formation of neural tissue. They carefully excised the presumptive nervous system tissue above the notochord and transplanted it to a different region of the embryo, the belly area. Remarkably, the transplanted tissue failed to develop into neural tissue at the new location. This experiment demonstrated the influential capacity of the transplanted tissue, indicating that it induced the surrounding cells to adopt specific fates. The notochord, acting as the primary organizer, played a vital role by releasing signaling molecules that guided neighboring cells to differentiate into neural tissue.

Spemann and Mangold's findings revolutionized our understanding of embryonic induction, revealing that certain tissues

or regions have the ability to direct neighboring cells towards specific developmental paths.

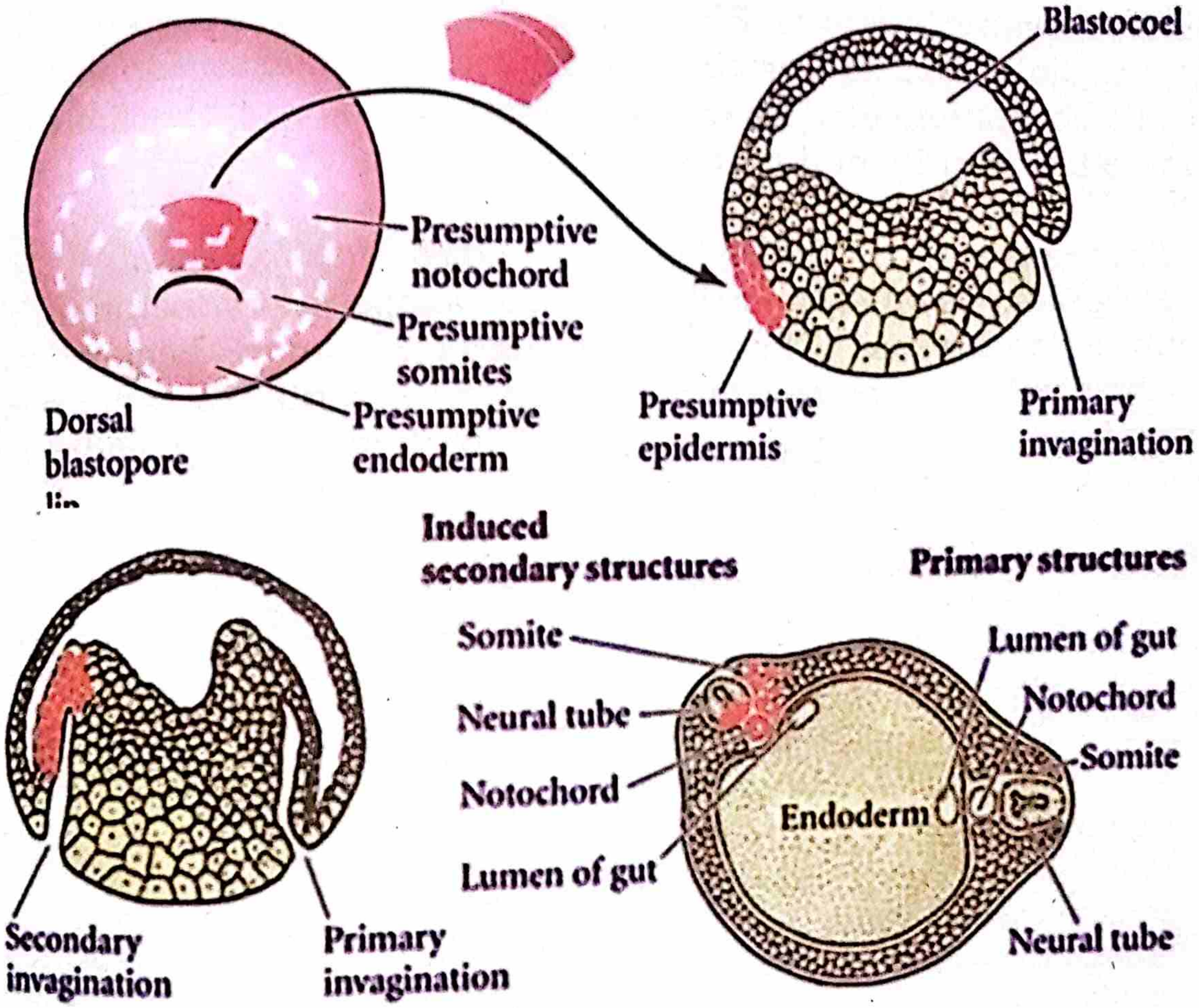


Fig. 21.9 Experiment performed by Hans Spemann and Mangold

21.2.4 Organizers

Organizers are cluster of cells that release diffusible signal molecules, which can induce or direct the differentiation of other cells or tissues.

There are two types of organizers: primary and secondary.

Primary organizers, also known as **embryonic organizers**, are regions that determine the basic body plan of the embryo. In vertebrates, the dorsal lip of the blastopore is considered the primary organizer, as it initiates gastrulation and gives rise to the three germ layers.

Secondary organizers, also known as **regional organizers**, develop later and are responsible for organizing specific regions of the embryo or promoting the differentiation of specific cell types. An example of a secondary organizer is the **ZPA** (zone of polarizing activity) in the developing limb bud of vertebrates. The ZPA releases signals that direct the formation of the anterior-posterior axis of the limb and determine the identity of different digits.

21.3 Pregnancy

Pregnancy is when a fertilized egg develops into a foetus within the mother's uterus. The process of pregnancy begins with fertilization, when a sperm cell penetrates and combines with an egg cell, forming a zygote. The zygote then begins to divide and undergoes several stages of development before it becomes a foetus.

Extra Reading Material

Science & Society: Proper nourishment of the mother during the third trimester

Proper nourishment of the mother during the third trimester of pregnancy is essential for various reasons. Firstly, this is a critical period for the fetus as it undergoes rapid growth and development. Adequate intake of nutrients like protein, carbohydrates, and fats is crucial to support this growth. Insufficient nutrition can lead to complications such as low birth weight, developmental delays, and an increased risk of chronic diseases later in life.

Secondly, the mother's body experiences significant changes during the third trimester to accommodate the growing fetus. These changes require extra energy and nutrients. For instance, blood volume increases, the uterus expands, and breast tissue develops in preparation for lactation. Without proper nourishment, the mother may experience fatigue and lack the necessary resources to support these bodily changes.

Lastly, maintaining proper nutrition during the third trimester can help reduce the risk of delivery complications. Well-nourished women are less likely to experience prolonged labor or require a cesarean delivery.

During pregnancy, the mother's body undergoes numerous physiological changes to support the growing foetus. Hormonal changes occur, leading to increased blood flow to the uterus, changes in metabolism, and growth of the placenta, which connects the foetus to the mother's blood supply. The development of the foetus is divided into three trimesters, each lasting approximately three months.

21.3.1. Human development in trimesters

Human development during pregnancy is divided into three trimesters, each lasting about three months. Let's take a brief look at the major milestones that occur during each trimester.

Table 21.3. Summary of Three Trimesters events

Trimester	Time frame	Major Developmental Events
First Trimester	First Month	Fertilization and implantation, formation of the blastocyst, and the beginning of embryonic development
	Second Month	Development of major organs and systems, including the heart, brain, limbs, and digestive system. The embryo becomes a foetus by the end of the second month.
	Third Month	Rapid growth and development of the foetus, including the formation of fingers and toes, eyelids, and external genitalia. The foetus can move its limbs and make facial expressions.
Second	Fourth Month	Continued growth and development, including the formation of hair and nails, and the development of a functioning urinary system. The foetus can hear sounds from outside the womb.
	Fifth Month	Development of taste buds, and the ability to swallow and digest amniotic fluid. The foetus has distinct sleeping and waking patterns, and can respond to light and touch.

Third	Sixth Month	Rapid brain development and the growth of hair and nails. The foetus has a good chance of survival if born prematurely.
	Seventh Month	Continued growth and development of organs, and the development of fat stores under the skin. The foetus can open and close its eyes and respond to external stimuli.
	Eighth Month	Increased weight gain, and continued development of the nervous and respiratory systems. The foetus can recognize its mother's voice and can turn head-down in preparation for birth.
	Ninth Month	Final stages of development, including the shedding of the lanugo hair and the formation of the vernix caseosa. The foetus is fully developed and ready for birth

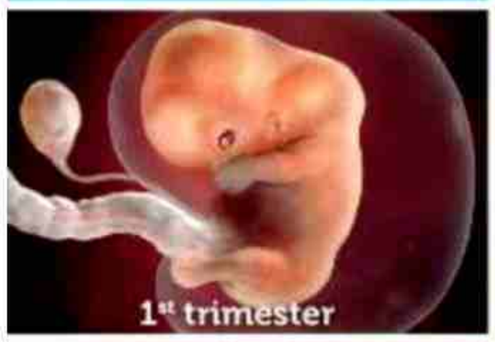
Trimester	Months pregnant*	Weeks pregnant
	0	0 - 4
	1	5 - 8
	2	9 - 12
	3	13
	3	14 - 17
	4	18 - 21
	5	22 - 25
	6	26 - 27
	6	28 - 30
	7	31 - 34
	8	35 - 38
	9	39 - 42

Fig. 21.10 Pregnancy by Weeks and Months

21.3.2 Twins and Quadruplets

The development of twins and quadruplets occurs when multiple embryos form from a single fertilized egg, or when multiple eggs are fertilized by multiple sperm.

Twins:

Twins are children which develop and are born together. Twins are of two types i.e. **Identical twins**, also known as **monozygotic twins**, occur when a single fertilized egg splits into two embryos. The embryos will have the same genetic material and will develop into two separate feotuses. The timing of the split determines if the twins will share a placenta and amniotic sac or have separate ones. This process occurs randomly and is not influenced by genetics or other external factors. **Fraternal twins**, or **dizygotic twins**, occur when two eggs are fertilized by two separate sperm. These embryos will have different genetic material and can develop into two separate foetuses. Fraternal twins may or may not share a placenta and amniotic sac, depending on when the eggs are fertilized.

The development of **quadruplets** follows a similar pattern to that of twins. Multiple eggs may be fertilized by multiple sperm or a single fertilized egg may split into multiple embryos. Quadruplets may share a placenta and amniotic sac or have separate ones, depending on the timing of embryo formation and implantation.

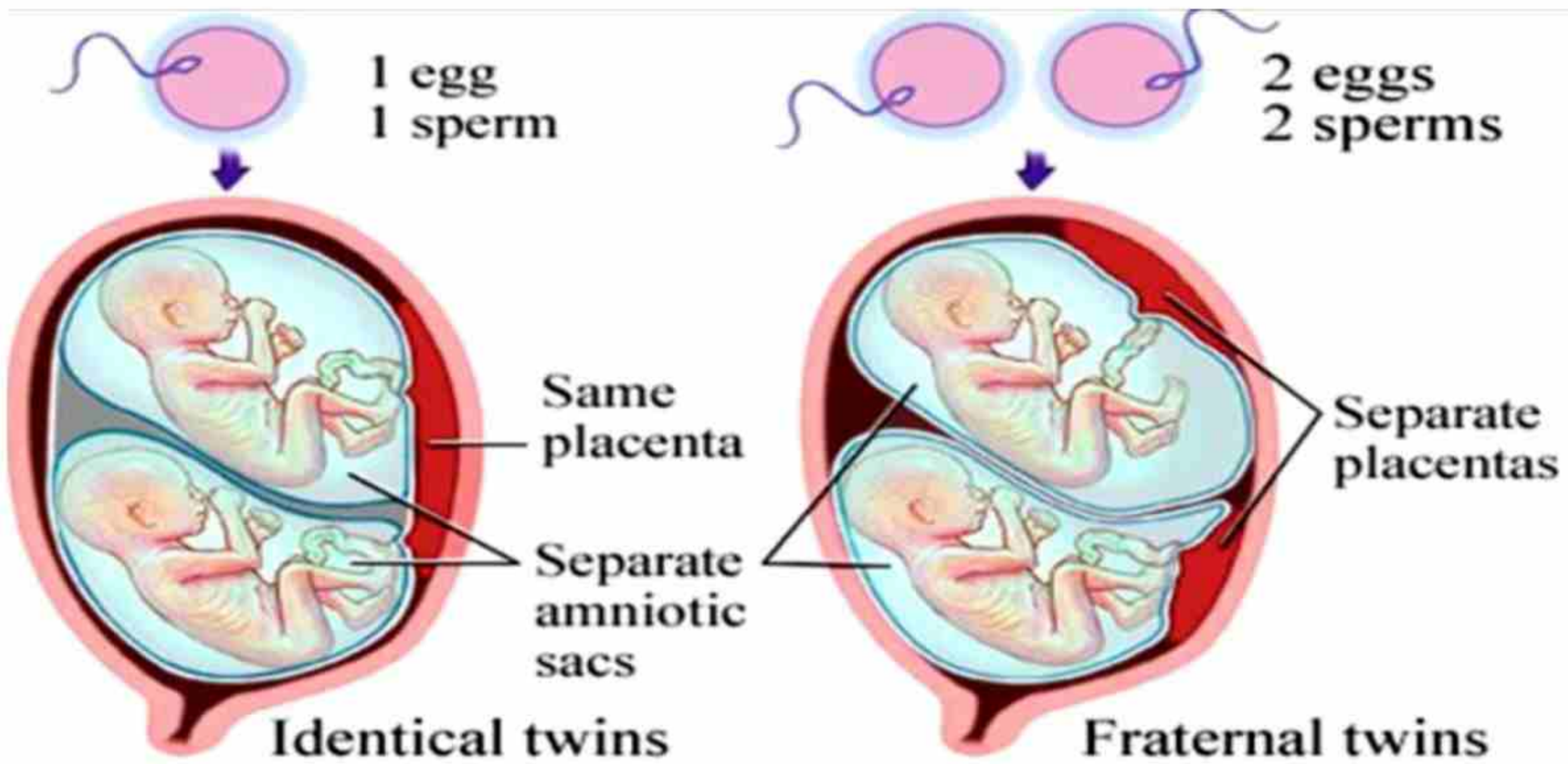


Fig. 21.11 Monozygotic and Dizygotic Twins

21.3.3. Placenta and Umbilical Cord

The placenta is a temporary organ that develops during pregnancy and serves as the interface between the maternal and foetal circulatory systems. It is formed from the chorion, the outermost foetal membrane, and the decidua, the lining of the uterus. The placenta is attached to the uterine wall and connected to the foetus by the umbilical cord.

The placenta has a disc-like shape and is composed of two layers: the **maternal side** and the **foetal side**. The maternal side of the placenta is rough and irregular in shape, while the foetal side is smooth and rounded. The maternal side contains maternal blood vessels that bring oxygen and nutrients to the foetus, while the foetal side contains foetal blood vessels that remove waste products and carbon dioxide from the foetal blood.

Umbilical cord

The umbilical cord (Latin: Funiculus Umbilicalis) is a tube-like structure that connects the developing foetus to the placenta. It has one umbilical vein and two umbilical arteries, which are used by the foetal heart to pump blood to and from the placenta, which exchanges nutrients and waste products with the mother's circulatory system. After birth, the umbilical cord is clamped and cut, leaving a small stump that becomes the belly button.

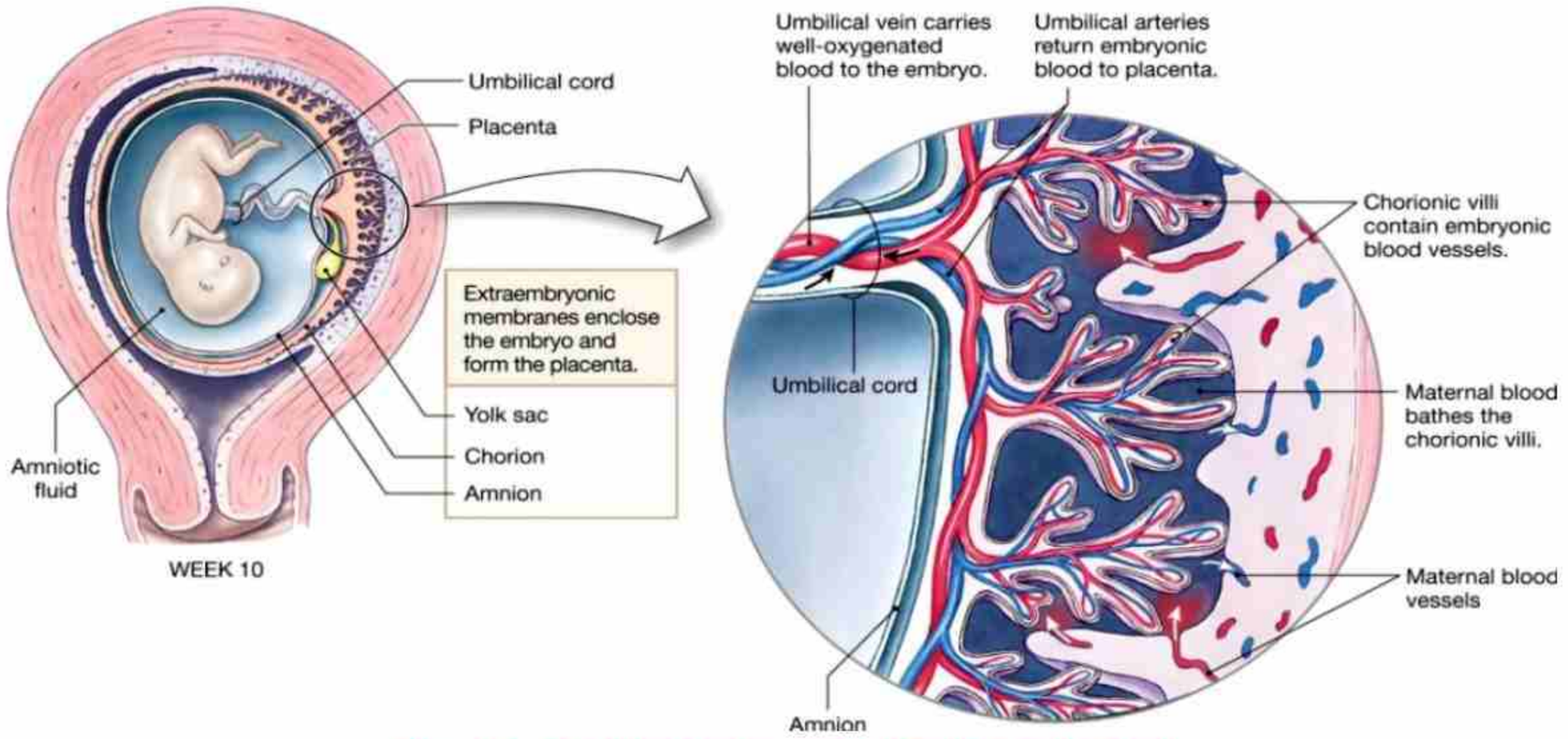


Fig. 21.12 Placenta and Umbilical Cord

21.3.4 Difference between Gestation and Pregnancy

The terms "**gestation**" and "**pregnancy**" are often used interchangeably, but they refer to different concepts. Gestation refers to the period during which an embryo is developing within the uterus. This includes the time from fertilization of the egg by the sperm to the birth of the offspring. In humans, gestation typically lasts around 38-42 weeks, or approximately 9 months.

On the other hand, pregnancy refers specifically to the condition of a female mammal (usually a human) in which she is carrying one or more offspring in her uterus. Pregnancy includes not only the period of gestation, but also the various physiological and hormonal changes that occur in the mother's body during this time. These changes include increased levels of hormones like progesterone and estrogen, as well as physical changes like weight gain and changes in the size and shape of the uterus.

21.4 EMBRYONIC DISORDERS

Disorders during embryonic development refer to a range of medical conditions that can occur during the early stages of human development. These disorders can be caused by genetic abnormalities, environmental factors, or a combination of both, and can have significant impacts on both the developing foetus and the mother.

21.4.1 The maternal-derived abnormalities

Maternal Health Problems:

Certain maternal health problems, such as uncontrolled diabetes or high blood pressure, can also have negative impacts on embryonic development.

Rubella is a viral infection that can be transmitted to the foetus during pregnancy, leading to a range of birth defects, collectively known as **Congenital Rubella Syndrome** (CRS). The infection can cause developmental delays, hearing loss, cataracts, heart defects, and intellectual disabilities in the developing foetus.

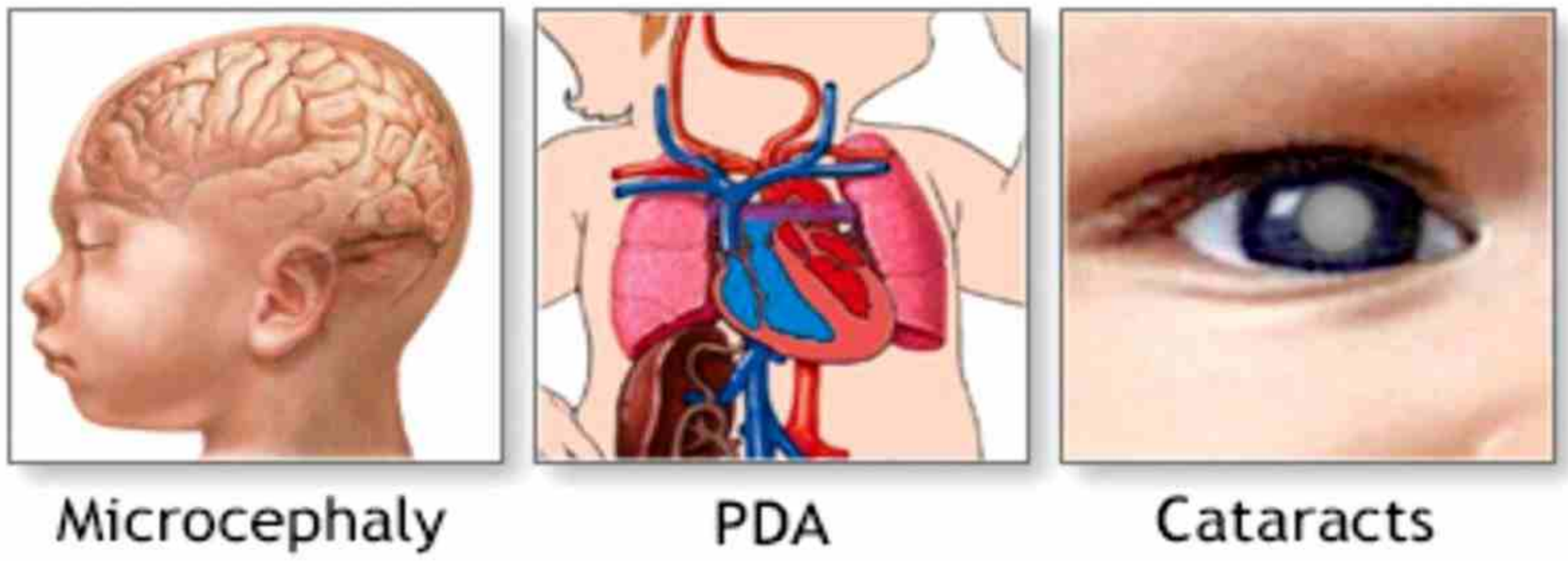


Fig. 21.13 Congenital Rubella Syndrome

Abnormal neural tube development can lead to neural tube defects (**NTDs**) in the developing foetus. NTDs occur due to the failure of the neural tube to close completely during embryonic development, leading to conditions such as spina bifida and anencephaly. These conditions can result in severe disabilities or even be fatal.

Thyroid gland dysfunction can cause developmental abnormalities in the foetus, as thyroid hormones play a crucial role in foetal growth and development. If the mother has an underactive thyroid gland (hypothyroidism) during pregnancy, it can lead to developmental delays, intellectual disability, and other abnormalities in the developing foetus.

Limb development issues can occur due to various maternal health factors and environmental exposures. Certain medications, infections, and genetic conditions can lead to limb abnormalities in the developing foetus, such as missing or extra fingers, shortened limbs, or limb deformities.

Proper prenatal care, including regular check-ups and proper management of maternal health conditions, can help prevent or minimize the risk of these maternal-derived abnormalities in the developing foetus

21.4.2 Genetic abnormalities & Spontaneous abortion

Spontaneous abortion, also known as miscarriage, is a common complication of pregnancy that results in the loss of the

foetus before the 20th week of gestation. It is estimated that up to 20% of all recognized pregnancies end in miscarriage, with the majority occurring during the first trimester. Many of these miscarriages are caused by major genetic abnormalities in the embryo.

Genetic abnormalities in embryos can arise from errors in chromosome number or structure, gene mutations, or epigenetic modifications. These abnormalities can affect various aspects of embryonic development, including cell proliferation, differentiation, and apoptosis. As a result, affected embryos may fail to implant properly, develop abnormal tissues or organs, or have severe developmental defects that are incompatible with life.

Some common genetic abnormalities that can cause spontaneous abortion include:

Chromosomal abnormalities: These are the most common cause of spontaneous abortion, accounting for up to 60% of cases. They include errors in chromosome number (such as trisomy or monosomy) or structure (such as deletions or translocations). Most chromosomal abnormalities are random events that occur during cell division in the egg or sperm, but some can be inherited from a parent.

Gene mutations: Mutations in specific genes can also cause spontaneous abortion. For example, mutations in genes that regulate cell proliferation or differentiation can disrupt normal embryonic development. Inherited mutations in genes such as BRCA1 and BRCA2, which are associated with an increased risk of breast and ovarian cancer, can also increase the risk of miscarriage.

Epigenetic modifications: Epigenetic modifications are changes in gene expression that do not involve alterations to the DNA sequence itself. They can be influenced by environmental factors such as diet and stress, as well as by inherited factors. Abnormal epigenetic modifications can affect gene expression in the developing embryo and increase the risk of miscarriage.

In summary, major genetic abnormalities in the embryo can lead to spontaneous abortion by disrupting normal embryonic development.

While some of these abnormalities are inherited, many are random events that cannot be prevented.

21.4.3 Foetal surgery

Foetal surgery is a medical procedure performed on a foetus in the uterus to correct structural or developmental abnormalities. This type of surgery is typically performed in cases where there is a high risk of foetal death or long-term disability if the issue is not corrected before birth.

One example of foetal surgery is the correction of **spina bifida**, a condition where the neural tube does not close properly during embryonic development, leading to damage to the spinal cord and nerves. In foetal surgery for spina bifida, a surgical team will make a small incision in the mother's abdomen and uterus and repair the opening in the baby's back. This can prevent further damage to the spinal cord and improve the baby's chances of being able to walk and have normal bladder and bowel function.

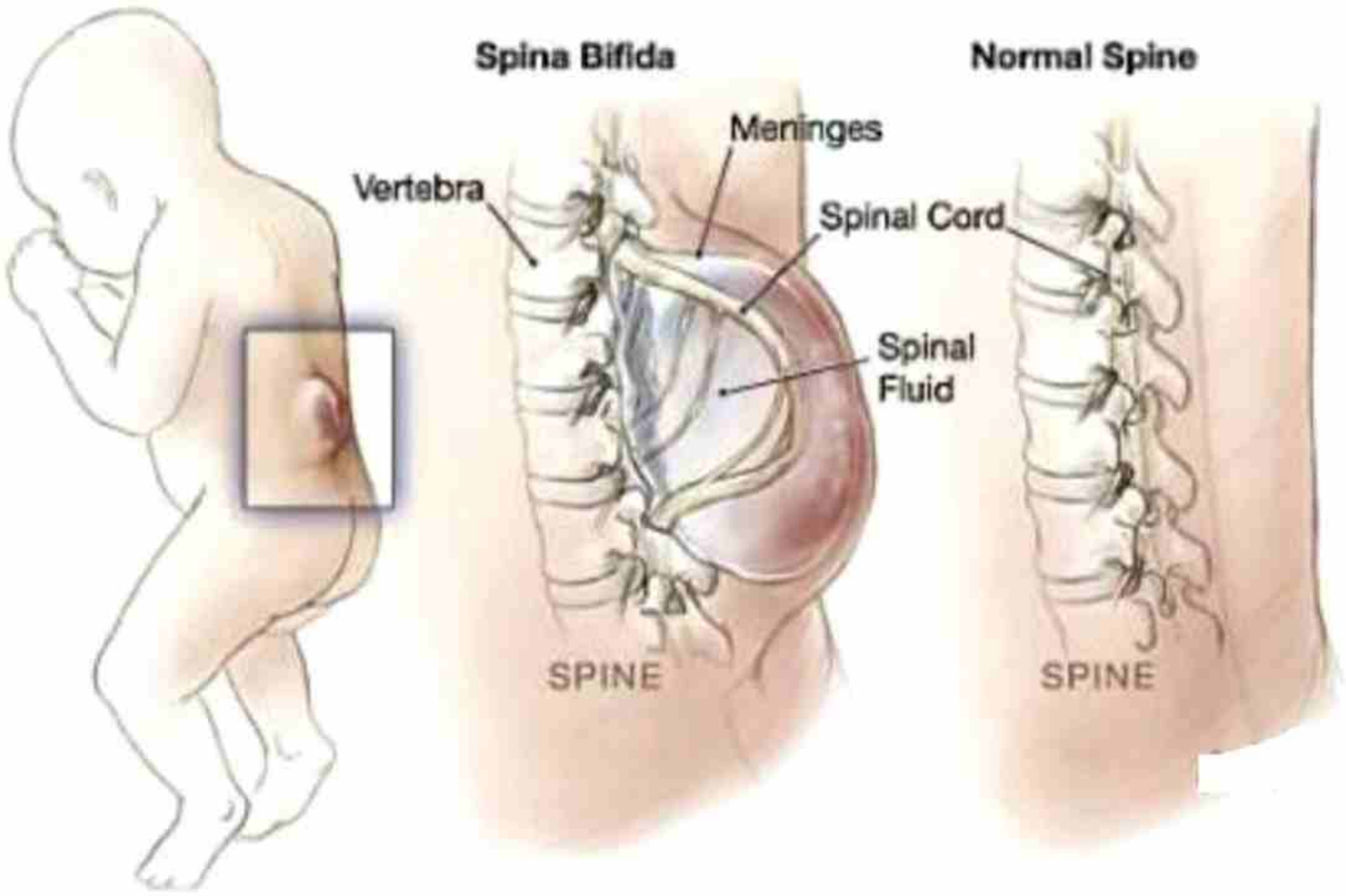


Fig. 21.14 Spina bifida and normal spine

21.5 AGING

Aging refers to the process of natural, gradual and irreversible changes that occur in living organisms over time, resulting in a decline in their physical and mental abilities. It is a biological phenomenon that affects all living organisms and is characterized by a progressive deterioration of physiological functions that eventually leads to death. The aging process is influenced by various factors such as genetics, environmental factors, lifestyle, and disease, and it varies from person to person.

21.5.1 Aging as part of normal development

Aging can be rationalized as a part of normal development because it is a natural and inevitable process that occurs in all living organisms. It is a result of progressive changes that occur in the body over time, including cellular damage, DNA damage, and metabolic changes. These changes lead to a gradual decline in the body's ability to function, resulting in death.

As humans age, they experience a decline in physical and cognitive function, including decreased muscle mass, decreased bone density, reduced sensory function, and decreased immune function. These changes can lead to an increased risk of chronic diseases, such as cardiovascular disease, diabetes, and cancer.

There are several genetic and extrinsic factors that can contribute to the aging process:

21.5.2 Aging: Genetic factors

Aging is a complex process that involves the progressive decline in cellular and physiological functions, leading to an increased vulnerability to age-related diseases.

Research has identified several genetic factors that contribute to the aging process. One of the most well-known genetic factors is the role of telomeres in aging. **Telomeres** are the protective caps at the end of chromosomes that shorten with each cell division. The length of telomeres has been associated with aging, as shorter telomeres are correlated with age-related diseases and decreased lifespan. Genetic variations in the genes that control telomere length have been linked to accelerated aging and increased risk of age-related diseases.

Another genetic factor that contributes to aging is the role of genes involved in DNA repair. As we age, the DNA in our cells becomes damaged, and if not repaired, can lead to mutations and cell death. Genetic variations in genes involved in DNA repair have been linked to increased risk of age-related diseases and decreased lifespan.

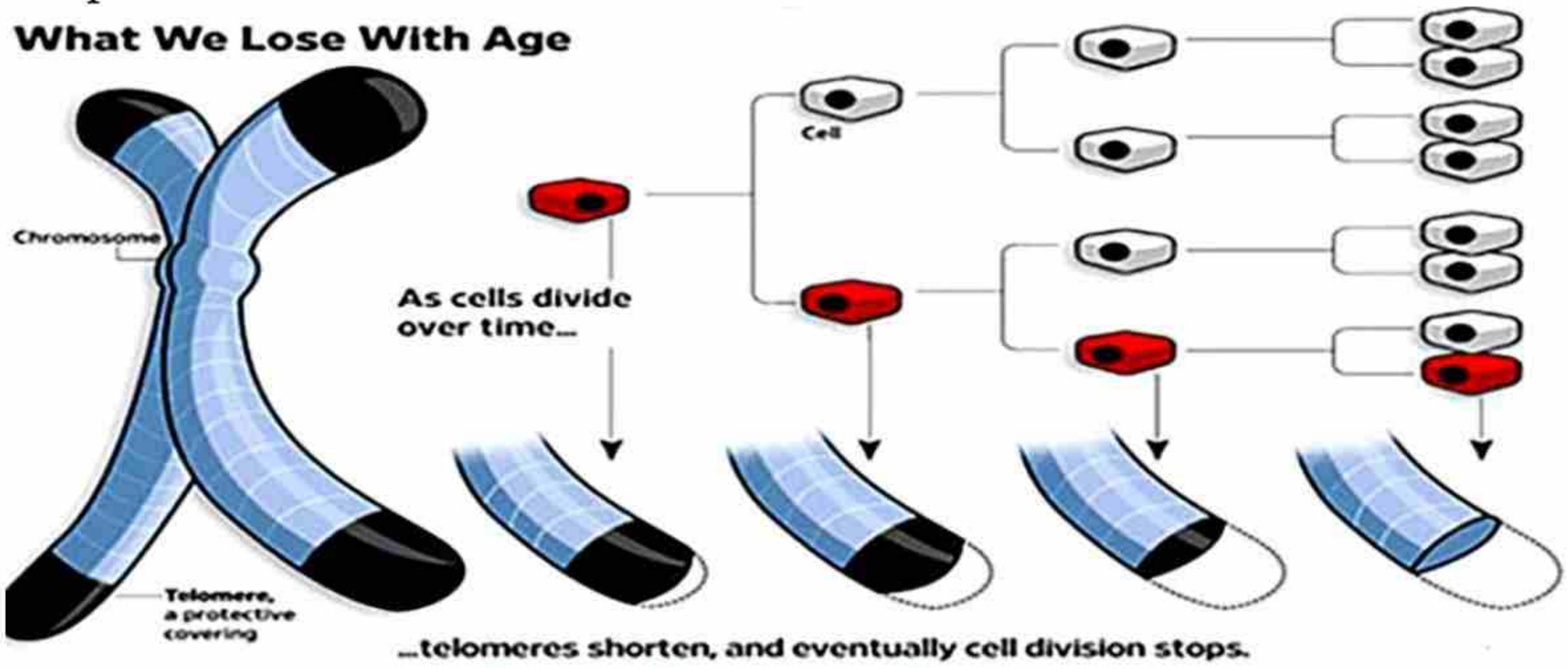


Fig. 21.15 Aging and Telomeres

In addition to telomere length and DNA repair genes, other genetic factors that contribute to aging include mitochondrial function, inflammation, and oxidative stress. Mitochondria are the energy-producing organelles in cells, and their dysfunction has been linked to aging and age-related diseases. Inflammation and oxidative stress are also key factors in aging, and genetic variations in genes that regulate these processes can influence an individual's rate of aging.

21.5.3 Extrinsic Factors

In addition to genetics, aging is also influenced by various **extrinsic** or **external factors**. These factors can include environmental, lifestyle, and social factors that can impact an individual's rate of aging.

Environmental factors such as pollution, radiation, and exposure to toxins can contribute to aging by causing damage to cellular components such as DNA, proteins, and lipids. For example, exposure to UV radiation from the sun can cause DNA damage, which can lead to mutations and cellular aging. Similarly, exposure

to air pollution has been linked to accelerated aging and increased risk of age-related diseases such as respiratory and cardiovascular disease.

Lifestyle factors such as diet, exercise, and sleep can also influence the aging process. A diet high in processed foods, sugar, and saturated fats can lead to chronic inflammation, oxidative stress, and metabolic dysfunction, which can accelerate aging and increase the risk of age-related diseases such as diabetes and heart disease. On the other hand, a diet rich in fruits, vegetables, whole grains, and lean proteins can promote cellular health and slow down the aging process.

Table 21.4 Aging Factors

Aging Factors	Description
Intrinsic	➢ Telomere length and DNA repair genes ➢ Mitochondrial dysfunction ➢ Inflammation and oxidative stress
Extrinsic	➢ Environmental factors (pollution, radiation, exposure to toxins ➢ Lifestyle factors (diet, exercise, sleep) ➢ Social factors (social support, education, socioeconomic status)

21.5.4 Primary aging

Primary aging refers to the natural, inevitable changes that occur as a person ages, and are not typically associated with disease or injury. Graying and thinning of hair occurs as melanin production decreases, while pigmented patches of skin result from an uneven distribution of melanin. Slow movements and fading vision are due to a decrease in the efficiency of nerve impulses and the gradual loss of muscle mass. Impaired hearing is often due to a gradual decline in the function of the inner ear.

Reduced ability to adapt to stress occurs due to a decrease in the body's ability to produce and regulate hormones such as cortisol. Finally, decreased resistance to infections is due to a weakened immune system caused by a decline in the function of the thymus

gland, which produces T-cells. These changes are a natural part of the aging process and occur in most people to varying degrees.

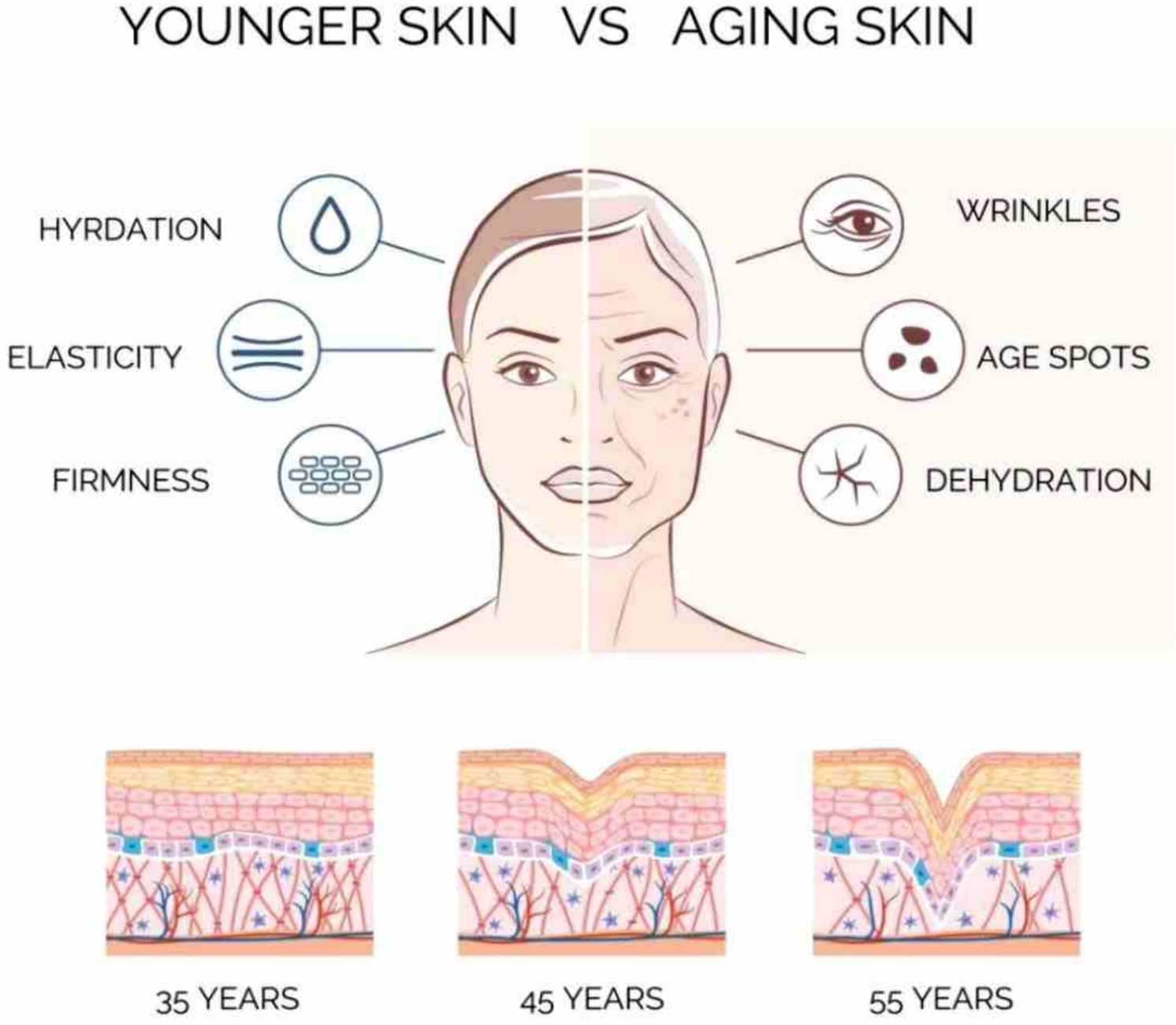


Fig. 21.16 Aging and Skin

21.5.5 Secondary aging

Secondary aging refers to body changes resulting from environmental and lifestyle factors such as disease, disuse, and abuse. These changes can accelerate the natural aging process and lead to a decline in physical and cognitive functions. Disease can be a major factor in secondary aging. Chronic conditions such as diabetes, cardiovascular disease, and cancer can have a significant impact on the body and accelerate the aging process. Infections, particularly those that are recurrent, can also contribute to secondary aging.

Lack of exercise can also accelerate aging. The muscles, bones, and joints require regular use to maintain their strength and flexibility. Without regular exercise, these structures can weaken and become more prone to injury. Abuse of substances such as smoking, alcohol, and drugs can also lead to secondary aging. Smoking is a major contributor to premature aging. It causes damage to the skin and respiratory system, and can increase the risk of heart disease, cancer, and stroke. Obesity and malnutrition can also have a significant impact on the body, leading to a range of health problems and accelerating the aging process.

Exposure to environmental factors such as ultra-violet light can also accelerate aging. Sun damage to the skin is a common example of this, leading to the development of wrinkles and age spots. Pollution, radiation, and other toxins in the environment can also contribute to secondary aging.

21.5.4 Changes that occur at the system level during aging

Cardiovascular system:

Reduced heart function, stiffening of blood vessels, and decreased blood flow to tissues.

Respiratory system: Decreased lung function and reduced oxygen supply to tissues.

Digestive system: Decreased production of digestive enzymes and reduced nutrient absorption.

Urinary system: Reduced kidney function and increased risk of urinary tract infections.

Musculoskeletal system: Reduced muscle mass, strength, and bone density, and increased risk of fractures.

21.5.5 Changes that occur at the cellular level during aging include:

DNA damage: Accumulation of DNA damage can lead to mutations and cellular dysfunction.

Telomere shortening: Telomeres, the protective caps at the ends of chromosomes, shorten with each cell division, leading to cellular senescence.

Mitochondrial dysfunction: Mitochondria, the energy-producing organelles in cells, become less efficient and generate more harmful byproducts as they age.

Oxidative stress: Accumulation of reactive oxygen species (ROS) can damage cellular components and contribute to aging-related diseases.

Inflammation: Chronic inflammation is a hallmark of aging and can contribute to age-related diseases such as cardiovascular disease, diabetes, and cancer

21.5.6 Age-related diseases & Medical science

Here is a list of age-related diseases along with their brief descriptions and common medical interventions:

Table 21.5 Age-related diseases & Medical science

Disease	Description	Medical Interventions
Cardiovascular disease	A group of conditions that affect the heart and blood vessels	Medications, lifestyle changes, surgical procedures
Alzheimer's disease	A progressive brain disorder that affects memory and cognitive function	Medications, cognitive/behavioral therapies, lifestyle changes
Osteoporosis	A condition that causes bone loss and increases the risk of fractures	Medications, calcium/vitamin D supplements, weight-bearing exercises
Arthritis	A group of conditions that cause joint pain, stiffness, and swelling	Medications, physical therapy, joint replacement surgery
Age-related macular degeneration	A progressive eye disease that can cause vision loss	Medications, laser therapy, surgical procedures
Type 2 diabetes	A chronic condition that affects how the body processes blood sugar	Medications, lifestyle changes, insulin therapy

SUMMARY

- Human embryonic development involves a series of stages that result in the formation of a foetus.
- The process of development is regulated by a combination of genetic, environmental, and epigenetic factors.
- During pregnancy, the mother undergoes significant physiological changes to support the developing foetus.
- The three trimesters of pregnancy are characterized by different stages of foetal development and maternal adaptations.
- Abnormalities in embryonic development can result in birth defects, genetic disorders, or miscarriage.
- Aging is a complex process that is influenced by both genetic and environmental factors.
- Age-related changes can occur in tissues, organs, and systems throughout the body, leading to a decline in function and increased risk for disease.
- The study of aging involves multiple disciplines, including genetics, physiology, and psychology.
- Genetic factors play a significant role in determining lifespan and the risk for age-related diseases.
- Environmental factors, such as diet, exercise, and exposure to toxins, can influence the aging process and disease risk.
- Interventions aimed at slowing or reversing aging include lifestyle modifications, pharmaceuticals, and gene therapies.
- The use of these interventions raises ethical, social, and economic issues related to access, safety, and societal values.
- The study of human embryonic development, pregnancy, disorders, and aging is important for understanding human health and disease.
- Studying human development and aging requires a multidisciplinary approach that draws on knowledge from genetics, developmental biology, physiology, psychology, and other fields.

EXERCISE

1. Encircle the correct choice

i) The genetic material of a fertilized egg is a combination of
(a) The mother's DNA only
(b) The father's DNA only
(c) Both the mother's and father's DNA
(d) None of the above

ii) Human embryonic development occurs in the
(a) Uterus (b) Fallopian tube
(c) Cervix (d) Vagina

iii) The process of cell differentiation involves:
(a) The formation of gametes
(b) The formation of zygotes
(c) The specialization of cells for different functions
(d) The replication of DNA

iv) The implantation of the embryo in the uterus occurs at
(a) 1 week after fertilization (b) 2 weeks after fertilization
(c) 4 weeks after fertilization (d) 8 weeks after fertilization

v) Aging is characterized by:
(a) The accumulation of genetic mutations
(b) The breakdown of cellular processes
(c) The cessation of mitosis
(d) The reduction in DNA replication

vi) The inner cell mass of a blastocyst gives rise to:
(a) The placenta (b) The embryo
(c) The umbilical cord (d) The amniotic fluid

vii) The process of fertilization occurs in the
(a) Uterus (b) Fallopian tube
(c) Cervix (d) Vagina Answer

viii) The stages of embryonic development are
(a) Cleavage, implantation, gastrulation, and organogenesis
(b) Fertilization, implantation, gastrulation, and organogenesis
(c) Cleavage, fertilization, gastrulation, and organogenesis
(d) Cleavage, fertilization, implantation, and organogenesis

ix) The placenta is responsible for
(a) Providing oxygen and nutrients to the developing embryo
(b) Removing waste products from the developing embryo
(c) Producing hormones that maintain the pregnancy
(d) All of the above

x) The formation of the neural tube occurs during
(a) Cleavage (b) Gastrulation
(c) Organogenesis (d) Implantation

2. Write short answer of the following:

i) Why cleavage in birds and reptiles called meroblastic?
ii) Why morula is named so?
iii) How embryonic tissues influence other embryonic tissues?
iv) Define organizers and differentiate between primary and secondary induction.
v) Differentiate between blastula and gastrula.
vi) Why monozygotic twins having same sex?

3. Write detailed answers to the following questions.

i) Explain blastula/blastocyst with emphasis on segmentation cavity.
ii) List the tissues and organs formed from the three germ layers.
iii) Through experimental narration, describe the role of the nucleus and cytoplasm in controlling development.
iv) Describe the events of development in humans in terms of first, second and third trimesters.
v) Describe the maternal derived abnormalities (rubella, abnormal neural tube, thyroid gland and limb development).

CHROMOSOME AND DNA

Chapter 22

Major Concept

In this Unit you will learn:

- Chromosomal Theory of Inheritance
- DNA as the hereditary material
- DNA Replication
- Gene Expression
- Regulation of Gene Expression
- Mutation

As we have studied in o ur previous classes that the nucleus of a cell contain a network of chromatin material. When it is placed in a dye this material became darkly stained to made it prominent. This chromatin material during cell-division condenses to form specific type of threads called **chromosome**. We have also studied about Mendelian imaginary unit of inheritance which he named **factors**. In this chapter we will study about the reality of Mendelian factors and its relation with chromosome

22.1 CHROMOSOMAL THEORY OF INHERITANCE

In 1860s Mendel presented his law of inheritance but unfortunately at that time no one was there to recognize his valueable work. He was unaware about the concept of chromosome. In 1900s and late 1890s so many cytologist work on cellular structure and chromosome so in 1900 Mendel's work got recognized by three European scientists **Hugo de varies**, **carl Corren** and **Erich Von Tschermark**. With these other scientists like **Walter Fleming**, **Waldeyer Walter Sutton**, **T. H. Morgan** and **Theodar Boven** also worked on chromosome structures, numbers and behavior during inheritance and sexual reproduction.

Carl Correns

22.1.1 History of chromosomal theory

The German embryologist Walter Fleming (1882) was the first scientist who put foundation stone for chromosomal theory by discovery of chromosome. He observed the dividing cell of salamander larvae where he found there thread like highly stained bodies and termed as coloured bodies i.e. Chromosome. The other two scientists who made major contribution for this theory, they were Walter Sutton an American graduate student of E. B. Willson's at Columbia University and Theodar a German biologist, both independently observed the behavior of chromosome distribution in sperms and eggs during meiosis. They observed that in somatic cell each chromosomes are found in pair but during meiosis the

members of each pair segregate so the sperm and egg receives only one from there W. Sutton observed the cells of Grass hopper and found that the segregation pattern of chromosomes during meiosis matched the segregation pattern of Mendel's genes, so 1902 he published his finding in a paper with the title "**The chromosome in Hereditary**". The same findings were observed by T. Boven that chromosomes number are reduced in half as egg cell matures and concluded that sperm and egg nucleus have one set of chromosomes rather than as found in all body cell.

In 1890 a German geneticist **Carl Correns**. He rediscovered and independently verified Mendel's work in a separate model organism and published his first paper on 25 January 1900 with the title "**Mendel's law concerning the behavior of progeny of Racial Hybrids**", where first time he developed the relationship of hereditary units with chromosomes.

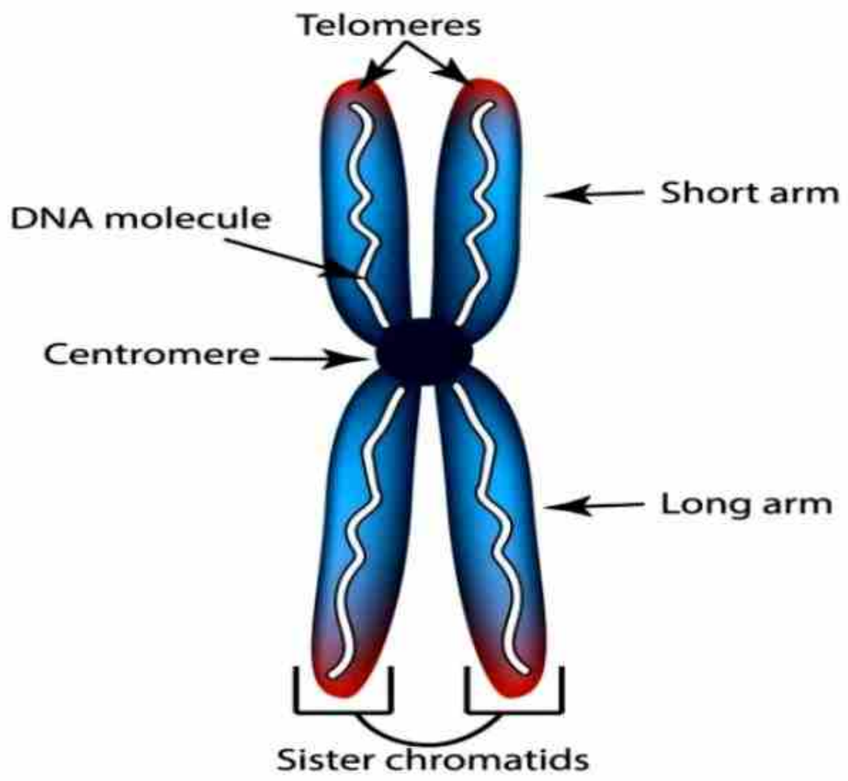


Fig. 22.1 *Chromosome*

Statement and evidences of chromosomal theory of inheritance

The research of many biologists which is discussed above led to the chromosomal theory of inheritance first formulated by W. Sutton in 1902. It states that the genes are located at chromosomes, which inherit through chromosomes of gametes cells, so chromosomes act as carriers of hereditary, the theory was supported by following evidences based on the research of different biologist.

Walter Sutton

1) Sexual reproduction involves the initial union of only two cells i.e. egg and sperm. If Mendel's model is correct then these two gametes must make equal hereditary contributions, sperm however contains little cytoplasm, therefore, considered that the hereditary material must reside within the nucleus of gametes.
2) Chromosomes segregate during meiosis in a manner similar to the Mendelian "factors" segregate according to law of segregation.
3) Gametes have one copy of each pair of homologous chromosomes, diploid individual has two copies. In Mendelian model gametes have one copy of the factor while diploid individuals have two copies.
4) During meiosis, each pair of homologous chromosomes orients on the metaphase plate, independent of any other pair. Thus, independent assortments of chromosomes are like factors of assorted trait as explained by Mendels law of independent assortment.

There was one problem with this theory as many investigators soon pointed out. If Mendelian traits are determined by factors located on the chromosomes and if the independent assortment of Mandelian traits reflects the independent assortment of these chromosomes in meiosis, why is it that the number of factors that assort independently of one another in a given type of organisms is often greater in number of chromosomes pairs that the organism possess? This seemed a fatal objection and it led many early researchers have serious reservations about Sutton's theory.

22.1.2 Experimental Verification By T.H Morgan To Chromosomal Theory Of Inheritance

Thomas Hunt Morgan in 1910 performed various breeding experiments with wild type red-eyed *Drosophila melanogaster* flies. He noticed a white eyed male mutant, crossed this white eyed male with true red-eyed female. The F_1 and F_2 population followed the simple Mendelian ratios but when white-eyed female was crossed with red-eyed male, the results were different.

All F_1 progeny had red eyes when members of F_1 generation crossed with each other. He found 18% white eyed and remaining were red-eyed. Although the ratio of red eyes to white eyes in F_2

generation was greater than 3 : 1, the result of cross was clearly showed the segregation of eye colour factors but a strange and unpredicted result was also there that in F_2 generation all white eyed Drosophita were male.

The above result left many questions unanswered. Do it was impossible to have white eyed in female? Do white eyed female are unable to survive? To get the answers of the above questions Morgan made original test cross between female of F_1 generation and the original white eyed male. He obtained both white eyed and red eyed males and females in a ratio of 1 : 1 : 1 : 1 now it is clear that a female could have white eyes. Only question was left behind that why there were no white eyed female among the progeny of original cross?

T.H Morgan

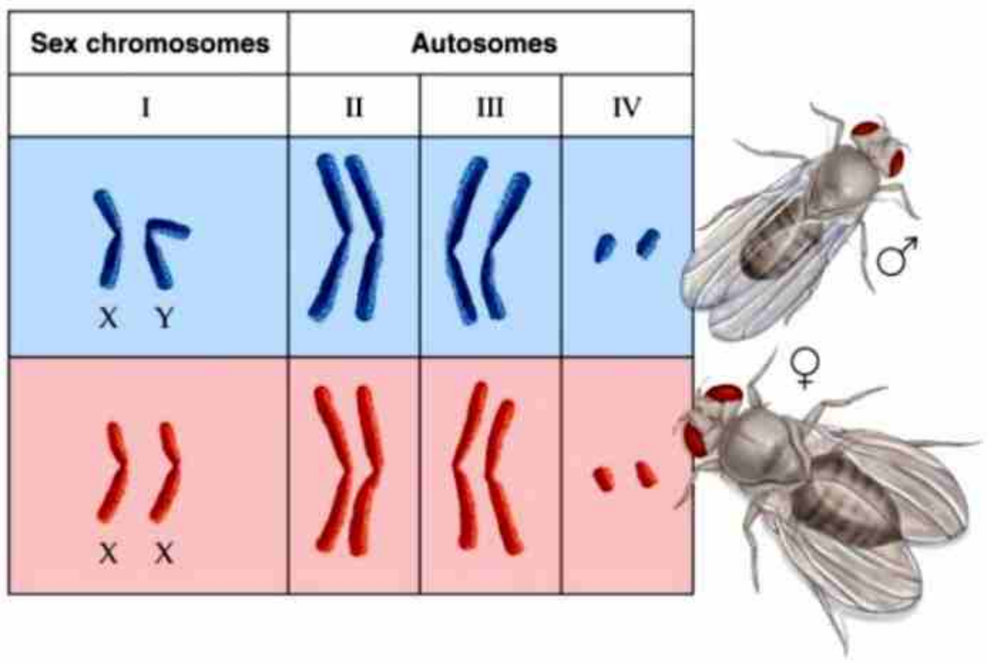


Fig.22.2. ***Drosophila and its Karyotype***

22.1.3 Chromosomes (Chroma = Colour, Soma = Body)

The literal meaning of chromosomes is coloured body but the chromosomes are not coloured bodies therefore this term is called misnomer. They were first observed by a German embryologist **Walter Fleming** in 1882 when he stained Salamander larval cell with a dye called **Perkin's Aniline**. He found darkly stained threads which he named chromosome. **Chromosomes** are thread like structure made up of highly condensed chromatin material, appear during cell-division in specific numbers according to species, and carry gene on it. In the beginning of cell-division each chromosome is consist of two identical threads which are attached with each other and called

sister chromatids. Each chromatid contains a **primary constriction** which is called **centromere** and sometime another constriction is also present called **secondary constriction**. Each chromatid consists of one or two arms. On the basis of centromere position the chromosomes are classified into 4 types i.e. **Metacentric**, equal arms where centromere is located exact in the center. If the centromere is located slightly away from center the slightly unequal arms develop these chromosome called **Sub-metacentric**, if centromere located away from center so the two arms become unique chromosome called **Sub-telocentric** or **Acrocentric,** if it is located at end called **Telocentric**.

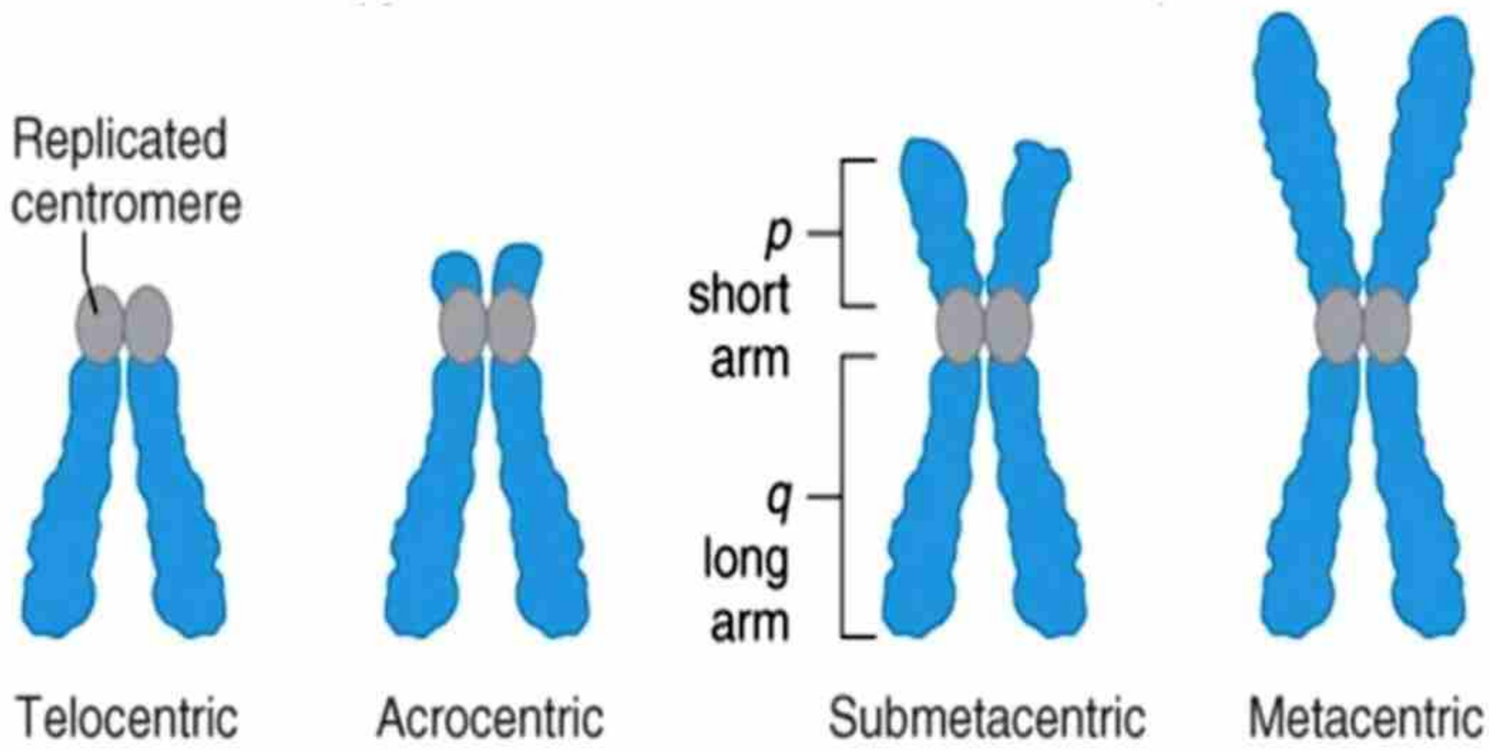


Fig.22.3. Types of Chromosomes

The secondary constriction may present which is also called **nuclear organizer**, develop from nucleolus during interphase. Due to secondary constriction, the end of chromosomes become knob like called **Satellite** which contain useless DNA i.e junk DNA called the terminated end of chromosome called **Telomeres**, require to prevent attachment of two chromosomes.

22.1.3.1 Chemical composition of chromosomes

Chromosomes are nucleoprotein made up of 40% DNA and 60% protein, a significant amount of RNA is also present due to site of RNA synthesis but RNA is not the constituent part of chromosome.

The highly condensed, double stranded, very long DNA is present in chromosome which is unbroken through the entire length of a chromosome, If the strands of DNA from a single set of human chromosome were laid out in a straight line it would be more than 7 feet (2 meter) long, this is too long to fit into a cell.

Now the question arises here how is the coiling of this long DNA fiber achieved, On examination of eukaryotic chromosome under electron microscope it was found like a string of beads. Where 200 nucleotide containing DNA duplex is coiled around an octamer of histone protein, which are small in size with high amount of basic amino acid i.e Arginine and Lysine. The octamer of histone form core which is highly positive in charge due to basic amino acids attracted by negatively charged DNA due to phosphate. The DNA wrapped around octamer and forms a unit called **nucleosome**. The nucleosome or histone core thus acts as magnetic forms that promote and guide the coiling of DNA. Further coiling occurs when the string of nucleosome wraps up into higher order called **Super coil**.

The organization of chromosome occurs in three stages.

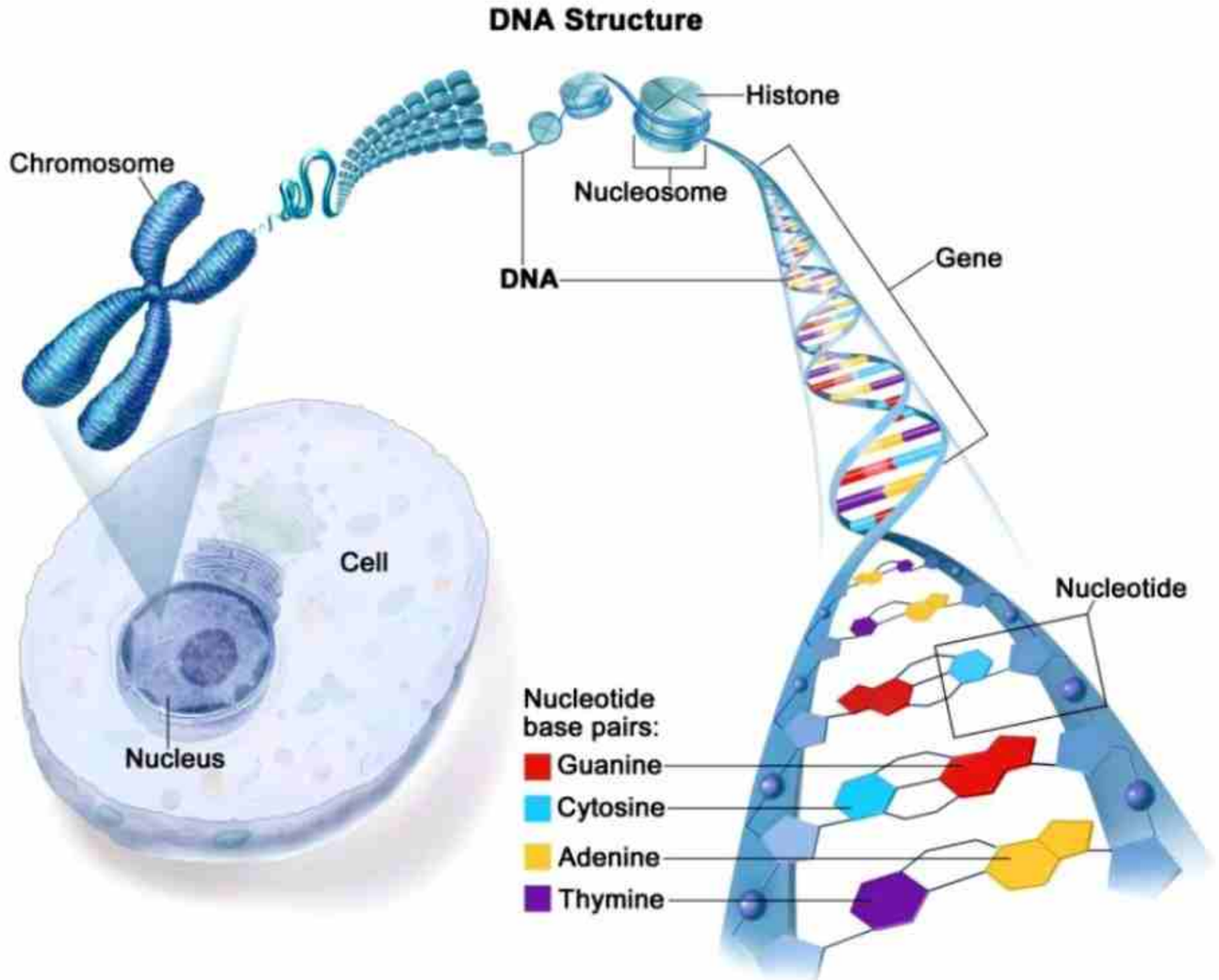


Fig.22.4. Ultra structure of Chromosome

i) Nucleosome string formation

During S-phase of cell-cycle, just after replication of DNA, negatively charged DNA coiled around a positively charge histone core which result in the formation of a complex called **nucleosome**. Each nucleosome is linked by a small segment of DNA called linker DNA 2nm thick. In this way a chain of bead appearance is formed called **Nucleosome string (10nm thick)**

ii) Chromatin fiber

Nucleosome string begins to coil again at its axis. In this way another thick fiber of 30nm is formed called **Chromatin fiber**. During G_2 phase of interphase chromatin fiber shows two regions i.e. **Heterochromatin** and **Euchromatin**. Heterochromatin is highly condensed and unexpressed while euchromatin in non-condensed it becomes condensed only during cell-division. The genes of euchromatin expressed and establish uniform chromatin fiber.

iii) Super coil formation to form chromatids

During prophase of cell-division chromatin fiber starts higher order of coiling from a super coiled structure of 300 nm. Immediately super coil developed into chromatids of 700 nm.

22.1.4 GENE AND GENE LOCUS

In 19th century Gregor John Mendel first time introduce the concept of gene which controls the expression of a character. He introduced it as "**factor**" and represented it by letter. In Biology a **gene** (Gr: genos meaning generation of birth or gender) is a basic unit of hereditary. Twenty years later in 1909, William Johansen introduced the term "**gene**" and 1906 geneticist **William Bateson** and **Eduard Strasburger** used the term "**Pangene**" for fundamental physical and functional unit of hereditary.

Now a day the gene is a small part of DNA which has information to synthesize specific polypeptide chain which work as enzyme to metabolize a specific reaction in a living organism. It means physically a gene is made up of nucleotide sequences.

Previously we have discussed chromosomal theory of inheritance according to it the genes are located at chromosomes. Each gene is located at its fixed position at particular chromosome.

This position of gene on chromosome is called **"gene locus"** (Pl: loci) we already know that both parents of an organism donated one set of chromosome so each cell usually contain two sets of chromosomes (Diploid cells). In this way each cell contain pairs of chromosomes, each pair contain maternal and paternal chromosomes if these chromosomes are morphologically similar and have same gene loci called **homologous chromosome**, if they are morphologically different chromosome and have different gene loci called **heterologous chromosome**. At homologous chromosome the gene of a trait at particular locus may be similar or different e.g. the gene of skin colour is located at same gene locus on both chromosomes. It may be of black colour on both or it may be of different colour i.e. black or white, this alternative form of a gene for a trait located at same gene locus called **alleles**. Mendel found two alleles for each traits. Mendel observed seven traits in *Pisum* plants and found two alternative forms in each trait. For example his length of *Pisum* plant trait had two alternative forms i.e. tall and dwarf both are controlled by different genes. These alternative forms located at same gene locus on homologous chromosomes are called allele. Now it is found that many traits have number of alternative forms, not only two like Mendelian traits.

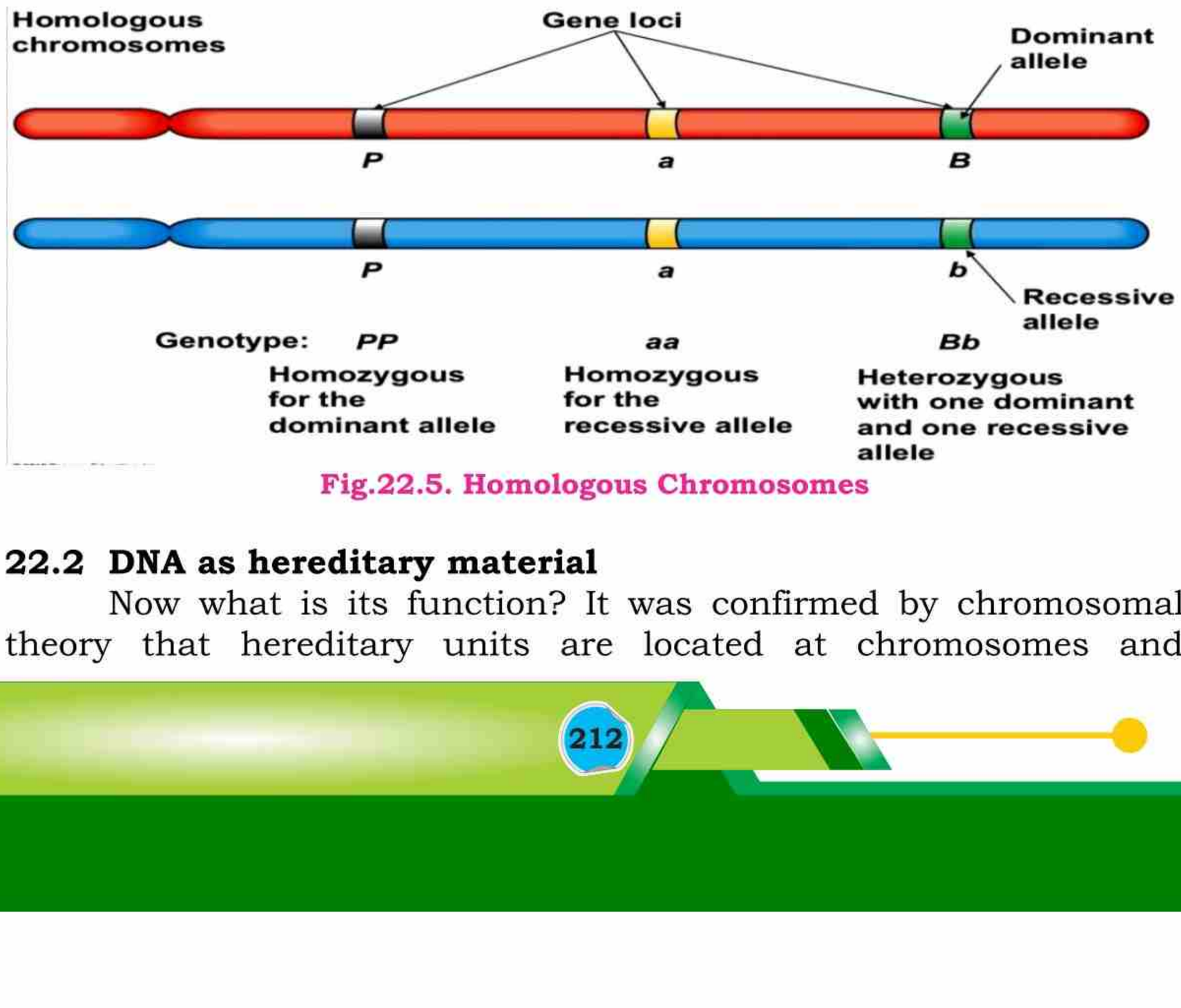


Fig.22.5. Homologous Chromosomes

22.2 DNA as hereditary material

Now what is its function? It was confirmed by chromosomal theory that hereditary units are located at chromosomes and

transformed through chromosomes from one generation to other. Whereas chemically chromosomes are made up of only DNA and protein. So question arises here which of the molecules work as heredity material or both combinely works as hereditary units. A series of experimental work had conducted by different scientists to reveal this mystery. In the beginning Fredrick Griffith had some success.

22.2.1 Evidence of DNA as hereditary material

Streptococcus pneumonia, a bacterium cause pneumonia found in two strands i.e. capsulated smooth form (S-type) and non-capsulate (R-type) S-type virulent while R-type are non-virulent both are genetically variable.

Fredrick Griffith designed some experiment, during the course of experiments. He injected R-type in laboratory mice and observed no ill effect on them whereas the injection of S-type proved fatal for mice. It was also observed that if both strains are heated, both killed at high temperature.

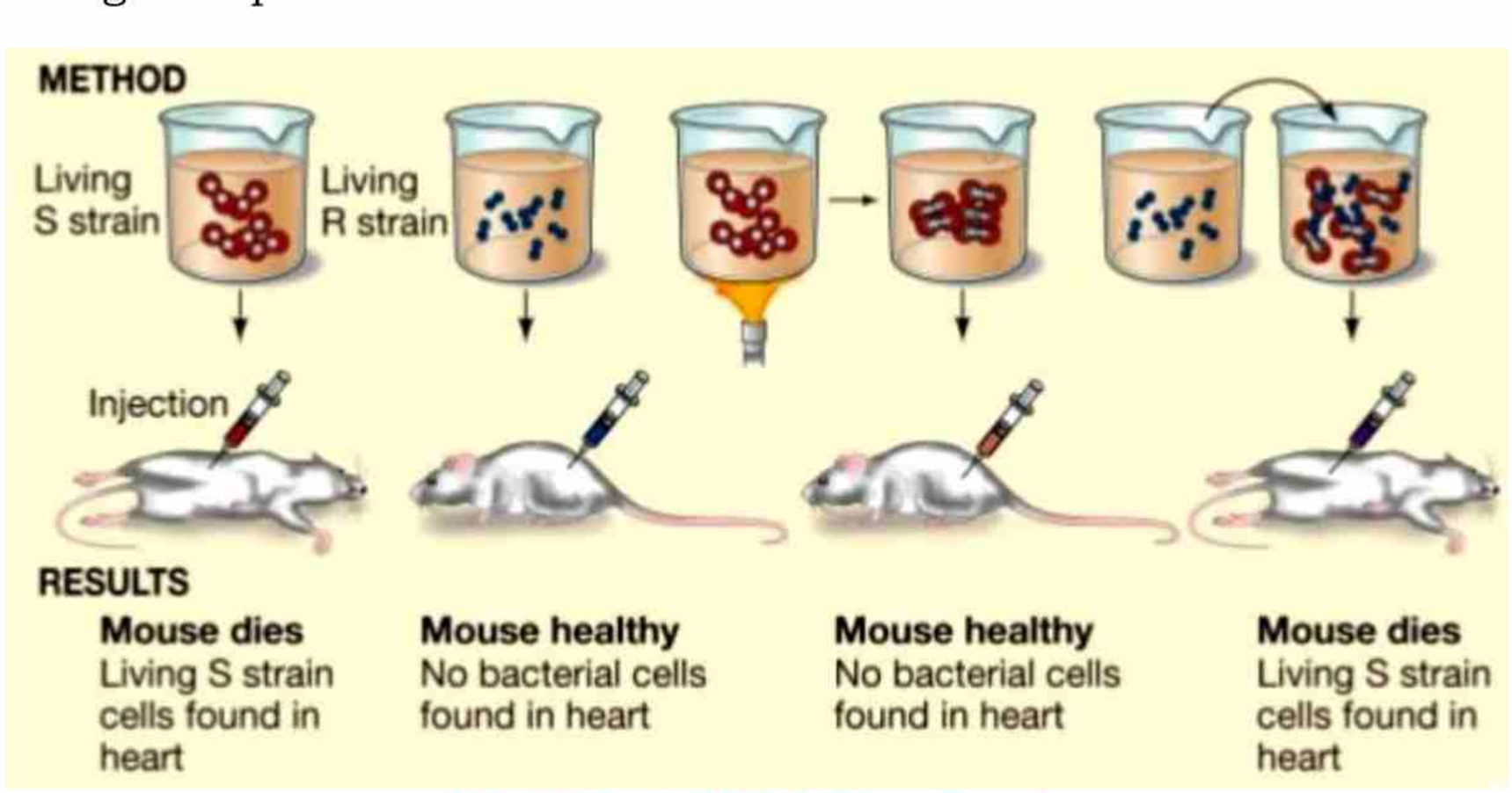


Fig.22.6. Griffith's Experiment

When heat killed S-type injected to nice no ill effect were observed on mice so it was concluded that alive R-type and heat

killed S-type had no ill effects on mice. He designed some more experiments and found unexpected results. He found when live R-type were injected to mice and heat killed S-type injected to same mice, high mortality of mice were observed. These experiment, were conducted in 1928, at that time he has no satisfactory explanation of these results. It was thought that heat killed S-type somehow become alive in the mice, but it was unacceptable. It was concluded that R-type become S-type when they come in contact with heat killed S-type. The phenomenon in which heat killed S-type could have hereditary effect on R-type is called **Transformation**.

Nearby 16 years later in 1944, Avery, MacLeod, and McCarty discovered and identify the transforming material of Griffith. They tested reaction of heat killed bacteria for their transforming ability and found out that it was not RNA or various proteins but only DNA that possessed transforming property. If the enzyme deoxyribonuclease that hydrolyses DNA was added to the heat killed S-type bacteria, the transforming property was lost. Therefore it has become clear beyond any doubt that DNA must be the genetic material.

22.2.2 Hershey and Chase

Alfred Hershey and **Martha Chase** in 1952 performed experiments on bacteriophage after findings of Avery and co-workers. They chose bacteriophage as experimental material because the composition of chromosome and bacteriophage are similar both are made up of DNA and proteins. During lytic life cycle bacteriophage produce so many new phages but at that time no one knew that which of the molecule of phage work as hereditary material so Hershey and Chase developed experiments to find out the hereditary material of Bacteriophage.

During their experiment they radio labeled DNA of bacteriophage with $\mathbf{P^{32}}$ and its protein coat with $\mathbf{S^{35}}$. The labeled viruses were permitted to attack the bacteria. The new phages which were coming out from host contain only P^{32} not S^{35}, the S^{35} was found in medium on the basis of these result it was cleared that only

P^{32} containing DNA entered in host are directed to produce new phages. It showed that the DNA worked as hereditary material.

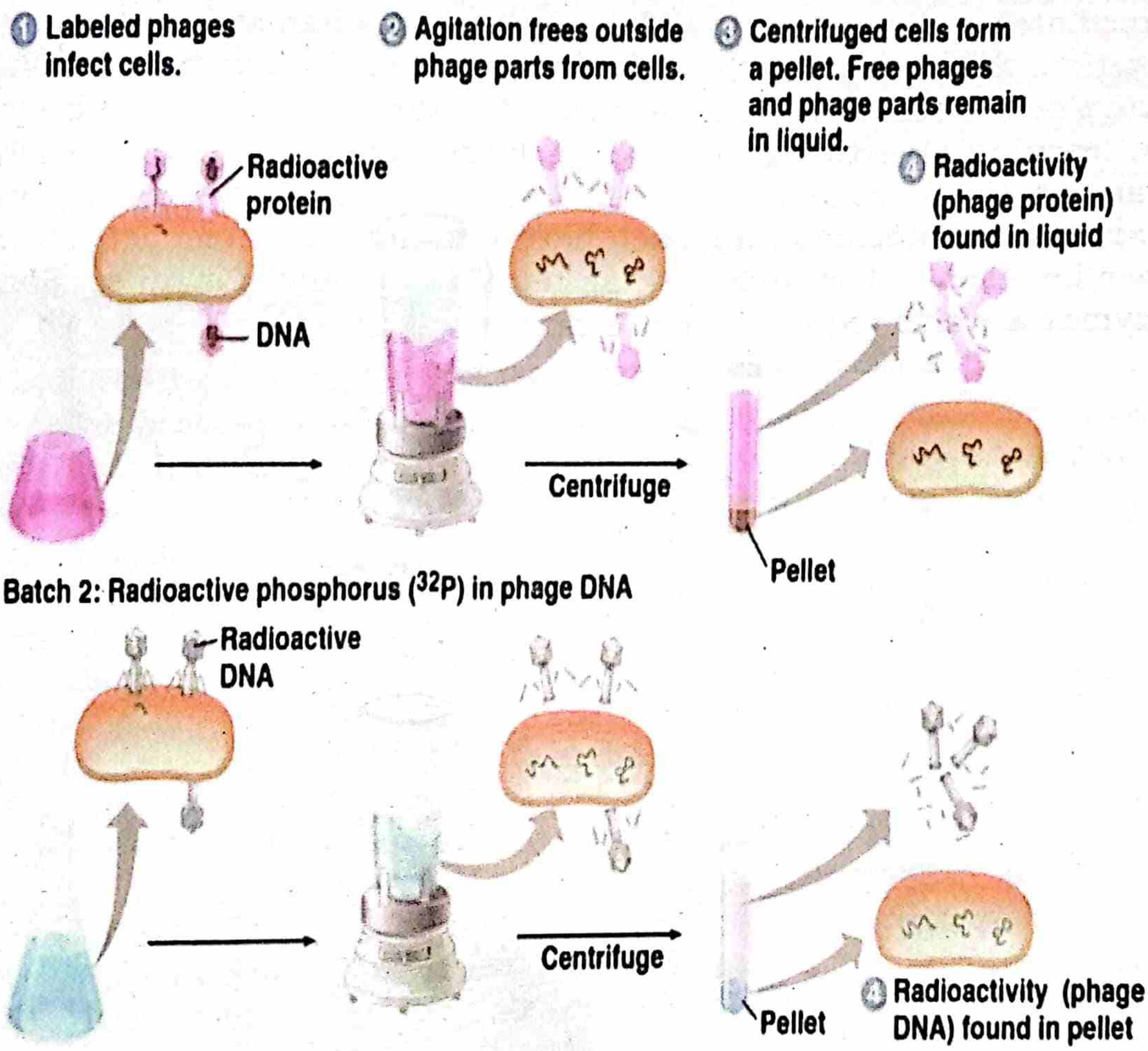


Fig.22.7. Hershey and Chase experiment

22.3 DNA REPLICAITON

The Watson and Crick Model of DNA suggest that DNA is double helix where specific pairing of nitrogenous bases occurs. They also understood the functional significance of base-pairing rules. They ended their classic paper with this statement "It has not escaped our notice that the specific pairing we have postulated immediately suggests possible copying mechanism for genetic material, this exact copying of DNA is called duplication of DNA, occurs before cell-division in S-Phase of interphase during cell-cycle. The learning objective here is to visualize how a cell copies a DNA strands to form another DNA by following base-pairing rules. The two strands are complementary, each have information to reconstruct the other i.e. each old strand work as template (mould) for other. Some enzymes are also required for this process.

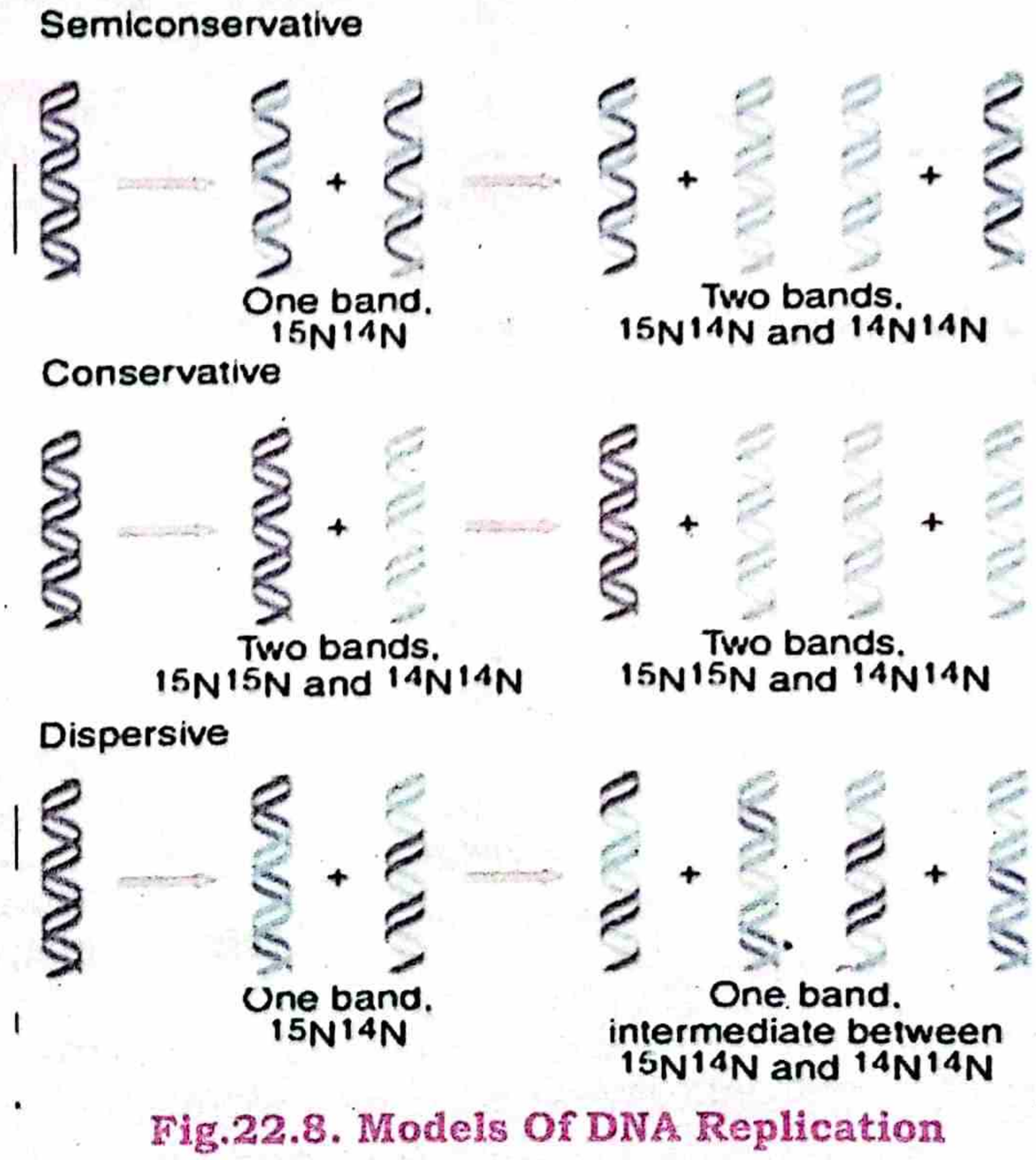


Fig.22.8. Models Of DNA Replication

22.3.1 Models of DNA Replication

The Mechanism of DNA replication was not clear. To understand this mechanism three models were proposed, these were (i) Conservative, (ii) Semi conservative, (iii) Disperssive model.

(i) Conservative Model: According to this model, the parental double helix remains intact i.e. conserved and the new molecule is formed entirely from scratch (all new copy).

(ii) Semi Conservative Model: According to this model, the two strands of parential DNA molecule separate, and each function as template for the synthesis of new complementary strands. It means the two daughter molecules formed as a result of replication, each contains one parental (old) and one newly formed DNA strand. It means some part of parental DNA is conserved.

(iii) Disperssive Model: In this model, all four strands of DNA after replication have mixture of old and new DNA.

22.3.2 Replication of DNA is Semi Conservative

The process of DNA replication suggested by Watson and Crick model is called semi conservative process because after one round of replication, the original duplex is not conserved, instead, each strand of the duplex become part of the other duplex. This prediction of Watson – Crick model was tested in 1958 by Mathew Meselson and Frank Stahl of the California Institute of Technology.

They grew bacteria for several generations in a medium containing heavy isotopes of Nitrogen (N^{15}). In this way the DNA of bacteria were, eventually denser than. Normal (N^{14}). They then transfered the growing cells to a new medium containing lighter isotope of Nitrogen (N^{14}) and harvested the DNA at various intervals.

At first, the bacteria grow in N^{15} produce all DNA contained N^{15}, but the bacteria grow in N^{14} manufactured DNA with only N^{14} in their DNA. After one round of DNA replication this bacteria which transferred from N^{15} to N^{14}, the density of the bacterial DNA has decreased to value intermediate between all light isotope and all heavy isotopes DNA. After another round of replication, two density classes were observed, one intermediate and other light isotopes, corresponding to DNA that include none of the heavy isotope. These results indicated that after one round of replication each daughter DNA duplex possessed one of the labeled heavy strand of parent molecule. When this hybrid duplex replicated, it contributed one heavy strand to form another hybrid duplex and one light strand to

form a lighter duplex, Meselson and Stahl's experiment thus clearly confirmed production of the Watson and Crick model that DNA replicate in a semi conservative manner.

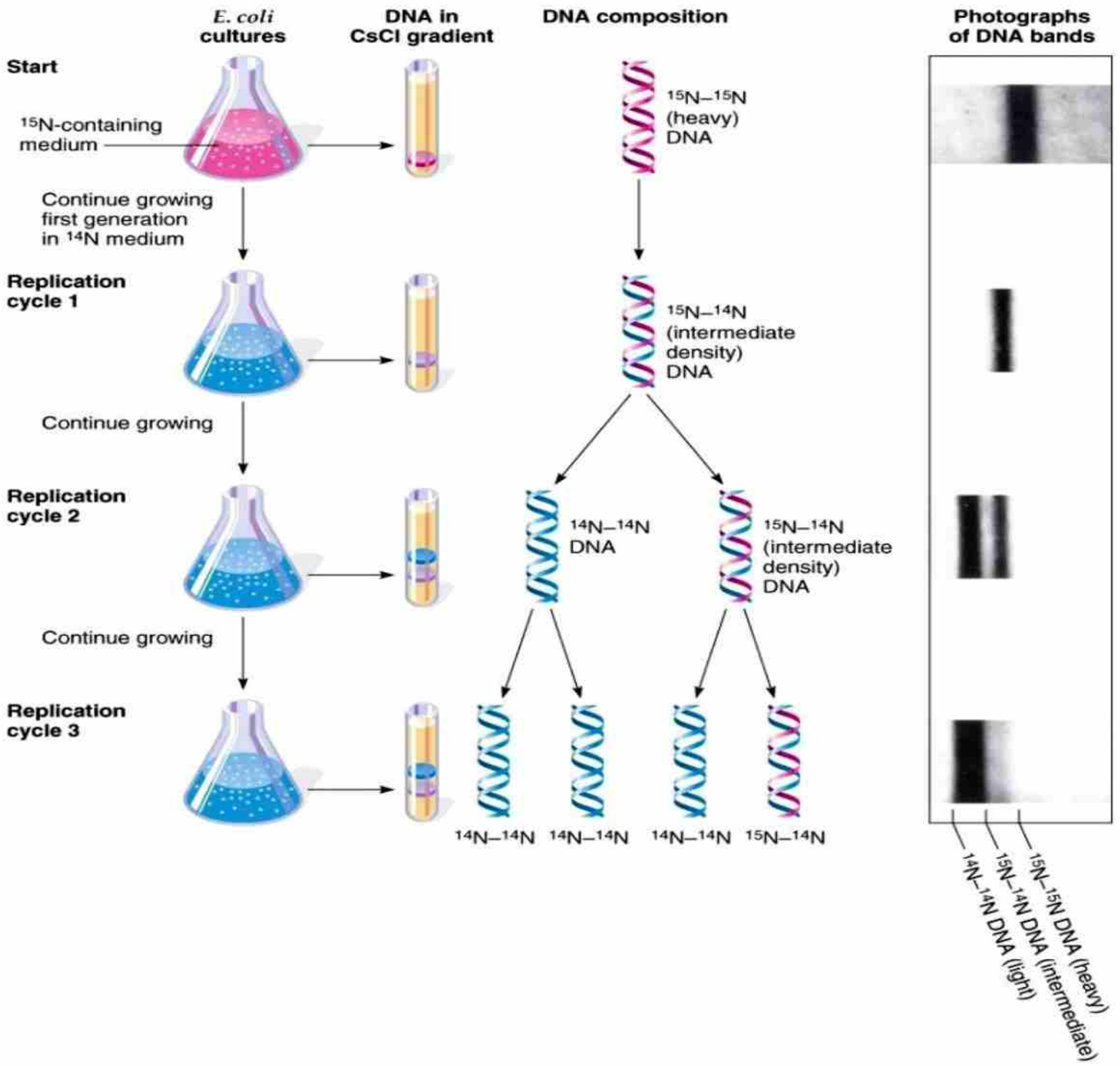


Fig.22.9. Meselson and Sthal Experiment

22.3.3 Process Of DNA Replication

The copying of DNA is remarkable in its speed and accuracy, more than a dozen enzymes and protein participate in DNA replication with number of nucleotides. The basic step of replication in prokaryote and eukaryote seems to be similar with minor

differences. We can divide this mechanism in following steps for our understanding.

(a) Origin of Replication:

The replication of DNA molecules starts at specific site called **origin of replication**. In prokaryotes a single origin site having a specific sequence of nucleotides. In eukaryotes each chromosomal DNA has hundreds and thousands of Origin of replications".

The enzyme **helicase** recognize these origin sites and open the turn of DNA duplex by breaking H-bonds present between complementary base pairs. In this way two strands of DNA are separated. Another enzyme **DNA gyrase** also works little ahead the DNA helicase to facilitate in unwinding of DNA duplex by reducing the tension created during unwinding process. As a result the complementary strands of DNA duplex gradually separate from each other which form a bubble like structure called **replication bubble**. A protein also work to prevent the re-binding of complementary strand of replication bubble, this protein is called **single stranded binding proteins (SSB)**. Both of these stranded DNA work as template for new strand of DNA. The fork like shape is formed by two separated strands of DNA called **replication fork**.

(b) Elongation of New Strands:

The phase of replication where daughter strands are formed, this elongation of new DNA strands at replication fork is catalyzed by enzymes called **DNA polymerases**. Three types of DNA polymerases are found with the name of DNA polymerase I, II and III. They perform different functions during this elongation phase. The elongation only takes place from 3' end of replication fork strand. Thus a new DNA strand can elongate only in the direction of 5' $\rightarrow$ 3'. Along one template strand, DNA polymerase synthesizes a continuous DNA strand by elongating the DNA in 5' $\rightarrow$ 3' direction called **leading strand**. To elongate other new strand of DNA polymerase work along the template away from the replication fork, and synthesize a short segment of DNA. As the bubble widen another short segment of this strand is formed this strand is synthesized in small segments these segments are called **Okazaki fragments**. Each

segment contains 100 to 200 nucleotides in eukaryotic cell. These segments are joined together by an enzyme called **DNA ligase** to form a simple DNA strand. This strand called **lagging strand**.

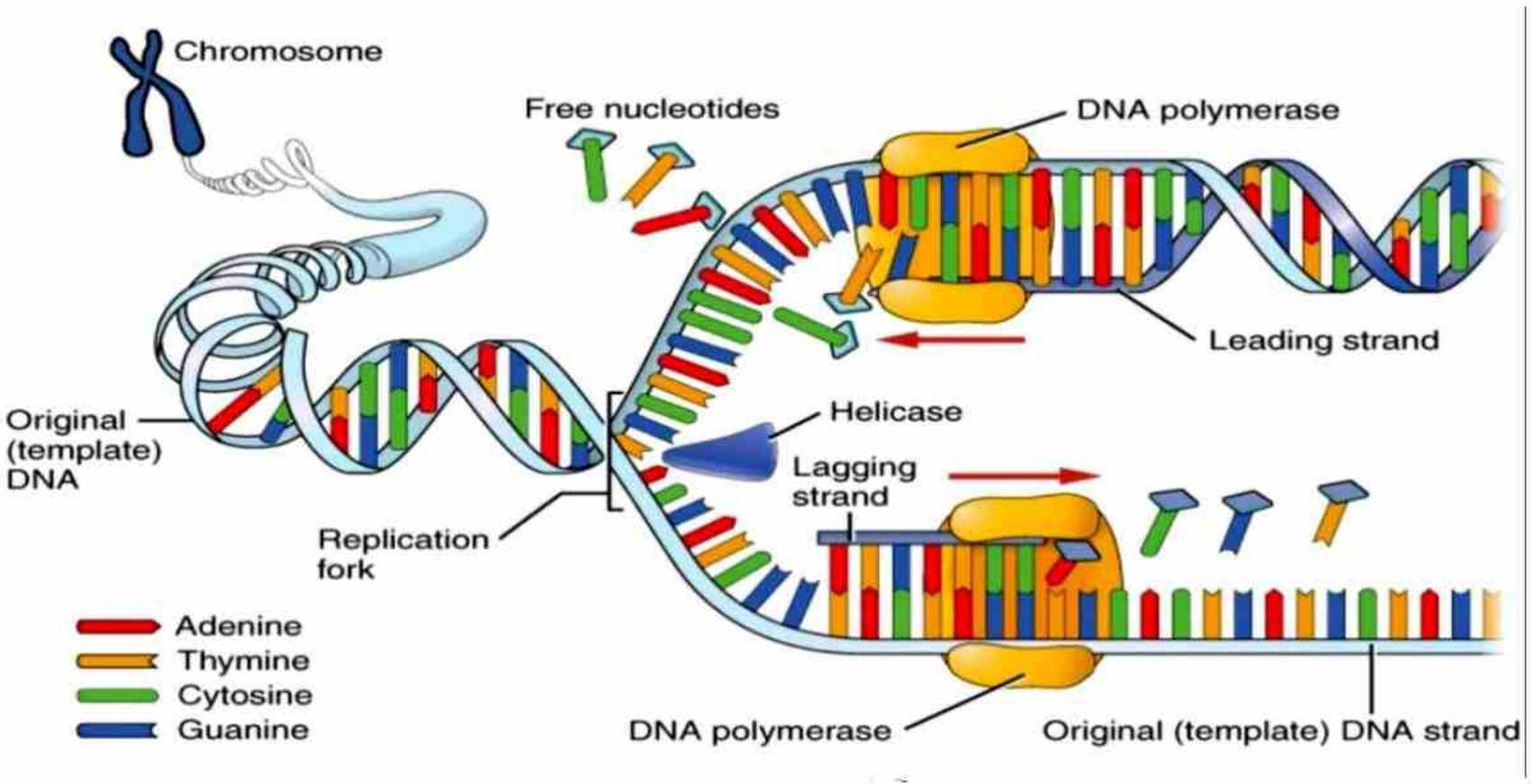


Fig.22.10. Replication of DNA

(c) Priming DNA Synthesis:

The formation of new strands is called **elongation**, takes place by an enzyme called DNA polymerase. The DNA polymerase cannot work in the absence of nucleotide already present on template strand. So the nucleotide must be added to the end of already existing chain called **primer**. The primer is a short piece of RNA, which is about 10 nucleotide long in eukaryotes only one primer, is required for polymerase to begin synthesis of new DNA. The enzyme is also required to join RNA nucleotide to make primer called **primase**.

(d) Types of DNA Polymerase and their Functions:

As we discussed earlier that there are 3 types of DNA polymerase, they play different roles during replication of DNA.

(i) DNA Polymerase-I: It performs the function of replacement of RNA primer by DNA nucleotide during termination phase.

(ii) DNA Polymerase-II: It performs the function of proof-reading, also perform the repairing of DNA damages throughout the lifetime.

(iii) DNA Polymerase-III: Main enzyme of replication which perform elongation and formation of new daughter strand.

(e) Termination:

Before termination one of the type of DNA polymerase performs proof reading during this process, it removes wrong nucleotide if it is added mistakenly. During termination phase replacement of primer by DNA nucleotide and joining of Okazaki fragment in lagging strand occur.

The primer nucleotides are removed and DNA nucleotides are replaced by DNA polymerase-I. It performs dual function i.e. exonuclease and polymerase. The joining of Okazaki fragment takes place by DNA ligase enzyme so a continuous strand DNA in synthesized.

STEPS AND ENZYMES INVOLVE IN REPLICATION

DNA Helicase & single strand binding protein

↓

Replication Fork (Double helix unwind provide single strand DNA template)

Synthesis of leading strand primase	Synthesis of lagging strand (primase)
↓	↓
Priming DNA polymerase-III	Priming for okazaki fragments (DNA polymeras III)
↓	↓
Elongation DNA polymerase-I	Elogation of fragments DNA (polymerase-III)
↓	↓
Removal of primer and replacement of DNA nucleotide (polymerase-I)	Removal of RNA primer and replacement of DNA nuclear (polymerase-I)
	↓
	Joining of Okazaki fragment (Ligase)

22.3.4. Replication of DNA as a Process of Stability and Variability

Replication of DNA is a process where stability and consistency of genetic information is maintained generation after generation or parents to off spring. This stability and high degree of accuracy is provided by hydrogen bonding between base pairs of old and newly formed DNA strands. Although DNA replication is not perfect at 1st step, it is due to speed of replication i.e. 50 to 500 nucleotides per second due to spontaneous chemical flip-flop in the base, DNA polymerase III occasionally incorporate incorrectly matched bases i.e. one mistake for every 10,000 bases pairs.

In mammalian cells, the completed DNA strand contains only about one mistake for every billion base pairs. For this rear inaccuracy the DNA, replication has a proof reading system which we have discussed earlier. This proof reading takes place by another DNA polymerase-II. The one-way directionality of DNA, each daughter strand as it structure allows the polymerase-II enzyme to recognize the parental strand, running in one direction as the right-stuff and to correct any mismatches by changing the daughter strand, which run in the other direction.

During prophase each chromosomes contain two chromatids, each chromatid contain double helix of DNA, which is consist of one original (parental) and one new strand (daughter), this new strand of DNA is an exact copy of parental strand, when these sister chromatids separate at anaphase and reach to daughter cells, each received an exact copy of parental chromosomes. Thus, if there is no spontaneous mistake in whole process, the constancy and stability of genetic information will be maintain from cell to cell and from parents to off spring.

Genetic variability can also occur due to change in DNA sequences which is termed as **mutation**. A mutation is a permanent alteration to a DNA sequence. *Denovo* change occur where there is an error occur during replication that is not corrected by DNA repair enzyme during proof reading, when this error is copied by DNA replication fixed in the DNA and transferred to next generation. DNA replication timings is also associated with variation in genome. The late replicating DNA is one of the factors which is generally more prone to mutation.

Another cause of mistake in replication is the presence of "Tautomeric forms" (interconvertable structural isomers) of nitrogenous bases. After publishing of Watson and Crick model of DNA, biologists thought that most replication errors were caused by shifting of H-group from one atom to another in nitrogenous bases, the changed form of nitrogenous base is called **tautomeric form** or **shift**. Both purine and pyrimidine bases in DNA exist in different chemical forms or tautomers, where protons occupy different position as shown in Fig.22.11 Biologist believed that if and when a nucleotide base into its rare tautomeric form it result in base-pair mismatching as shown in Fig. 22.12.

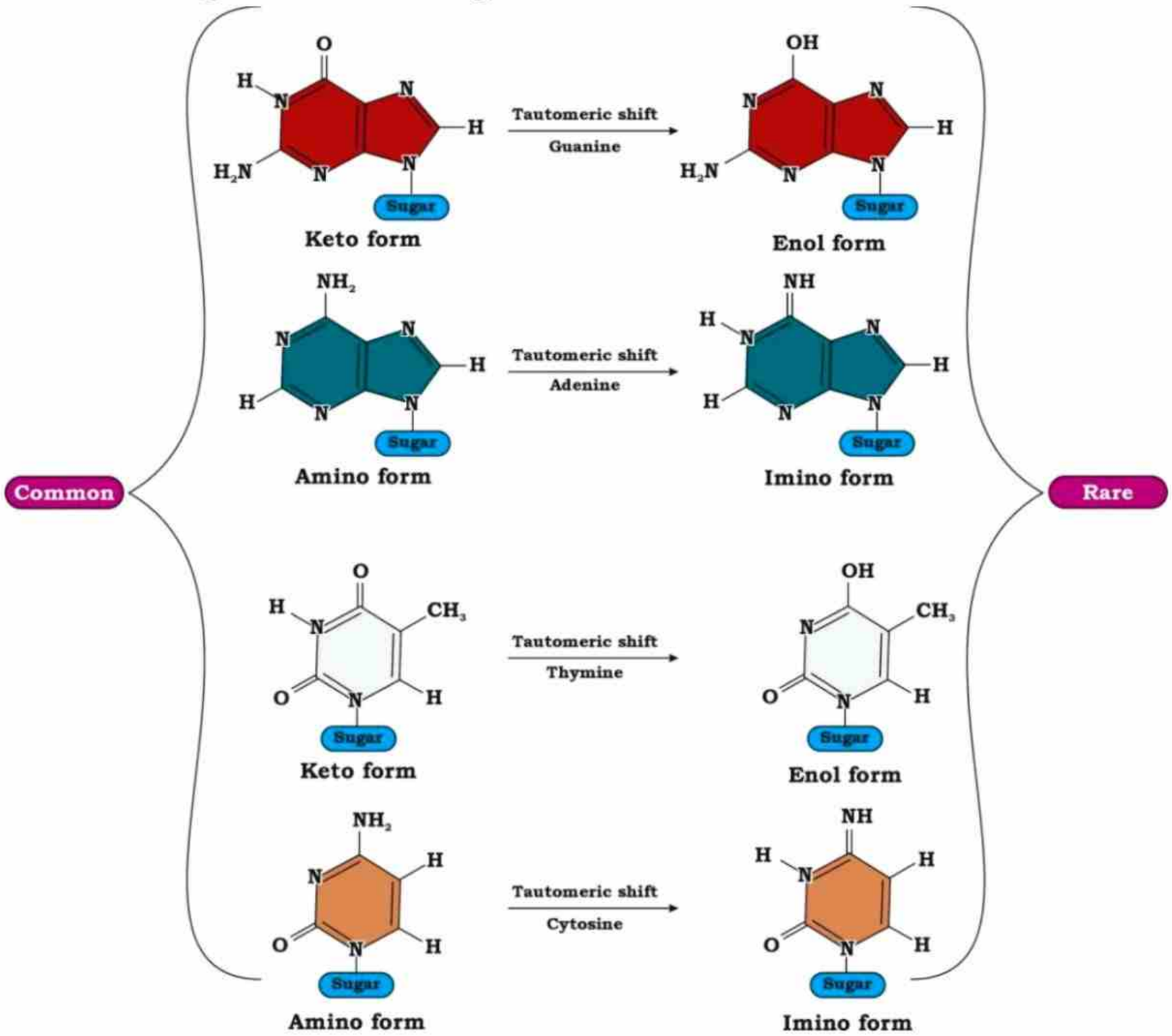


Fig. 22.11 Common and Rare Nucleotide forms

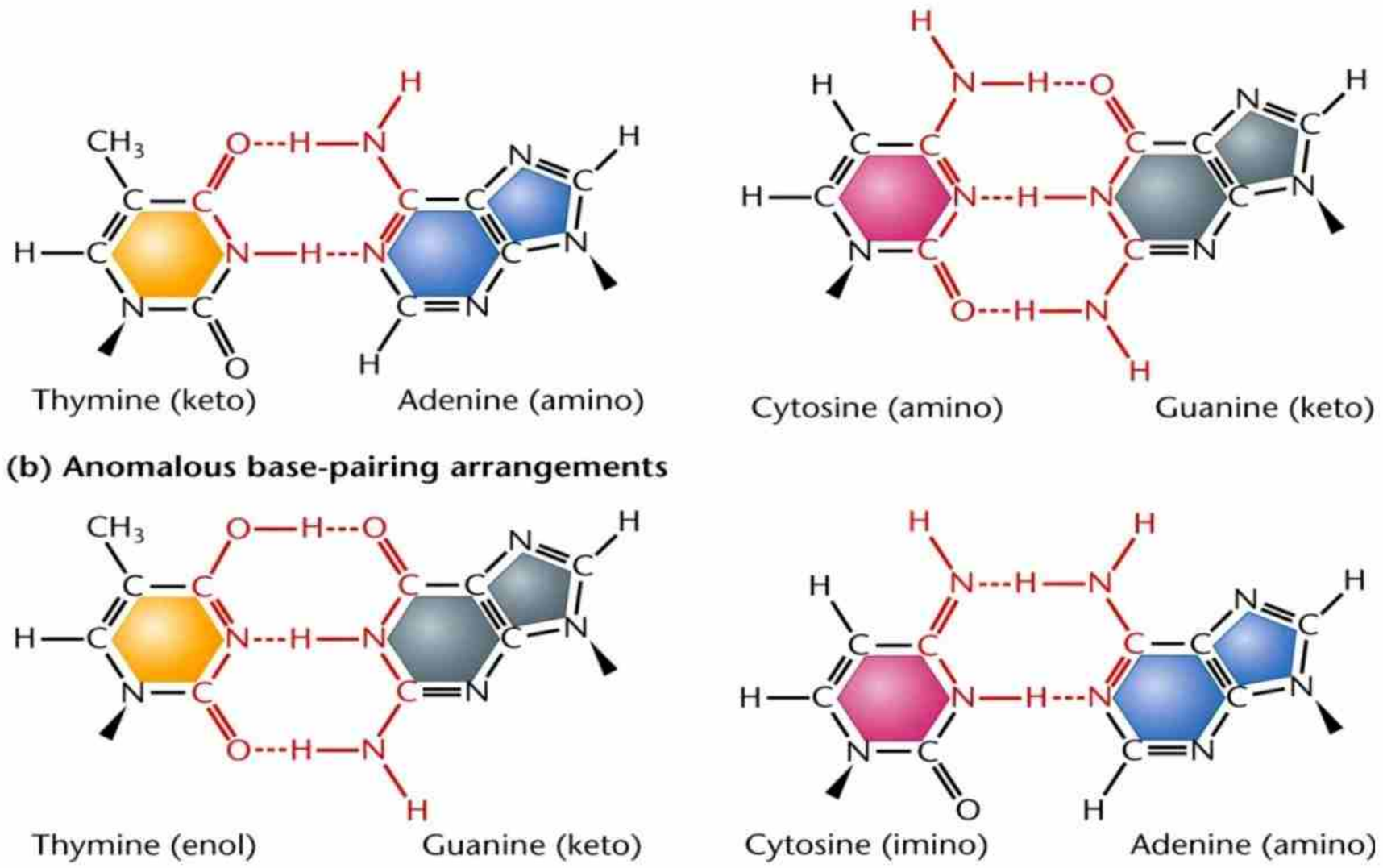


Fig. 22.12 Standard and Anomalous Base-pairing

22.4 GENE EXPRESSION

It is a process where information present on gene is used to produce a functional product required by living organism for their existence called gene expression.

22.4.1 Central Dogma of Gene Expressions

In English central dogma means basic principle but in biology especially in molecular biology it means that how genetic information flows from DNA to RNA for synthesizing a polypeptide chain or protein which works as an enzyme. This genetic information flows from DNA to proteins, in two steps.

(i) Transcription:

It is the process where information present on a specific part of DNA is copied in a complementary form to form mRNA. This mRNA carries information of DNA (gene) in coded form from nucleus to the ribosomes present in the cytoplasm to synthesize a particular

polypeptide chain. Although all three types of RNA are transcribed from DNA.

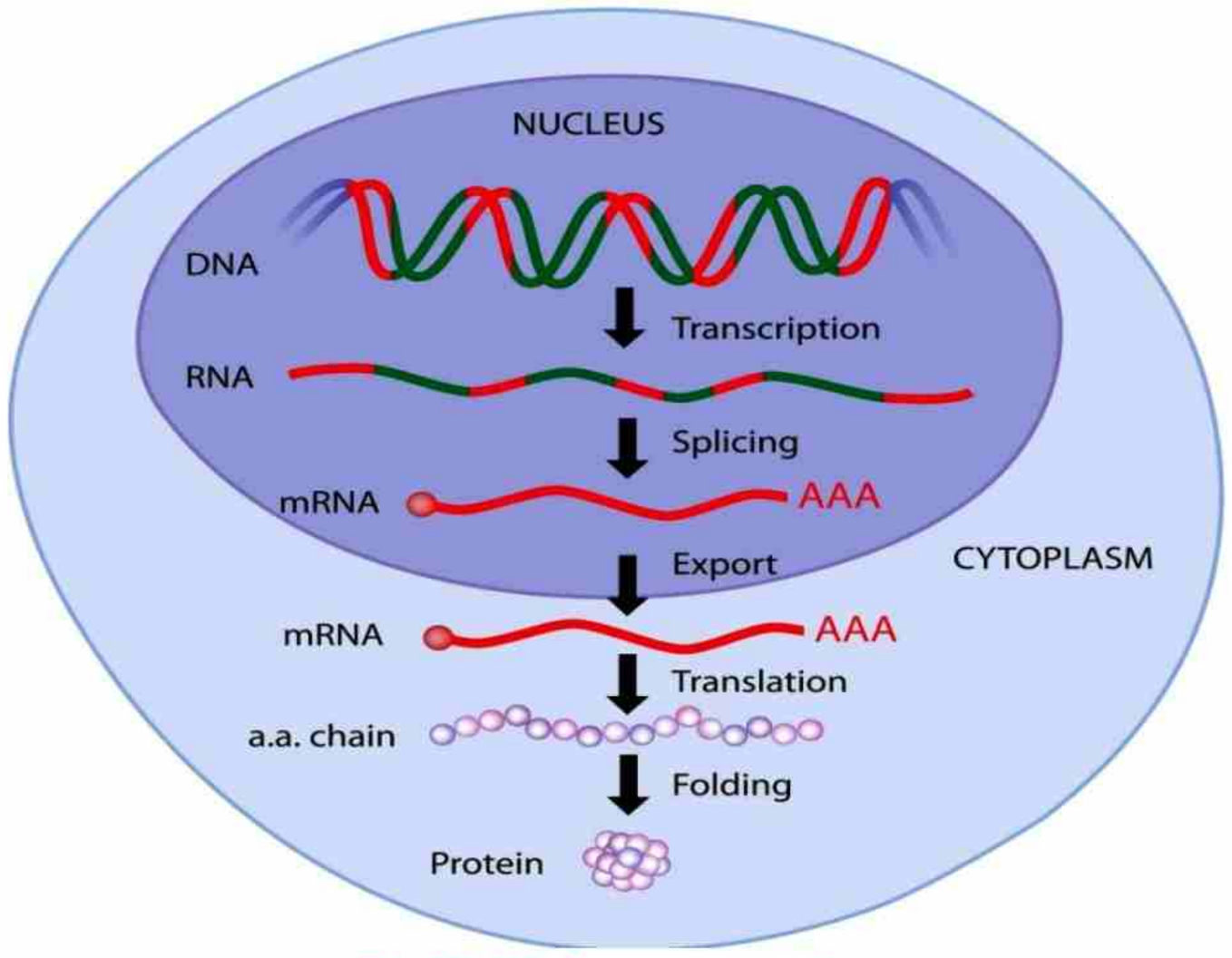
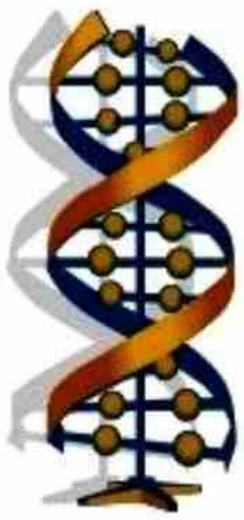


Fig.22.13. Gene expression

(ii) Translation:

The process of converting information on mRNA (messenger RNA) into correct sequences of amino acids to synthesize a protein with the help of tRNA (transfer RNA) and rRNA (ribosomal RNA)



Transcription

DNA
Protein (Enzyme)

mRNA — Translation
tRNA — Amino Acids
rRNA — Peptide Linkage

Transcription
Translation

22.4.2 Gene and Genetic Code

According to work of Archibald Garrod, William Batson, George Beadle and Edward Tatum which they concluded from their experimental work that Gene is a segment of DNA that contains the information needed to synthesize a protein. In other words gene is the basic functional unit of hereditary material. It is also observed that different genes have different base sequences and different proteins have different amino acid sequences. Therefore the sequences of nitrogenous bases in a gene work as the codes for the sequence of amino acids in proteins. Now questions arises how these bases work as codes for amino acids?

Genetic Codes

In the above discussion we have repeatedly used the word **genetic codes**. Now question arises what is genetic code? The genetic code is the set of rules used to store the genetic information within DNA for a particular protein synthesis. We know that when we want to send a secrete message or want to load pre-paid amount in our cell phone. This mobile card strip has combination of numbers on it. When we send correct sequence to the company they load specific amount which is asked for. In the same manner information about a specific protein synthesis is stored in DNA in the form of specific sequence of their nitrogenous bases. It gives three information to cell.

i) The amino acids required for this protein.

ii) The sequence of these amino acids in this protein.

iii) The length of polypeptide chain of this protein.

When this information of **Gene** in the form of genetic codes transcribed in the form of mRNA they work for amino acids during translation. The DNA and RNA both are made up of four types of nucleotides, but there are twenty (20) different amino acids which forms protein so these bases cannot serve as one to one codes for amino acids. If these sequence will be very short i.e. just consist of only two bases codes for an amino acid then there will be 16 possible combinations of bases. This is not enough either for 20 amino acids.

If three base pairs combination will be used, gives 64 combinations which is more than enough, the biologist hypothesized that each amino acid is coded by triplet of base pairs. In 1961 Francis Crick and three co-workers demonstrated that this hypothesis is correct.

	U		C		A		G		
U	UUU	Phenylalanine (Phe)	UCU	Serine (Ser)	UAU	Tyrosine (Tyr)	UGU	Cysteine (Cys)	U
	UUC		UCC		UAC		UGC		C
	UUA	Leucine (Leu)	UCA		UAA	Stop	UGA	Stop	A
	UUG		UCG		UAG	Stop	UGG	Tryptophan (Trp)	G
C	CUU	Leucine (Leu)	CCU	Proline (Pro)	CAU	Histidine (His)	CGU	Arginine (Arg)	U
	CUC		CCC		CAC		CGC		C
	CUA		CCA		CAA	Glutamine (Gln)	CGA		A
	CUG		CCG		CAG		CGG		G
A	AUU	Isoleucine (Ile)	ACU	Threonine (Thr)	AAU	Asparagine (Asn)	AGU	Serine (Ser)	U
	AUC		ACC		AAC		AGC		C
	AUA		ACA		AAA	Lysine (Lys)	AGA	Arginine (Arg)	A
	AUG	Methionine (Met)	ACG		AAG		AGG		G
G	GUU	Valine (Val)	GCU	Alanine (Ala)	GAU	Aspartic acid (Asp)	GGU	Glycine (Gly)	U
	GUC		GCC		GAC		GGC		C
	GUA		GCA		GAA	Glutamic acid (Glu)	GGA		A
	GUG		GCG		GAG		GGG		G

Fig.22.14. Genetic Codes

Further experimental work verified that the mRNA has information for amino acid in the form of their triplet base pair these triplets of bases on mRNA which encode one amino acids are called CODONS. Now there are 64 codons, some works as starts CODON and some of them work as stop CODON. Research showed that the CODON AUG signals "starts" while three codons work as stop codon i.e. UAG, UAA, UGA the genetic codes and codon does not need and does not have punctuation, between them have. It is like "**FATMANHITTHECAR**"

Table 22.1 The CODON for each amino acid

GENETIC CODES AT DNA

Gene	T	A	G	T	A	G	T	A	G	T	A	G	T	A	G	T	A	G	T	A	G
mRNA	A	U	C	A	U	C	A	U	C	A	U	C	A	U	C	A	U	C	A	U	C
	Codon			Codon			Codon			Codon			Codon			Codon			Codon		

AUC is the CODON for Isoleucine. If a polypeptide chain will be synthesized if will contain seven isoleucine amino acids in it. As we have discussed that there are 61 codons to code 20 amino acids, with these 61 codons some are stop codons. All 61 codons are used in the genetic coding for amino acid. The genetic code is thus highly redundant or degenerate. We can say that, a single amino acid may be specified by several CODONS. e.g. six different codons are present for a single amino acid i.e. Arginine. Even the code is redundant, but it is not ambiguous. Each codon specifies one and only one amino acid.

Gene (DNA)	G	C	A	G	C	G	G	C	T	G	C	C	T	C	T	T	C	C	G	C	G	T	C	T
mRNA	C	G	U	C	G	C	C	G	A	C	G	G	A	G	A	A	G	G	C	G	C	A	G	A
Polypeptide chain	Arg			Arg			Arg			Arg			Arg			Arg			Arg			Arg		

Mechanism of Transcription

'The process of copying over, 'in the form of RNA' is called Transcription, where a particular part of DNA is copying in a form of RNA.

Transcription has two limitations:

(i) Only a selected part i.e. gene part of DNA is transcribed e.g cell of hair follicle transcribe only the DNA which contain genetic information about keratin protein synthesis.

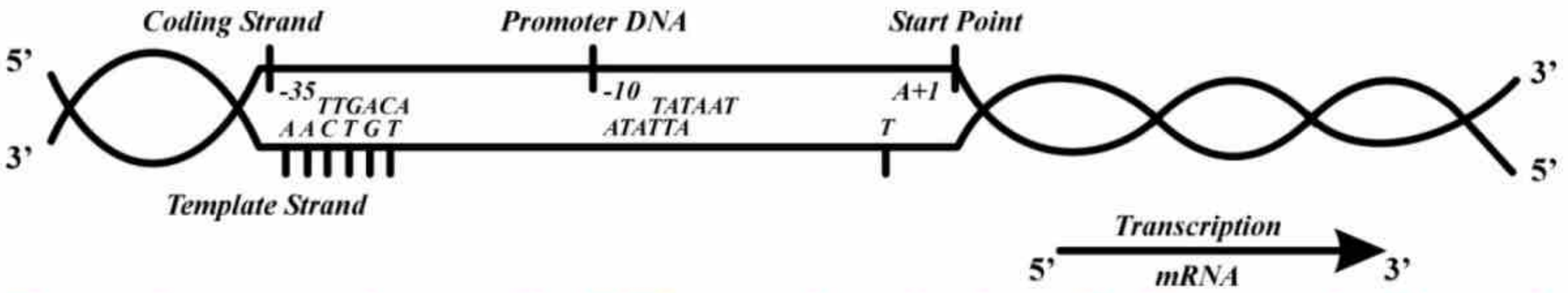
(ii) It occurs only when it is required, it copies only one strand of DNA because the two strands of DNA are complementary not identical. If the sequence of bases on the strand present at one strands that form keratin protein will not found on other strand.

The DNA strand which contains exact information about functional protein is called template strand or **anti-sense** strand. The opposite strand is called **coding strand** or the **sense strand**. The RNA polymerase enzyme synthesizes RNA from 5` → 3` direction. Keeping in view the above limitations we can divide the process of transcription in following three steps.

(i) Initiation (ii) Elongation (iii) Termination

(i) Initiation: It is the first step of transcription where attachment of RNA polymerase at the start of gene occurs. This start region of gene is called **Promoter region**. The promoter region of a gene is a

short sequence of DNA bases located just in the 3' direction. The RNA polymerase recognizes the base sequences of promoter at the beginning of gene and bind with it. In prokaryotic DNA three promoters are TATAAT or -10 sequence and TTGACA or -35 sequences. In eukaryotic DNA TATA (TATA box) or -25 sequences and CAAT (CAAT box) or -70 sequence.



Promoter region of DNA and start of Transcription in Prokaryotes

(ii) Elongation: After binding of RNA polymerase at promoter site, it forces to unzip DNA double helix from beginning of gene, moves along the template strand of the DNA in the 3` → 5` direction. The free ribonucleotides present in the nucleus now utilize to make and elongate RNA polymer. In this way during elongation a single strand of RNA which is complementary to template strand of DNA is synthesized. The same base pairing rules are used during transcription for RNA synthesis as for DNA replication except that Uracil is paired with adenine instead of thymine as follows.

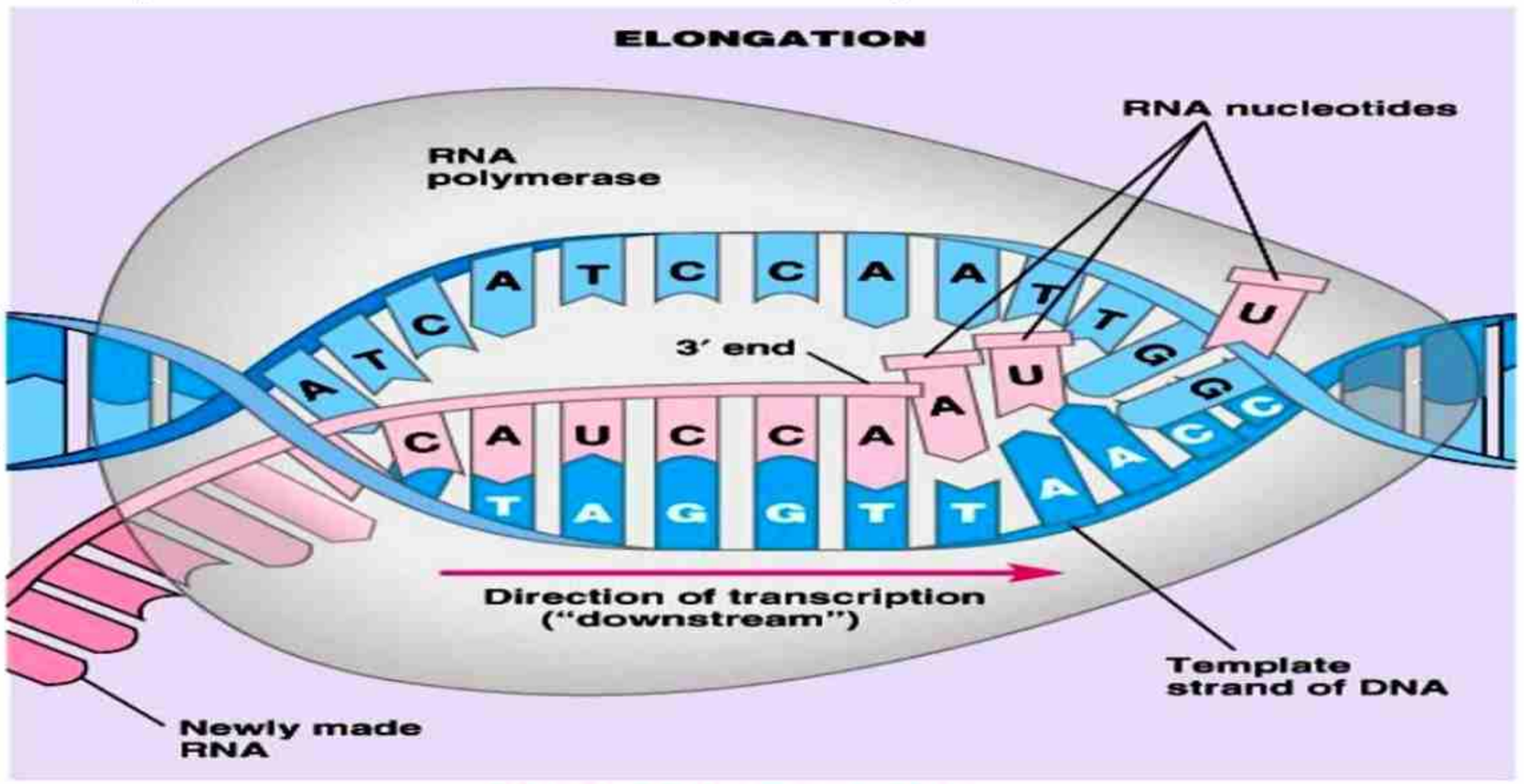


Fig.22.15.Transcription

The RNA polymerase adds RNA nucleotides to the growing RNA strand according to rule of base-pairing but this pairing does not persist. After about 10 nucleotides have been added to the growing RNA chain, the beginning of the RNA molecule separate from DNA. In this way long 'tail' drift away from DNA. The elongation remains continue till the RNA polymerase reaches the terminator region of the gene.

(iii) Termination: As we have discussed that the RNA polymerase adds RNA nucleotides when RNA polymerase continues along the template strand until it reaches the termination region (signal). Termination region is a sequence of DNA bases trigger two events. Firstly, the RNA molecule completely separate from both the DNA and the RNA polymerase. Secondly, the RNA polymerase detach from template strand of the DNA. These events terminate transcription. The terminator region consists of a series of GC base pair followed by AT base pairs. The mRNA region transcribed by this region form a loop like structure called **GC hairpin** followed by a small tail of polynucleotides. The GC hairpin causes the RNA polymerase to stop the synthesis of RNA.

Modification in mRNA before Translation

The mRNA before translation is modified in eukaryotes for next stage i.e. translation. In prokaryotic cell transcription and translation both takes place in cytoplasm therefore it does not require any modification in mRNA of prokaryotic cell. The genome of eukaryotic DNA contains coding and non-coding regions within the genes. The coding regions are called **Exons** while the non-coding regions of gene are called **Introns**. During transcription both exon and intron regions are transcribed but before translation the transcription of intron region are spliced, new mRNA contain transcripts of exon region only. The removal of introns and the conversion of long primary mRNA into short secondary RNA without intron called RNA **splicing**. It requires

a small nuclear ribonucleoprotein (sn RNPS) i.e. a RNA protein complex RNA splicing takes place in following three steps.

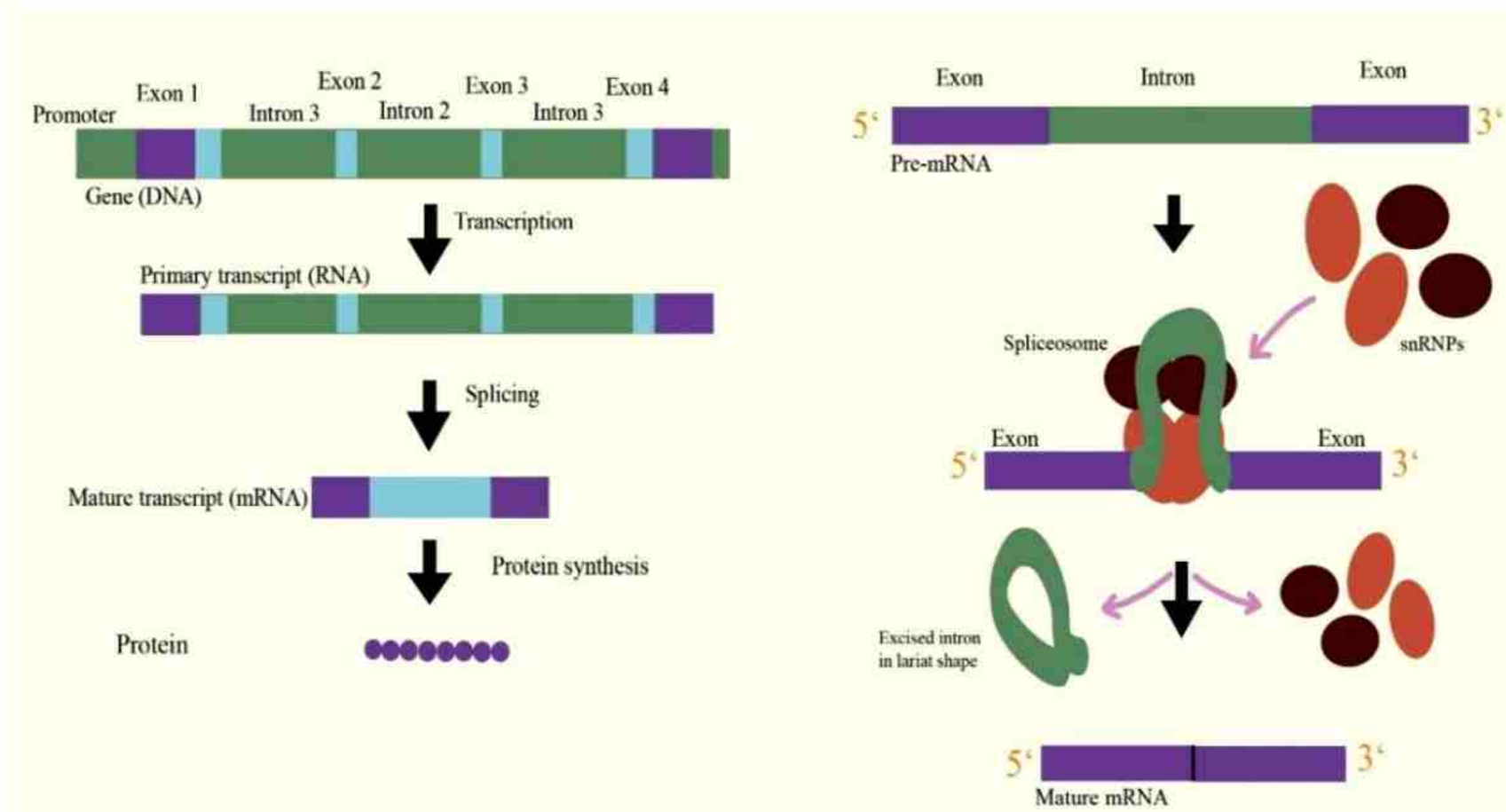


Fig.22.16.RNA splicing

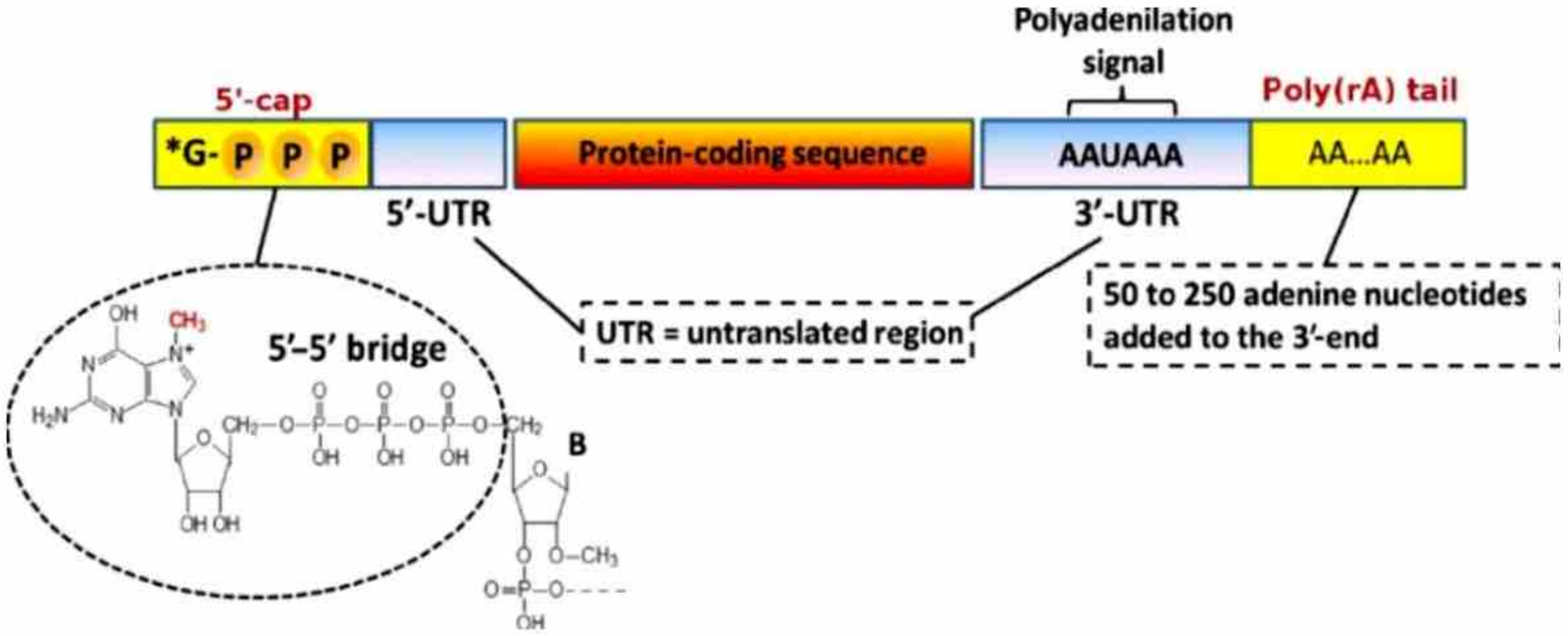
Step – I: A group of sn RNPS's bind to intron of primary mRNA.

Step – II: Binding sn RNPS's at intron, which cause folding of mRNA which bring the 5' and 3' ends of the intron closer, which make a loop in this way, the end of the exon also come closer, and ultimately join each other.

Step – III: The intron removed and splice site connect to make a mRNA, the intron are also used in other process. The sn RNA detach from the intron and reused.

Another modification occurs in primary mRNA that a cap and tail are added to it. It is to protect mRNA from degradation and remain stable. The cap is in the form of 7 – methyl GTP linked 5' → 5' with the first nucleotide. On the opposite end of mRNA a small chain of adenine nucleotide called **poly A tail** is attached i.e. at 3' end.

These changes protect secondary mRNA from degrading enzyme like nuclease and phosphate.



22.17. 7-methyl GTP and Poly A

Translation

It is the second phase of gene expression or protein synthesis. During translation the secondary mRNA attaches with ribosome and decoded its information with the help of tRNA. The tRNA contains anticodon which translates CODON of mRNA and carries related amino acid to ribosome in sequential manner where rRNA bind and form peptide linkage to form polypeptide chain. For our convenience we can divide it in four phases. i.e. activation of amino acid, formation of initiation complex, elongation and termination.

(i) Activation of Amino Acids:

The cytoplasm of cell contains amino acids which are taken from digested food or synthesized in cell. These amino acids when bind with a particular tRNA is called activation of amino acid. As we know that tRNA has 4 sites at 3' end three unpaired nucleotide site called **amino acid site** is present, opposite to it five nucleotide containing site is called **anticodon site**, whereas out of them five nucleotide the middle three nucleotides work as **anticodon**. Another loop is called **activation site** where an enzyme **aminoacyl synthase** attach to activate this tRNA. A particular amino acid attach with its specific tRNA through this activating enzyme, one of which exists for each of the 20 amino acid.

(ii) Formation of Initiation Complex:

Translation require initiation complex. This initiation complex is a complex of ribosomal subunit mRNA and first aminoacyl tRNA complex. The first aminoacyl tRNA complex contains a modified **methionine**. The initiation complex formation is metabolized by an enzyme called **Initiation factor-I**. During this process 5' end of mRNA molecule also bind to the smaller sub-unit of ribosome with the help of another enzyme called **Initiation factor-II**. In the last of this initiation complex formation process, large sub-unit is placed on smaller sub-unit.

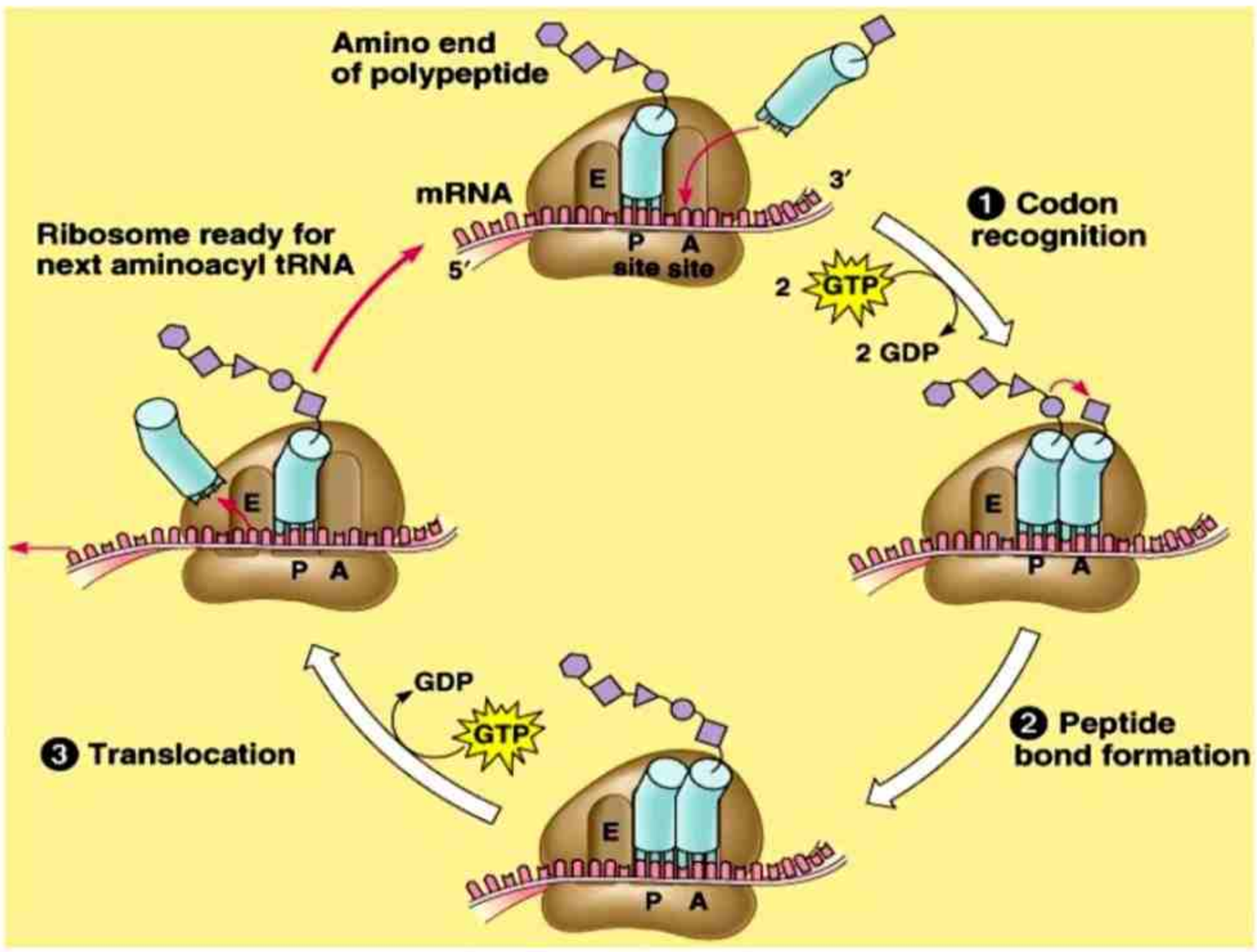


Fig.22.18.Translation

(iii) Elongation

The ribosome has 3 sites **P site**, i.e. peptidyl site, **A site** i.e. aminoacyl site and **E site** i.e. exit site, as shown in Fig. 22.18. Another tRNA with appropriate amino acid binds at next site i.e. A site. Its anticodon bearing aminoacyl tRNA complex bind with the help of an enzyme called the **elongation factor**. In the next step an enzyme peptidyl transferase released from P site, remove the amino acid from tRNA present on P site and bind to new amino acid present on A site by making peptide bond, It take place at the site on large

sub-unit called **catalytic site**. After it, ribosomal sub-unit slightly move along mRNA from 5' → 3' end so that the empty tRNA shift to E-site, while the tRNA at A site shifted to P-site and a new CODON is exposed at A site the movement of ribosome called **translocation**, another tRNA with its amino acid reached at A site to bind with its anticodon. In the same way the process is repeated again and again to form a poly peptide chain until the ribosome is reached to stop codon at A site.

(iv) Termination

When the ribosome is reached at stop codon which is also called **non-sense CODON**, this codon do not bind with any tRNA so no elongation takes place further. Now the polypeptide chain is released from ribosome by separating ribosomal sub-units from mRNA.

Difference between protein synthesis in Prokaryotic and Eukaryotic

Prokaryotes	***Eukaryotes***
➢ Prokaryotes have ribosomes in cytosol so protein synthesize completely takes place in cytosol.	➢ Ribosomes of Eukaryotes are attached with RER so it mainly occurs in R.E.R.
➢ The prokaryotic gene (DNA) found in cytosol so transcription and translation both occur in cytosol.	➢ The Eukaryotic genes are found in nucleus, so transcription occurs in nucleus and translation occurs in cytoplasm.
➢ The prokaryotic gene does not contain intron.	➢ Eukaryotic gene contain exon and intron region.
➢ In prokaryotes the gene promoter-I for transcription are TATAAT or -10. sequence and TTGACA -35 sequences.	➢ In Eukaryotes DNA gene promoters are TATA or -25 sequences and CAAT or -70 sequences.
➢ The ribosomes are 70s for translation initial amino acid is modified N-formyl methionine.	➢ The ribosomes are 80s for translation the initial amino acid is not modified i.e. methionine.
➢ In prokaryotes no cap and tail are formed with mRNA.	➢ In Eukaryotes the Cap of 7 – methyl GTP and poly-A tail is formed.

22.5 REGULATING GENE EXPRESSION

The cell requires protein in the form of enzymes for regulating its function, developing its structure and for its differentiation. Therefore all cells regulate synthesis of protein from information present on DNA. The process of turning ON or OFF a gene is called **Regulatory gene expression**. Each cell controls the gene expression according to its requirement i.e. when and how its genes are expressed. This control requires a mechanism which tells the cell when a gene is expressed and when it will be stopped i.e. this protein is no longer required by cell.

22.5.1 Importance of Regulating Gene Expression

The regulation of gene expression conserves energy and space. The process of gene expression requires enormous amount of energy so it is important to save energy. Therefore the gene only express at the time of its requirement. On the other hand DNA is present in the form of highly coiled form in the nucleus of cell. To express a gene this part of DNA should be unwind, only that part of DNA unwind where required gene is located, it save the space of cell.

In multicellular organisms, high degree of cellular differentiation occurs due to regulation of gene expression. All cells of multicellular organism contain same genome but cells do not express all genes present in them, only specific genes are expressed in particular type of cell by this regulation process.

The regulation of gene expression also regulate normal metabolism of an organisms by synthesizing proper activating and inhibiting factors at proper time. If this regulatory process of gene expression is disturbed, metabolic disorders and other genetical disorder take place. Like cancer, lysosomal disorder e.g. Liver perform a function of alcohol removal from blood stream, for this liver cells express gene of an enzyme called alcohol dehydrogenase. This enzyme breaks alcohol into non-toxic substance but the R.B.C cannot do it, so R.B.C keep this gene turned off. Similarly the liver cell cannot carry O_2 so they keep their genes turn off which synthesized hemoglobin protein.

Method of Gene Regulation

Regulation of gene expression takes place in two ways i.e. positive and negative regulation. The genes are expressed by specific protein called **activators** this type of regulation is called **positive gene regulation**. On the other hand the gene expression is suppressed by the presence of specific regulator protein, i.e. **repressor** this type of gene regulation is called **negative gene regulation**.

Unicellular living things regulate gene expression so that their metabolic and biosynthetic pathways change in response to changes in their environment. e.g. *E.coli* bacteria, growing in the presence of lactose, synthesize enzymes which allow lactose to be utilize as energy source, if lactose is replaced by another disaccharide then a different set of metabolic genes are expressed and the genes required for lactose metabolism are not regulated, so the genes of lactose are repressed.

Multicellular organisms have additional capacity to regulate gene expression so that many genes are expressed in specific tissues. The sequential activation of specific genes in different regions of the embryo drives the development of the embryo, the formation of the different tissues and cell types. In these cells DNA remains in nucleus, some of its regions (genes) transcribed into RNA which transported out of the nucleus into cytoplasm where ribosome translate it into protein.

The genes can regulate at all stages of gene expression. This regulation can be occur when DNA is uncoiled from nucleosome to bind with transcription factor i.e. epigenetic level or when RNA is transcribed i.e. transcriptional level or when it is transported to cytoplasm from nucleus i.e. Post transcriptional level or when mRNA is translated into protein i.e. translational level or after the protein has been synthesized i.e. Post translational level.

Regulatory element can operate. So that the product of one gene controls the activity of other gene. Some of which may themselves regulate other gene. Activation of one gene can initiate a cascade of regulatory event.

Role of Intron and Exon in Gene Expression

The eukaryotic genomes contain introns and exons while prokaryotic gene does not contain intron. During gene expression all introns are transcribed into RNA and replicated during replication process but introns do not participate in translation because before coming out from nucleus the introns regions are eliminated by spliceosome.

The total genomes contain 40% of intron on average. Now question arises here why introns are present in genome? The existence of introns in genome is a real mystery given the expensive energy cost for a cell to pay for copying the entire length of several introns in a gene and eliminates them at the exact position, controlled by big RNA and protein complex after transcription. Do introns are not totally junk? It has come to know that introns are not totally junk, these are crucial because protein variety is greatly enhanced by alternative splicing in which introns play important role. The alternate splicing is a controlled molecular mechanism for synthesizing multiple variant proteins from a single gene.

Introns also play important role in positive regulation of gene expression. It was found that without introns the protein products were significantly diminished. It was also found that some introns are designed to construct expression vectors for guaranteeing a high level of expression compared to genes without introns. Introns are involved in transcription, initiation and termination processes.

These processes require some sequence elements, in intron in correct order. Introns may be associated with mRNA transport or chromatin assembly. Intron also plays some indirect role. The first intron plays important role in transcription. It has been found that the first intron is the longest introns which work as the signal for the transcription. So many other roles of introns are going to be established day by day research in molecular biology.

22.6 MUTATION

There are so many ways to explain the terms mutation. The DNA is the genetic material which is responsible to store information of an organism and its inheritance faithfully to next generation. If it does not take place properly it is called **Mutation**. In a sense, mutation is the failure to store genetic information faithfully. In

Eukaryotes, DNA is present on chromosomes, so historically, the term mutation includes both chromosomal changes in their number and structure. The changes occur in the location of gene on chromosome and changes within a single gene also called mutation. We discussed all of these here under the title of heteroploidy, chromosomal aberration and gene mutation respectively.

22.6.1 Sources and Types of Mutation

The substances which cause mutation or responsible of mutation are called **mutagens**. The mutagens or mutagenic agents may be physical, chemical or biological.

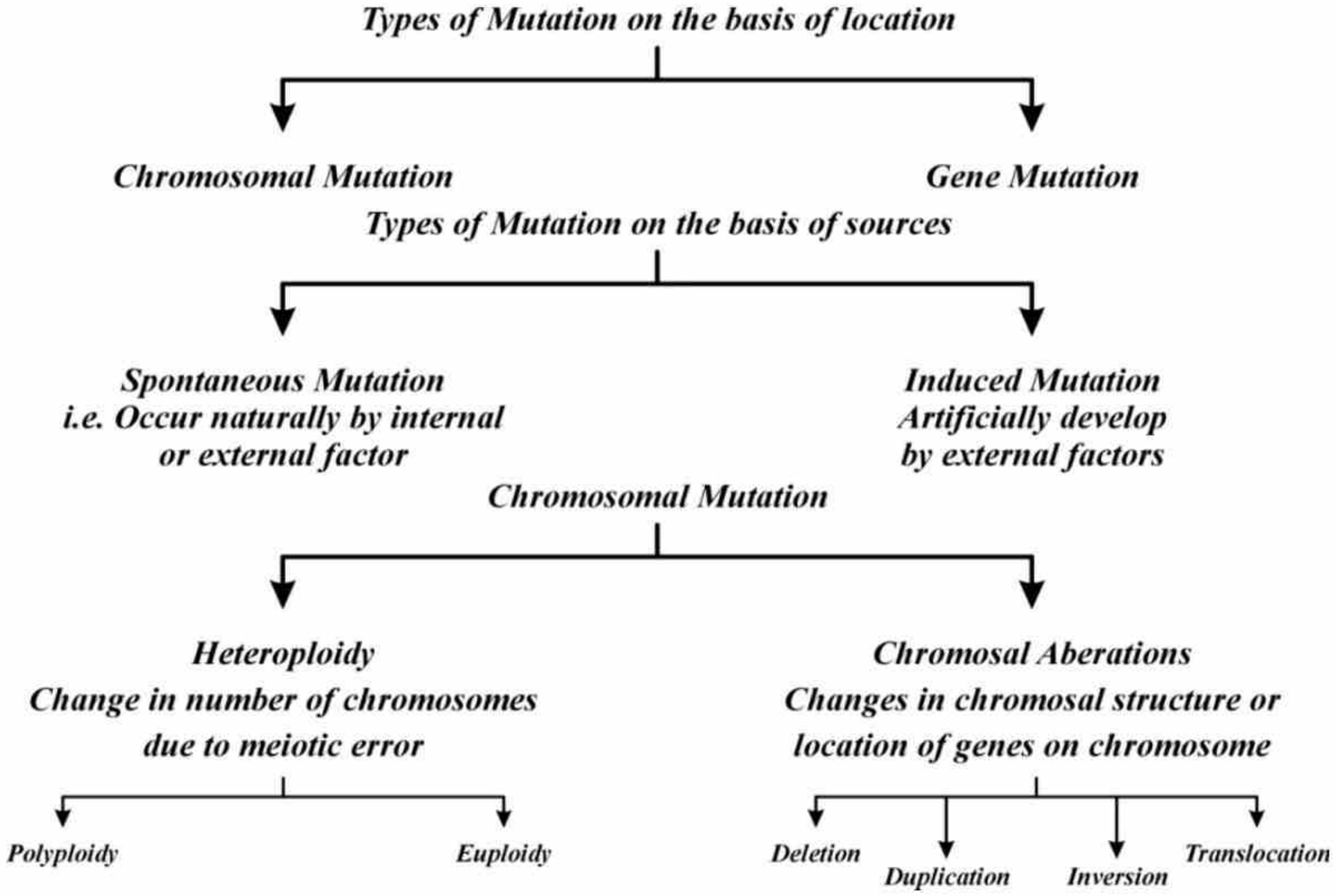
Physical Mutagens: These are the physical forces which are responsible to break any type of bond present in the DNA i.e. phosphodiester bond of DNA or bonds present in nitrogenous bases. These physical mutagen may be ionizing radiation like gamma (γ) rays, x-rays or other types of radiation like ultra violet radiation sometimes cosmic waves or ultrasonic waves, it may be high temperature.

Chemical Mutagens: A number of chemical compounds may alter the shape of DNA and its nucleotides, some of them are very similar to nitrogenous bases which can be replaced by original nitrogenous bases. The other chemicals may be environmental or industrial like Nitrous oxide, mustard gas, photochemical, or radioactive isotopes, free oxygen may work as mutagenic chemical.

Biological Mutagens: Some micro-organism and biochemical, which are produced during metabolism may work as mutagenic agent, sometime errors in normal physiological processes leads to mutation e.g. error in disjunction leads to heteroploidy or some viruses like HIV lead to skin cancer i.e. Kaposi's sarcoma.

Types of Mutations

The process of mutation is called mutagenesis, the organisms in which mutation occur called **mutant** and the organism where mutation does not occur or found in its original form called **wild type**. There are so many ways to classify the types of mutation.



22.6.3 Do Most Mutation are Harmful

It is generally considered by the people that changes in genetic material in any way is harmful for the living organisms this is not true completely, although in number of cases mutation is harmful but there are three types of mutation i.e. negative mutation, positive mutation and neutral mutation.

(i) Negative Mutation: It is the type of mutation which is harmful for living organisms and cause different types of abnormalities like, sickle cell anemia, Down's syndrome etc. These mutant genes are usually eliminated by natural selection from gene pool.

(ii) Positive Mutation: It is the type of mutation which produced better allele to produce more adaptable genes. These genes are selected repeatedly by natural selection. e.g. mutated gene of black skin colour, polyploidy, to produce different varieties within the same species of plants, genes of beaks and claws in birds etc.

(iii) Neutral Mutation: The some genes are mutated but do not leave any harmful or observable effects on phenotype. These genes inherit in normal pattern this type of mutation is called **neutral mutation**.

Mutation produces fitness to adapt in a specific environmental condition, which leads to evolution of organism. It explains the evolution of aquatic animals and plants to land habitat. The organisms which do not accumulate mutated genes became unable to survive on land. Nature only selects those which accumulate mutated genes, which were required to develop, characters for survival on land. Above discussion showed that the mutation is not only harmful process.

22.6.4 Chromosomal Mutation

As we have classified mutation in different groups, one of it is chromosomal mutation, i.e. any change in number and shape of chromosomes is called **chromosomal mutation**. It is further classified into two groups.

(i) Heteroploidy (ii) Chromosomal aberration

(i) Heteroploidy: Heteroploidy is the change in the number of chromosomes due to non-disjunction during **Diakinesis** of meiotic prophase-I. There are two types of heteroploidy (a) Polyploidy (b) Aneuploidy

Polyploidy: It is a type of heteroploidy, where a set of chromosomes may increase i.e. As a result of polyploidy triploid (3N) tetraploid (4N) etc organisms are produced. The polyploidy produce varieties within the species of on organism, especially in plants e.g. different varieties of wheat and rice are produced.

Aneuploidy: It is the type of chromosomal mutation where one or two chromosome increase or decrease in the karyotype of an organism i.e. monosomy where one chromosome decrease (2N – 1), Trisomy where are chromosome increases (2N +1). Some example of monosomy and Trisomy of human are given below.

(a) Down's Syndrome: It is a trisomic (2n+1) condition of autosomal chromosome number 21, found in both male and female of human beings.

Symptoms: Abnormal body and mental development, round face small head, skin flap at the back of neck, wide short hands with short fingers and long tongue.

Treatment: There is no treatment but continuous psychological counseling and some medicine required to reduce aggression of patient.

(b) Klinefelter's Syndrom: It is also a trisomic condition but it is a trisomy of sex-chromosome (44 + XXY).

Symptoms: It is a male disorder having feminine character i.e. less body and facial hairs, enlarged breast, long neck, wide hips, curved shoulder and thighs. The male has small testicles, voices are not deep as male and infertile male.

Treatment: Testosterone therapy is the only solution but it does not help in reducing infertility.

(c) Turner's Syndrome: It is monosomic (2n-1) condition of sex-chromosome in female i.e. (44 + X).

Symptoms: The effected individuals are infertile female with short height, webbed neck, low hairline at the back of neck, edema in the hands and feet, low IQ level.

Treatment: There is no specific treatment, only growth hormone therapy is administered in this case. Female hormonal therapy also helps in the development of puberty characters and reproductive cycle. It is started at the age of 12 or 13 years.

(ii) Chromosomal Aberration: The type of chromosomal mutation where change in chromosome structure or position of genes on chromosome occur. There are four types of chromosomal aberration

(A) DELETION OR DEFICIENCY: A chromosome breaks from one or more than one places so some of its portion is lost. The remaining part in the karyotype is left this loss in genetic material is called Deletion or deficiency. As a result the chromosomal size reduces.

(b) Duplication: Processes where a broken part of a chromosome attaches with its homologous chromosome, the genes of same characters become duplicated and the size of chromosome increases.

(c) Translocation: A process where a broken part of a chromosome attaches with its non-homologous chromosome is called **Translocation**. As a result of translocation the size of that chromosome also increases but genes do not duplicate as present in duplication.

(d) Inversion: It is a type of structural variation in chromosome where arrangement of gene loci inverted due to 180° turn of chromosome.

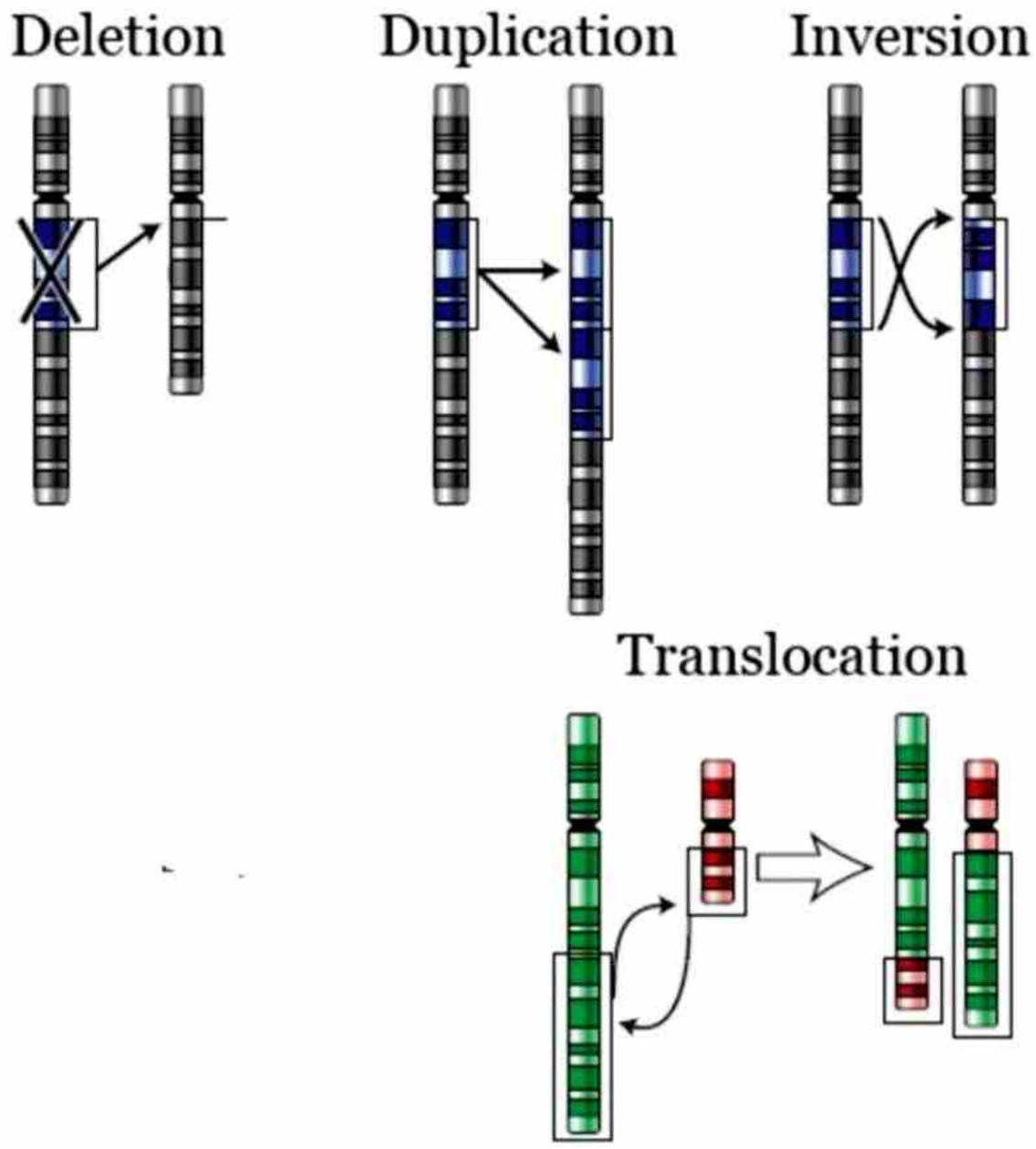


Fig.22.18. Chromosomal Aberration

22.6.5 Gene Mutation

Mutation occurs in a specific gene at specific genetic code(s) or the location of a gene change on chromosome, this type of mutation is called **Gene Mutation**.

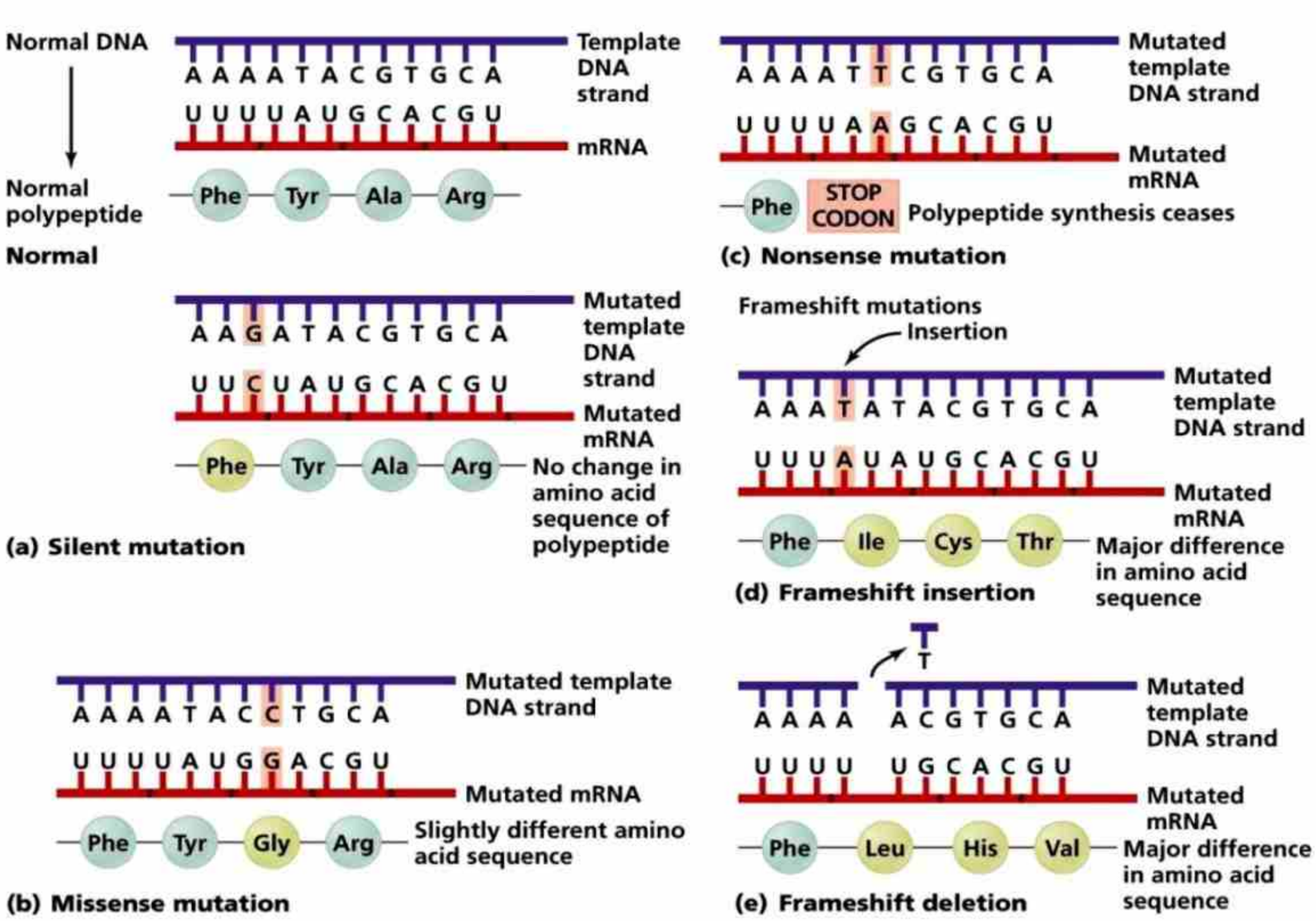


Fig.22.19.Gene mutation

If the change occurs at specific genetic code(s) this type of gene mutation is called **point mutation**. The change in nucleotide sequence at gene develops change in the sequence or type of amino acids, due to these changes in amino acid the nature of protein also alter. It may develop non-functional protein or different protein which develops new character in organism following are the two example of point mutation.

Sickle Cell Anemea

It is a disorder of Hemoglobin impairment. Affected individuals contain erythrocytes that under low oxygen tension become elongated and curved because of the polymerization of hemoglobin.

The normal individual has homozygous genotype Hb^A Hb^A while the affected individuals have homozygous genotype Hb^s Hb^s. The heterozygous individuals do not suffer from this disease because over half of their hemoglobin is normal.

Symptoms: At severe stage of a sickle cell anemia person feel fatigue, pain, fever, fast heartbeat, breathlessness and damage of various organs.

Cause: The genetic code at sixth position for **glutamic acid** in β-chain of hemoglobin is replaced by genetic code of **valine**, develop sickle shaped R.B.C due to this point mutation.

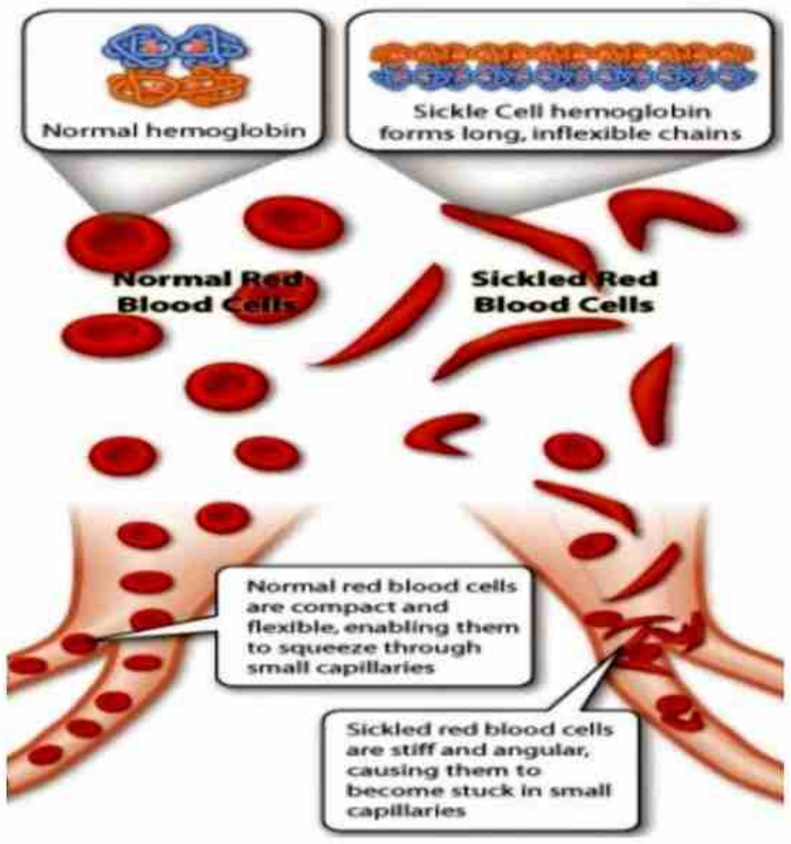


Fig.22.20.Sickle cell anemia

Effect of Sickle Shape R.B.C

The abnormal hemoglobin in sickle shape R.B.C lost oxygen binding capacity so these cells deliver less O_2 and accumulate in blood vessels.

Treatment: Blood transfusion, analgesic and use of high quantity of fluid. Bone marrow transplantation is the long term treatment of sickle cell anemia.

Phenyl Ketonuria (PKU)

Inherited disorder where a new born baby is unable to convert Phenylalanine, amino acid into Tyrosine called **PhenylKetonuria**. It is due to the fact the baby is unable to synthesize an enzyme Phenylalanine hydroxylase. The gene for the synthesis of this enzyme becomes defective due to point mutation. This point mutation converts phenylalanine into phenyl Ketone instead of Tyrosine which damages the nervous system. It appears in homozygous recessive person.

Treatment: Avoid phenylalanine containing diet at childhood, and at adult stage. An especial milk formula Lofenalac is available for PKU infant.

SUMMARY

- Chromosomal theory of inheritance states that the genes are located at chromosome inherits through gametes.
- Chromosome are thread like structure made up of highly condensed chromatin material, appear during cell division.
- Replication of DNA is semi-conservative process.
- Replication of DNA require helicase, DNA polymerase I, II, III, primase and Ligase.
- Replication is the process which provide stability of genes from generation to generation but if any charge occur in DNA before replication, it leads to variation.
- Gene expression is the process where information of gene is used to produce functional product.
- Gene expression is consist of two steps i.e. Transcription and translation.
- Transcription is the process where information present on a specific part of DNA is copied in a complementary form of mRNA.
- Translation process of converting information of mRNA into correct sequences of amino acid synthesize protein.
- Genetic code is the set of rules to store the genetic information within DNA for a particular protein synthesis.
- CODON is the triplet of nitrogenous bases on mRNA which encode one amino acid.
- Before translation, the transcribed introns are spliced, cap and tail are added to mRNA in Eukaryotic gene.
- The process of turning ON and OFF a gene is called regulation of gene expression.
- Introns are not useless part of gene, they play important role in positive regulation of gene expression.
- Mutation is the failure to store genetic information faithfully.
- The mutation may be sportenous or induced, may be chromosomal or genic, may be negative, positive or neutral.
- Chromosomal mutation may be change in number of chromosome or change in structure of chromosome.

EXERCISE

1. Encircle the correct answer:

i) W. Sutton and Theodor observed this behavior of chromosomes.
(a) Formation (b) Distribution
(c) Staining (d) Replication

ii) Which is not the part of chromosomal theory of inheritance.
(a) Gametes do not make equal hereditary contribution
(b) Chromosome segregate during meiosis
(c) Nucleus is the room of hereditary material
(d) Gametes have one copy of homologous chromosome

iii) Newly formed chromosome has two.
(a) Chromatids (b) Heterologous
(c) Centromere (c) Pairs

iv) The complex of histone octamer and two loops of duplex DNA is.
(a) Chromomer (b) Chromatin
(c) Nucleosome (d) Heterochromatin

v) Small part of DNA which has information to synthesize specific polypeptide chain is.
(a) Genome (b) Locus
(c) Gene (d) Nucleotide

vi) According to replication model, the parental double helix remain intact and conserved called.
(a) Semi conservative (b) Conservative
(c) Disposed (d) Eukaryotic replication

vii) A protein which prevents the re-binding of complementary strand during replication at fork is.
(a) DNA helicase (b) Ligase
(c) SSB (d) Primase

viii) The DNA strand which continuously replicate in the direction of 5' → 3' called.
(a) Lagging strand (b) Leading strand
(c) Primer (d) Okazaki fragment

ix) Process where information present on gene is used to produce a functional product by living organism called.
(a) Transcription
(b) Translation
(c) Gene expression
(d) Regulation of gene expression

x) The set of rules used to store the genetic information within a DNA for particular protein synthesis is.
(a) Gene (b) Genetic codes
(c) Codon (d) Anticodon

2. Write short answer of the following:

i) Why DNA is negatively charged molecules?
ii) Why replication is called semi-conservative process?
iii) Do genes of prokaryotic cell and eukaryotic cells are different in structure? If so give the main differences between them?
iv) What are leading and lagging strand of DNA?
v) Give the name of enzymes involved in replication of DNA, also give their brief functions.
vi) Do introns are transcribed, and involve in translation?
vii) Give changes occur in mRNA during transport from nucleus to cytoplasm.
viii) Give site at ribosome and their functions during translation.
ix) Draw structure of tRNA and give functions of their different sites.
x) Do mutation is always harmful? Justify you answer.

3. Give detail answer of following questions:

i) Describe the chromosomal theory of inheritance?
ii) Describe the semi conservative process of DNA replication?
iii) Describe the chemical structure of chromosome.
iv) Describe the process of transcription during gene expression.
v) What is gene regulation how gene regulate during expression?

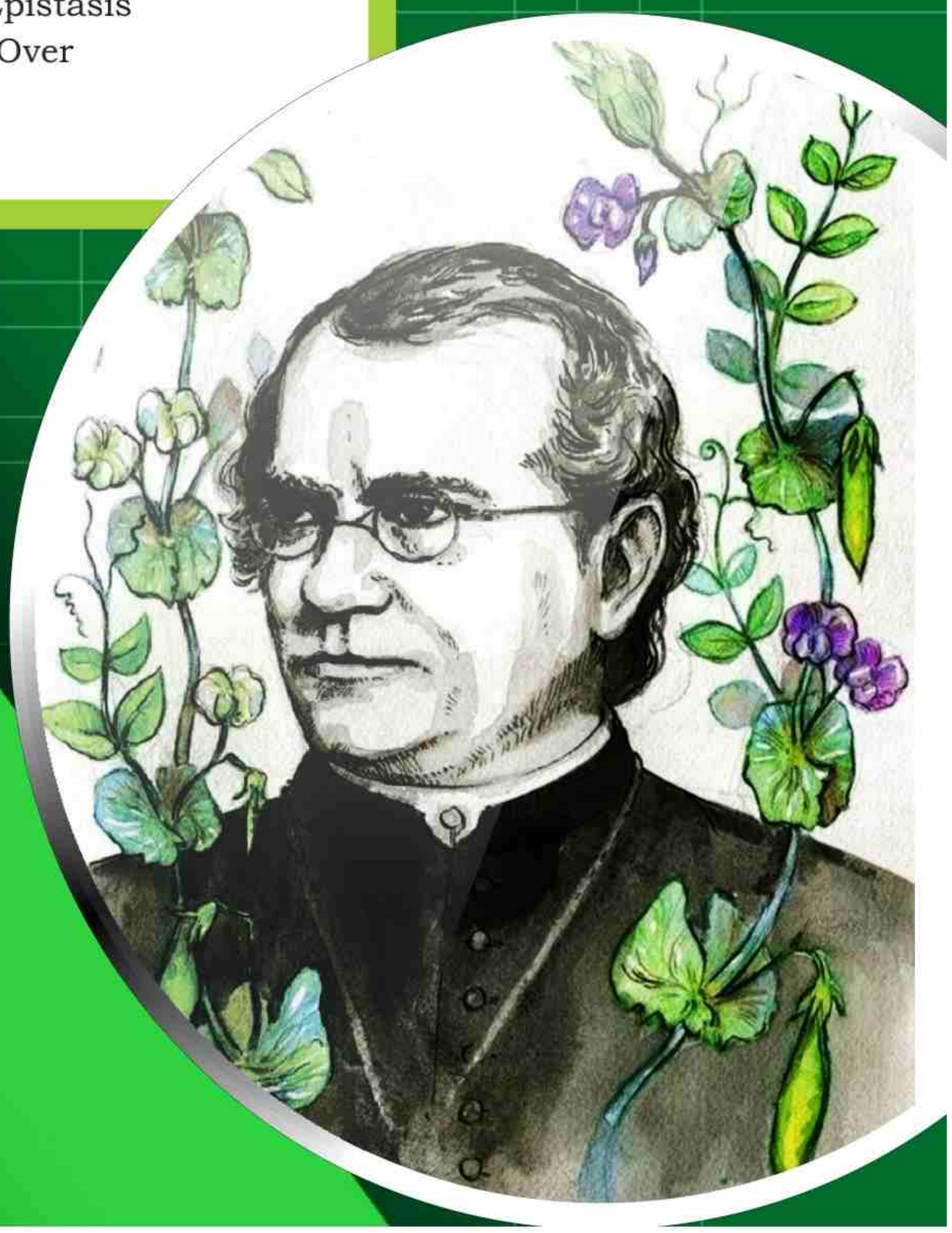
INHERITANCE

Chapter 23

Major Concept

In this Unit you will learn:

- Laws of Mendel
- Incomplete Dominance, Multiple Allele and Co-dominance
- ABO Blood group system.
- Rh Blood Type System and Erythroblastosis foetalis
- Polygenic Inheritance and Epistasis
- Gene linkage and Crossing Over
- Sex Determination
- Sex Linkage.



We have studied in early classes that the scientific study of inherited characters from parents to offspring, their pattern of inheritance and causes of variation called **Genetics**. In the course of history the simplicity was replaced by complex questions like what factors account for similarities between generation and varieties? What is inherited and what is not inherited? What heredity factors do members of species have in common and in what factors do they differ? How we can control heredity? These questions are addressed by Mendelian, non-Mendelian and modern advancement in genetics.

23.1 LAWS OF MENDEL

The earlier work on hybridization experiments on plant were failed because of their methodology and choice of material **Gregor John Mendel** an Austrian Monk succeeded to organize experiments and got logical results from them. The reason of his success lied in his choice of material and method of study. He chose *Pisum sativum*, because it is easy to cultivate and self-pollinated plant. It also contains big sized flower where cross-pollination can artificially takes place. The Pisum plant has number of varieties with sharply defined contrasting characters. As a result of cross-pollination they produce fertile hybrid offspring. He was not pure biologist so he avoided the complexities which troubled the earlier workers.

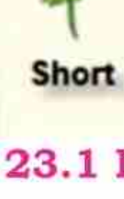
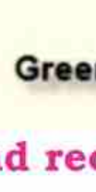
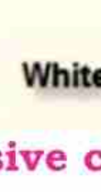
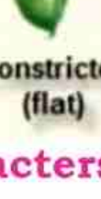
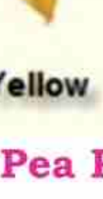
	Height	Seed Shape	Seed Color	Seed Coat Color	Pod Shape	Pod Color	Flower Position
Dominant	 Tall	 Round	 Yellow	 Green	 Inflated (full)	 Green	 Axial
Recessive Trait	 Short	 Wrinkled	 Green	 White	 Constricted (flat)	 Yellow	 Terminal

Fig. 23.1 Dominant and recessive characters of Pea Plant

Mendel started his studies by planting seeds with different contrasting characters which he selected for his studies. As a result he got pure breed of these plants. Then he planted the seed of these pure plants, at the time of flowering he crossed plants of contrasting characters to see the pattern of inheritance in the next generation, for example, he crossed smooth seeds producing plant with wrinkled seed producing plant. In this way he crossed plants of seven contracting characters plants as given in table 23.1.

Table: 23.1 Contrasting characters in pea plant

S. No	Cross between contrasting characters	Results of 1st Generation (F1)	Results of 2nd Generation (F2)	Ratio in F2
1	Tall x dwarf	All Tall	787 Tall 277 dwarf	2.84:1
2	Round seed x wrinkled seed	All Round seed	5474 Round 1850 wrinkled	2.96:1
3	Yellow cotyledon x green cotyledon	All Yellow cotyledon	6022 Yellow 2001 green	3.01:1
4	Purple flowers x white flowers	All Purple flower	705 Purple 224 white	3.15:1
5	Smooth pods x constricted pods	All Smooth pods	882 Smooth 299 constricted	2.95:1
6	Green pods x yellow pods	All Green pods	428 Green 152 yellow	2.82:1
7	Axial flower x terminal flower	All Axial flowers	651 Axial 207 terminal	3.14:1

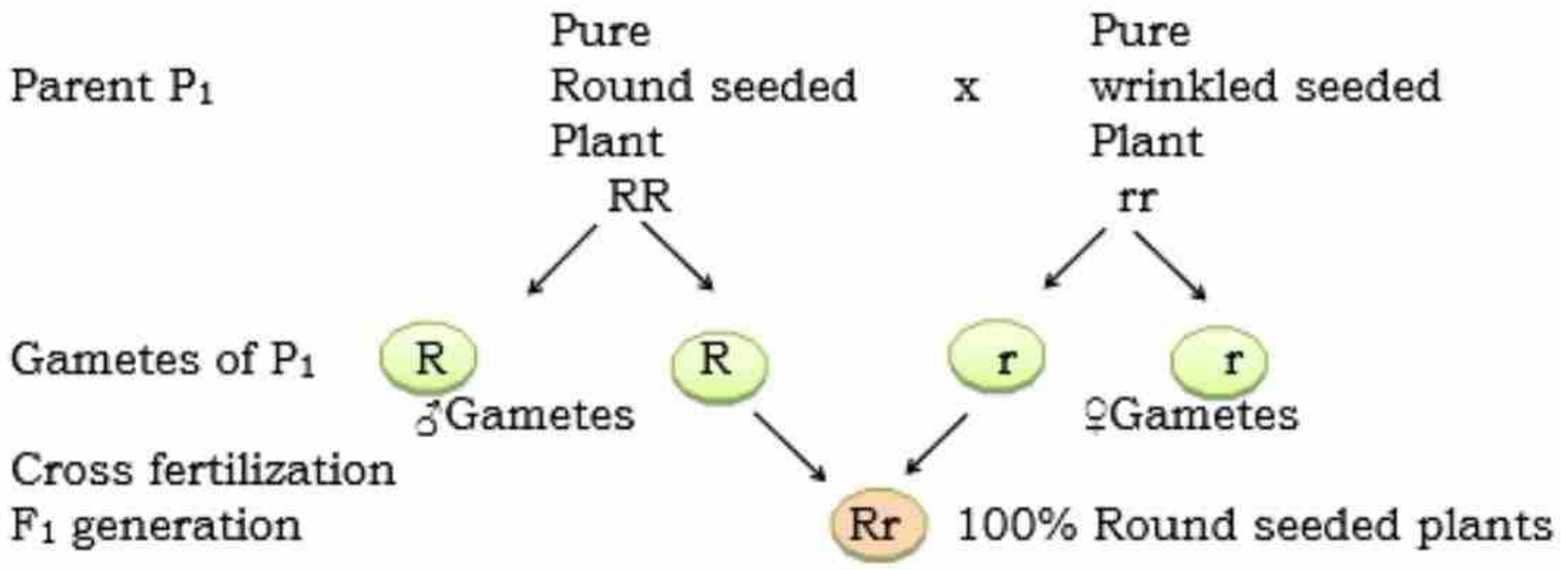
After crossing these plants he observed the result in 1st generation and maintained the record of data for each cross. He came to the conclusion that when pea plants with two contrasting expression of same character were crossed, one of the two expressed completely in the offspring while the other did not expressed at all. From this observation he derived the **law of dominance** which states that in **hybrid** (impure) condition only one character express, completely while other is masked completely. The character which was expressed in impure condition (1st generation, F1) called **Dominant** and its contrasting character, which was not expressed called **recessive**. He found same results in all studied characters of pea plant.

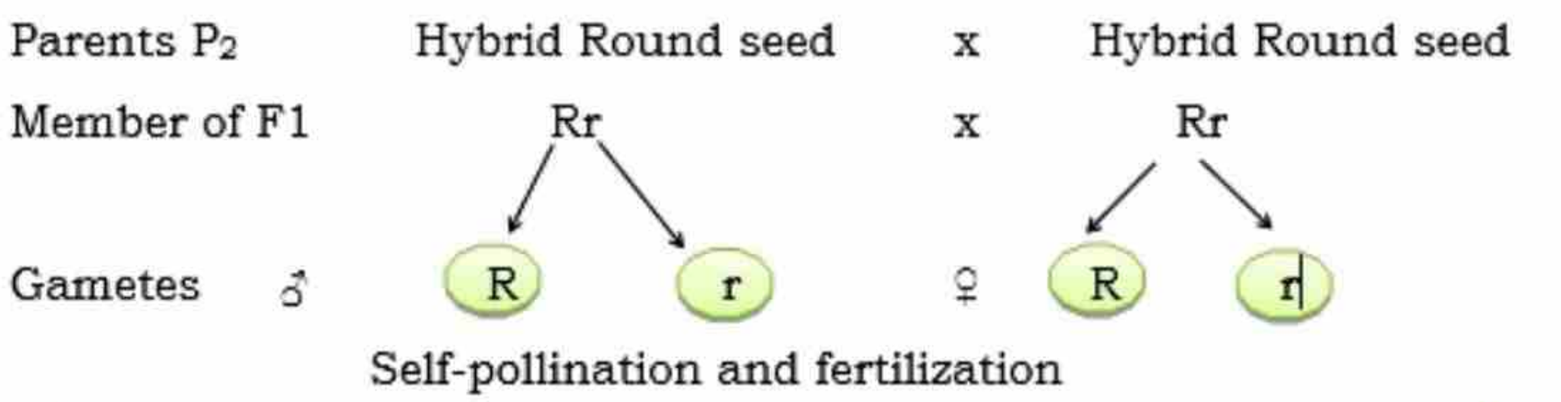
Mendel then proceeded to sow the hybrid seeds of the first generation (F1; Filial generation) and the plants were allowed to self-pollination for getting seeds of second generation (F2). When he sow these seeds he found that in F2 generation the dominant and recessive both appeared in the ration of 3:1. He also discovered that whatever the character pair he studied, the ration of plants with dominant character to those with recessive characters was always close to 3:1 as shown in table 23.1.

Mendel also explained that each organism contains two **factors** for each trait, one is **paternal** and other is **maternal**. They may be similar or different depend on parents. Due to logical mind Mendel gave a generalized theoretical explanation of his results obtained from these experiments in the form of law called **Law of Segregation**.

23.1.1 Law of Segregation

The law of segregation deals with the hybridization of only one character (trait) therefore the crosses involved in this experiment called monohybrid crosses. In this way it explains the inheritance of single trait. The law states that factors of each trait segregate cleanly during the formation of gametes so that each gamete contains only one factor of a trait. This law is also called **law of purity of gametes**, because each gamete contains only one factor of a trait.



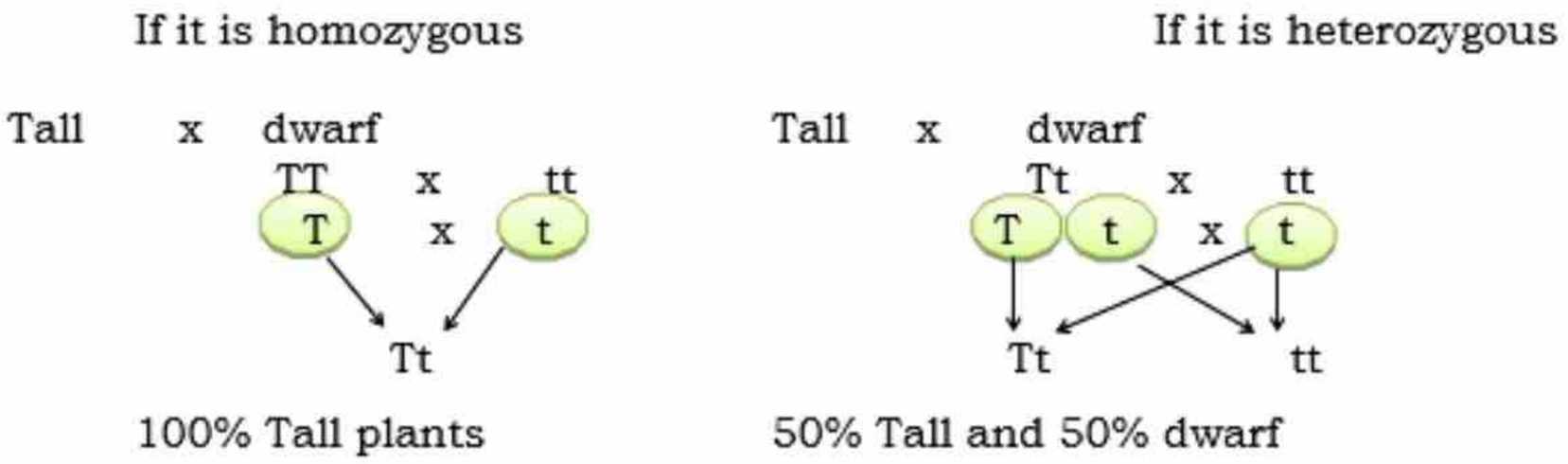


♂ / ♀	**R**	**r**
R	RR Pure Round seed	Rr Hybrid Round seed
r	Rr Hybrid Round seed	rr pure wrinkled seed

Now when are using some different terms from Mendalian terms like factors for genes and trait for character, **homozygous** for pure breed of a trait, **heterozygous** for hybrid or impure trait, for physical appearance of a trait we use **phenotype** and the pair of donated factors by parents for a trait called **genotype**. For example, Round seeded homozygous is RR while Round seeded heterozygous plant has genotype Rr.

During studies of single trait inheritance he found that if plants of heterozygous genotype are self-pollinated produce two types of plant, i.e. dominant and recessive, with the phenotypic ratio of 3:1 respectively. Genotypically they have ratio of 1:2:1 i.e. homozygous round seeded: heterozygous round seeded: homozygous wrinkled seeded.

Sometime it makes confusion that the phenotypically dominant individual is either homozygous or heterozygous because both are similar in their appearance. This confusion can be resolved by a cross called **Test cross**. This cross is made between phenotypically dominant individual and homozygous recessive individual to find out the **homozygosity** or **heterozygosity** of dominant parent. When dominant homozygous parent is crossed with recessive, all the offspring will be dominant phenotypically but when cross with heterozygous dominant then half one of the offspring will be dominant and half recessive, as follows



i.e 1:1 ratio.

Inheritance of Two Traits

Mendel experiment on garden peas were not limited to single traits but sometimes involved two or more traits. After studying inheritance pattern of single trait Mendel studied two trait inheritance patterns to find out the inheritance pattern of different traits of an organism at same time. He crossed pea plant having two traits of contrasting varieties. This cross is called di-hybrid cross and the result obtained as a result of these crosses called **Dihybrid ratio**.

Mendel chose a pure tall pea plant which produces round seed and a pure dwarf pea plant produces wrinkled seed cross together by artificial means. He found all tall plants which produce round seed, from these results he infer perhaps these two assorted traits of a plant are dependent on each other during inheritance because only one of the parental combination is produced in F1 generation. When he left the members of F_1 generation for self-pollination and get their offspring he found some new combinations which are different from parental combination i.e. some tall plants can produce wrinkled seed

or some dwarf plants can produce round seed as shown in flowing cross.

Parent (P_1) — Tall plant produce Round wrinkled seed homozygous for both TTRR — x — dwarf plant produce seed homozygous for both ttrr

Gametes of P_1 — TR, tr

F_1 generation — TtRr

All Tall and produce Round seeds

Self-pollination

TtRr x TtRr

Gametes — TR Tr tR tr x TR Tr tR tr

TR	TR	Tr	tR	tr
TR	TTRR Tall & Round seed	TTRr Tall & Round seed	TtRR Tall & Round seed	TtRr Tall & Round seed
Tr	TTRr Tall & Round seed	TTrr Tall & wrinkled seed	TtRr Tall & Round seed	Ttrr Tall & wrinkled
tR	TtRR Tall & Round seed	TtRr Tall & Round seed	ttRR dwarf & Round seed	ttRr dwarf & Round seed
tr	TtRr Tall & Round seed	Ttrr Tall & wrinkled seed	ttRr dwarf & Round seed	ttrr dwarf & wrinkled seed

This experiment revealed that in di-hybrid crosses some phenotypically new plants i.e. plants with non-parental combinations are also produced. According to above example tall plants do not

produce round seeds like parent they may produce wrinkled seed as well as some plant similarly dwarf plants do not produce wrinkled seeds they may produce round seeds in other dwarf plants. In this way Mendel found some parental and some non-parental combinations in F_2 ration as follows

Tall plants producing: Round seeds (Parental)	Tall plants producing: wrinkled seed (Non-Parental)	Tall plants producing: Round seeds (Non-Parental)	Tall plants producing: wrinkled seed (Parental)
$\frac{9}{16}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{1}{16}$

Above results led him to the formulation of a law called **Law of Independent assortment** which states that "The factors of assorted traits are independent in their inheritance". OR

The members of one pair of gene segregate independently of the other.

Extra Reading Material

In an experiment Mendel found Green seed colour (G) is dominant over yellow (g). Find out genotype of following parents whose phenotypes are given F1

Parents	Green	Yellow
i) Green x yellow	82	78
ii) Green x Green	118	39
iii) White x yellow	0	50
iv) Green x yellow	74	0
v) Green x Green	90	0

Exception to the Mendel's Law of inheritance.

Basically Mendel was a Monk, his knowledge of inheritance was based on the experimental results which he observed during cross breeding between different strains of pea plants. In this way he had given basic concept of genes, alleles, dominant and recessive allele. His understanding was limited, up to his observation that each

trait has only two alternating forms i.e. **Allele** or when these two contrasting allele of a trait gather in an organism only one expresses while other does not, which he said **complete dominance**. After Mendel, breeding experiments were carried in different plants and animals where many exceptions were also found. As a result of these cross-breeding experiments, different types of phenotypes and phenotypic ratio were observed which were different from Mendelian ratio. These exceptions were named as non-Mendalian inheritance i.e. incomplete dominance, co-dominance, multiple alleles etc.

Incomplete Dominance

Carl Correns in 1889 worked on 4 o'clock plants (*Mirabillis jalapa*), During his cross-breeding experiment of pure breed Red flowering plant with white flowering plant he found pink flowering plants. This studies of inheritance showed that many trait have not showed that Mendalian behavior of complete dominance because the 4 o'clock plant in F1 generation had not produced any of the parent phenotype i.e Red or white. Furthermore, when Correns self-fertilized F1 pink flowered plant, the F2 generation showed all three phenotypes of flowers in the ratio of 1(Red) : 2(Pink) : 1(white), the Red and white were homozygous while the pink were heterozygous genotypically.

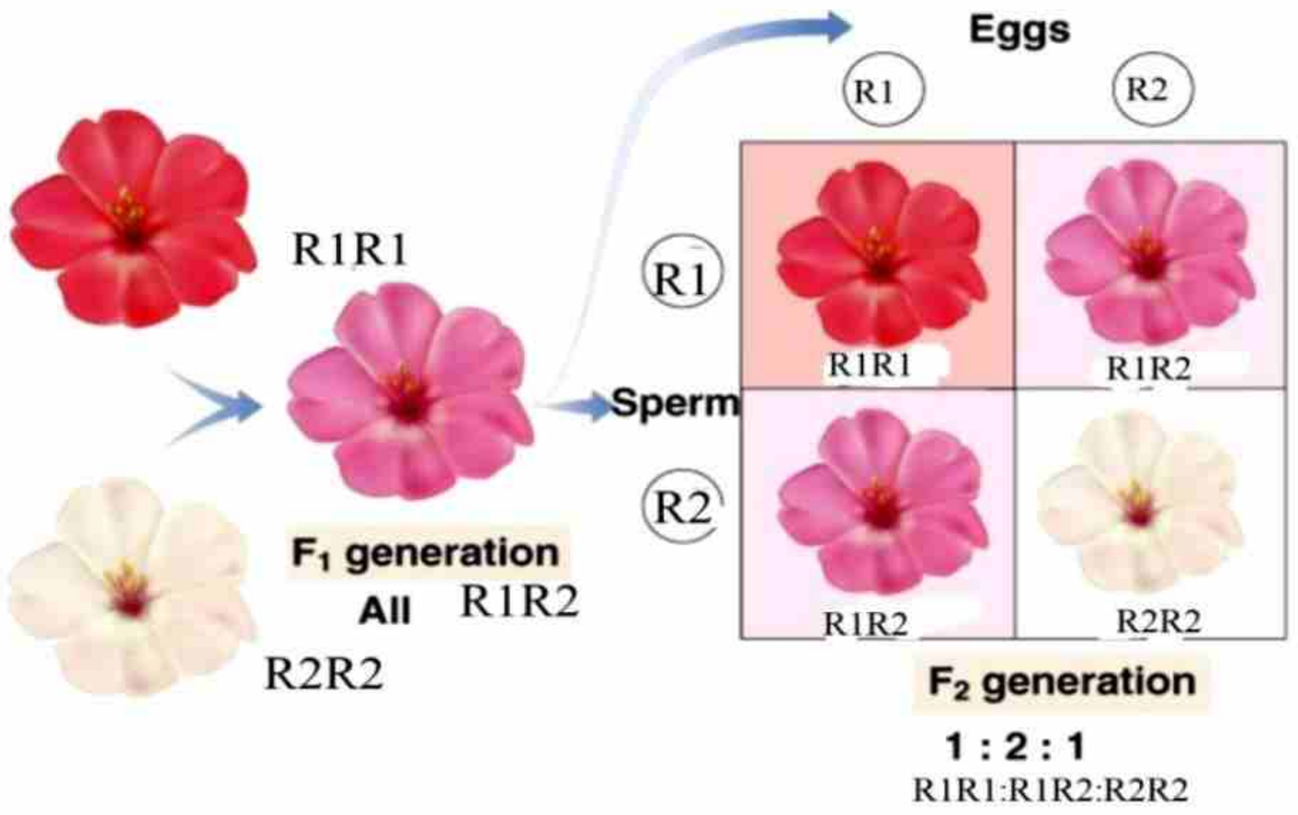


Fig. 23.2 Incomplete dominance

It showed that when contrasting allele exist in an individual none of them masked the expression of other, both of them tried to express but these expressions get blended to produce a new phenotype. So he stated that in heterozygous condition both the contrasting allele express and expression get blended to form a new phenotype is called incomplete or partial dominance.

The capital and small letters are used for complete dominant and complete recessive alleles respectively but in the case of incomplete dominance none of the allele is completely dominant over the other so alleles are represented by same letters with sub-script number to distinguish them from each other e.g. for Red flowers (R_1) and White flowers (R_2).

Co-Dominance

Another type of deviation from Mendalian complete dominance is co-dominance, where heterozygous individuals where both contrasting alleles of same locus express independently and form their respective products, these products show their expression clearly and independently without any blending.

It may be described as phenomenon of inheritance in which both contrasting allele of a trait are dominant and express themselves in heterozygous individual neither masking nor blending the effect of one another.

In a cross between a true breeding short horn red cattle and a true breeding short horn white cattle, the offspring have roan colour, a close examination of skin of roan coloured animal shows that the animal does not possess an intermediate shade of skin colour, but it appears so because of presence of red and white hairs evenly present at the skin. It is clear from it that none of the two genes is dominant over the other.

Landsteiner and Levine discovered MN blood type in man on the basis of specific antigen present in RBC, produce specific antibodies. There are three phenotypes M, N and MN which are produced by L^M and L^N genes.

Phenotype	Genotype	Antigen on RBC
M	$L^M L^M$	M
N	$L^N L^N$	N
MN	$L^M L^N$	M and N

If a man of M blood group marries a woman of N blood group all their all their children will be of MN

Difference between incomplete and co-dominance

Incomplete Dominance	Co-dominance
➢ Phenomenon of inheritance where expression of both contrasting allele blend in heterozygous condition. ➢ New phenotype produce as a result of incomplete dominance. ➢ Quantitatively both express equally. ➢ e.g flower colour in 4o'clock plants	➢ Phenomenon of inheritance where expression of both contrasting allele does not blend in heterozygous condition. ➢ New phenotype does not produce as a result of co-dominance. ➢ Quantitatively both express unequally. ➢ e.g hair colour in cow or MN blood group.

Multiple Alleles

A trait may have more than two alternative forms but Mendels only found two alternative forms of a gene. The genes which have more than two alternative forms are called multiple alleles. These multiple forms of gene are produced by gene mutation. These multiple forms of gene occupy same gene locus on chromosome, some traits have more than 100 alleles but each individual has two of them in diploid cell or only one in haploid cell. A well-known example of multiple allele in human being is ABO blood group.

Karl Landsteiner in 1901 discovered ABO blood group, has four different phenotype on the basis of presence of A or B antigen on the surface of RBC i.e a person with antigen A has a **blood group A** and that with antigen B has **blood group B**. A person with A and B antigen **blood group AB**. Similarly a person without both antigens on its RBC has **blood group 0**.

The genetic basis of ABO system was explained by Bernstein in 1924. He explained that there are three alleles responsible for the trait of blood group i.e. I^A, I^B and i. These alleles have six possible combinations i.e. genotype, i.e. I^AI^A, I^Ai, I^BI^B, I^Bi, I^AI^B, ii.

Table: 23.2 ABO blood groups of human

Blood Group	Genotype	Antigen	Phenotype
Blood Group A	I^AI^A	A	A homozygous
	I^Ai	A	heterozygous
Blood Group B	I^BI^B	B	homozygous
	I^Bi	B	heterozygous
Blood Group AB	I^AI^B	A & B	AB heterozygous
Blood Group O	ii	No antigen	O homozygous

Co-Dominance in Human Blood Group AB

The phenomenon of Inheritance where both contrasting alleles of same gene locus express independently without affecting each other called co-dominance. In co-dominance the phenotype of both the alleles becomes apparent. Human AB blood group is the best example of co-Dominance, where both I^A and I^B are co-dominant alleles produce two different antigens on the surface of same red blood cells. Therefore the person with I^A I^B genotype have Blood group AB.

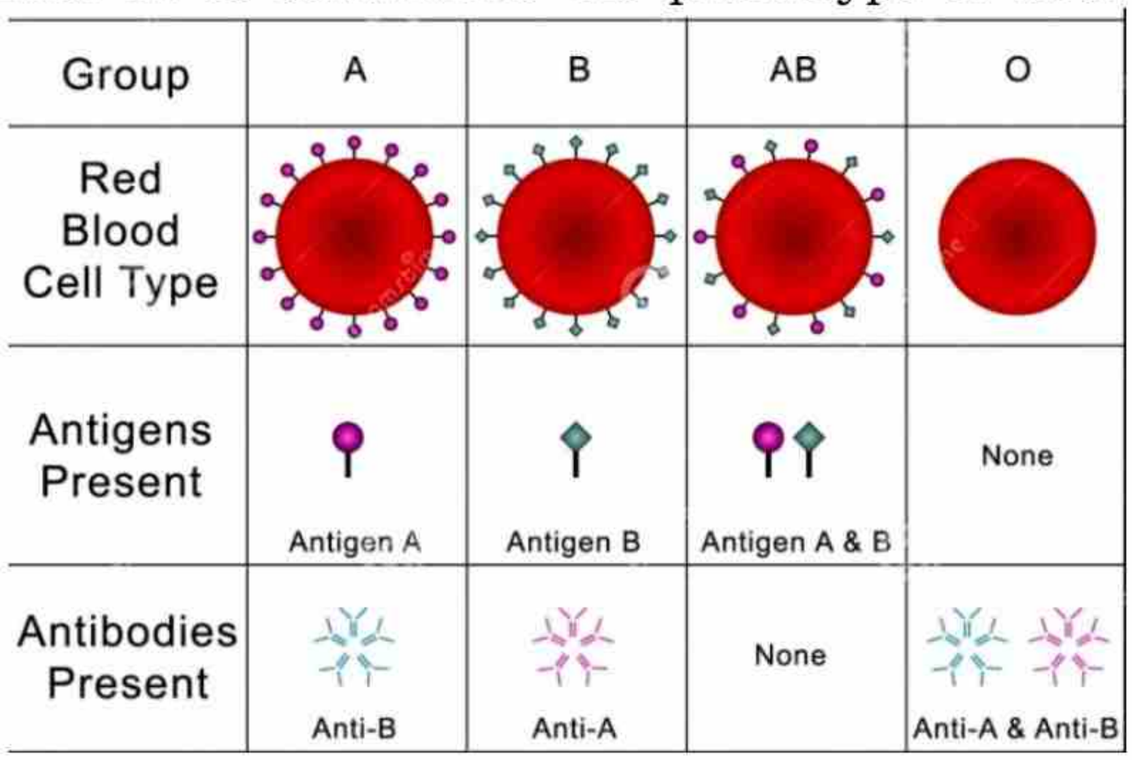


Fig.23.3 ABO blood system

Human Blood Group System

In human beings numbers of different blood group systems are investigated to explain the variability of cells, chemical and its interaction with other blood groups. It is observed and carefully selected at the time of blood transfusion therefore International Society of blood transfusion has found more than 30 types of blood group system. These systems are mainly based on the presence or absence of special molecules found on blood cells. These molecules are mainly present on the surface of R.B.C and belong to the group of conjugated molecules i.e glycoprotein. The main type of blood group

systems are MN blood group system, ABO blood group system and R^h system among these three, two are widely used i.e. ABO and R^h system.

It is due to the reason that the incompatibility between donor and recipient lead to the death of recipient. The MN blood group system is considered as the rare blood group.

Multiple Alleles of ABO Blood Group System

As we have discussed earlier that ABO blood group system is controlled by three alleles I^A, I^B and i. I stand for **isoagglutinogen**, other term stand for isoagglutinogen is antigen: Allele I^A specifies production of antigen A and allele I^B produce antigen B but allele i does not produce any antigen. Both I^A and I^B are dominant allele whereas i is recessive by I^A and I^B. These alleles start their expression at early embryonic stage and keep on expressing till death. Therefore the blood group of a person never changes throughout its life.

Table: 23.2 Blood group systems in human based on R.B.Cs antigen.

	Blood group system	Antigen on surface protein
1	ABO	A^1, A^2, A^3, A^4 B and others
2	Rhesus (R^h)	D, C, c C^w ,Cx, E, D4 and other
3	MNS	M, N, S, s
4	P	P, P^1 and P^k
5	Lutheran	Lu^a, Lu^b
6	Kell	K, k, K^a, K^h, Js^a, Js^b
7	Lewis	Le^a, Le^b
8	Duffy	Fy^a, Fy^b
9	Diego	Di^a, Di^b
10	Yt	Yt^a, Yt^b
11	I	I, i
12	Xg	Xg^a
13	Kidd	Kj

The person having A Blood group produce antibodies called anti-B antibodies in its blood serum. while the person of B-Blood group produce Anti-A antibodies Person of AB blood group neither have anti-A nor have anti-B-antibodies in its Serum. The Serum of 0-blood group person has both anti-A and anti-B antibodies. The blood serum which contains anti-bodies called antiserum.

There antiserum appear in plasma during the first month after birth. The person with A blood group which contain Anti-B antibody if transfused with B-blood group will agglutinate or clump R.B.C of B-antigen (B-blood group) on the other hand R.B.C of B-blood group will agglutinate by A-blood group R.B.C, while R.B.C of AB blood group will not agglutinate by any of them and O blood group will agglutinate by any blood group. The blood transfusion is only safe if it does not agglutinate. Agglutination is dangerous for health of a person because Clumped cells form a huge mass which cannot pass through fine capillaries. The blood samples of the donor and the recipient are cross-matched for compatibility before transfusion. If wrong (non-compatible) transfused hemolytic reaction occurs which become fatal for the person. In hemolytic reaction, the antibodies of the recipient destroy the R.B.C of donor or the antibodies of the donor hemolytic the R.B.C. of the recipient.

The person have A and AB blood group receive blood of A-group, the person of B and AB blood group can receive blood of B-Blood group because they do not have anti-B antibodies. The persons of AB blood group can donate their blood only to the persons of AB-blood group because they have neither anti-A nor anti-B antibodies, while O blood group can donate to persons of all blood group because these persons produce both anti-A and B-antibodies but person of O-blood group can accept only blood of O-group because it has neither A nor B-antigen on its R.B-Cs.

O-Ve as Universal Donor

If a person has O-ve blood group means it has neither antigen A, nor antigen B and antigen R^h is also absent on R.B.Cs, The O produce anti-A and B antibodies, these antibodies are quickly absorbed by recipient tissues or greatly diluted in the recipient blood streams this do not develop agglutination of R.B.Cs. there **O-ve blood** is called **universal donor**. On the other hand side **AB +ve blood** group individuals are called **universal acceptor** because they can receive blood from the persons of all blood groups.

Some person also have A and B antigens in saliva and other body tissues, these persons are called secretors. They carry dominant secretor gene Se on chromosome number 19.

R^h Blood System

Usually when we tell our blood group, we mix-up two different systems of blood, which are controlled by two different genes, although the expression of both genes appear phenotypically at the surface of R.B.Cs, this R^h blood system is usually represented by +ve or –ve sign, which refers to the presence or absence of R^h antigen. R^h blood group systems are explained on the basis of R^h antigen present on the surface of R.B.C. This antigen observed in Rhesus monkey by Landsteiner in 1930s.

The prime gene locus D is mainly responsible for the production of and R^h antigen the human population has two alleles of D i.e. **D** and **d**. The D is completely dominant over d. The person having DD, Dd genotype produce Rh antigen on R.B.C and called R^h +ve while a person with dd genotype is unable to produce R^h antigen therefore called -ve R^h Unlike the naturally occurring anti-A and Anti-B antibodies of ABO system, anti-R^h antibody production require a stimulus by human R^h antigen itself. If a person of –ve R^h receive blood of R^h +ve person which carry R^h antigen. The Recipient will begin to produce anti- R^h antibodies against R^h antigen or R.B.C of donor and start destroying it to from clump. On the other hand side -ve R^h blood which does not contain any anti- R^h antibody can be transfused to R^h +ve recipient.

Erythroblastosis Foetalis

It is a maternal foetal R^h incompatibility problem. It occurs when Rh-ve women marry a R^h +ve man, she conceive a child having R^h +ve blood. If this R^h +ve man has genotype DD, all of their children will have Dd genotype and phenotypically they are R^h+ve. On the other hand side if the genotype of man Dd (heterozygous) than the chances of R^h+ve and R^h –ve in their children will be 50% both. The chance of Erythroblastosis foetalis is found when an R^h +ve foetus is conceived by R^h–ve mother.

Erythroblastosis foetalis an antigen-antibody Reaction

It starts when a R^h-ve mother conceive R^h+ve foetus. At the time of 1st labour some R^h antigen seep into mother's blood which produces antibodies against it in the body of mother. At the time of next R^h+ve baby (foetus) some of the anti- R^h antibodies seep through

placenta into the blood of R^h +ve foetus and start break down of R.B.C i.e haemolysis. If this destruction remain continue the foetus become anemic, which start releasing immature erythroblasts in blood stream therefore this antigen-antibody reaction is called erythroblastosis foetalis. This anemia may lead to abortion or still birth or if pregnancy continues, the liver and spleen of foetus become enlarge due to fast destruction of R.B.Cs. The breakdown of R.B.C. produce large amount of bilirubin pigment which accumulate in the foetus and damage the neuron. It also tums skin and white part of eyes into yellow this problem is called jaundice. It means if the baby remained alive in this condition suffers from severe hemolytic anemia and jaundice.

Measures to counter the problem of Erythroblastosis foetalis

The R^h-ve mother is given R^h antiserum in injectable form during early pregnancy and immediately after labour. The R^h antibodies in R^h antiserum will destroy R^h R.B.C of the foetus before they stimulate production of maternal anti-R^h antibodies. The injected antiserum vanishes before next pregnancy therefore R^h antiserum should be given at the time of each pregnancy. If a baby is born with this defect, the blood with high level of bilirubin of baby should be immediately replaced by R^h negative blood free from anti-R^h antibodies

Polygenic Inheritance and Epistasis

The traits are expressed either qualitatively or quantitatively. We have discussed qualitative inheritance in our pervious discussion where traits are controlled by one gene present on single gene locus e.g. Tall, dwarf, blood group, R^h factors etc. Although these gene have multiple alleles, the phenotype was dependent on the presence of a particular allele. On the other hand some traits are controlled by many genes located at different loci.

Their phenotype will work in the additive manner therefore, this inheritance is quantitative inheritance. The phenomenon of inheritance where a single trait is controlled by two or more than two separate pairs of genes which manifest themselves in additive manner to yield variable phenotype called Polygenic Inheritance and these traits are called continuously varying traits.

On contrary there is another phenomenon of inheritance where expression of a gene is controlled by another gene which is located on different locus. This phenomenon of interference in called Epistasis (Gr- Epi- above, stasis = standing or stop). In this phenomenon, non-locus genes alter the expression of original gene which is independently inherited. It should not be confused with dominance because dominance is the relationship between allele of same gene located at same gene locus but epistasis is the interaction between different genes, located at different gene loci.

Polygenic Traits in Plants and Animals

As we have discussed above that a continuously varying trait is encoded by alleles of two different gene pairs located at different loci, all work for a same trait and express in additive manner to show quantitative effect, are called polygenes. Each gene of a polygenic group has a small positive or negative effect on the character. Polygenes support each other to produce positive or negative effects e.g wheat grain colour in plant and skin colour in animals.

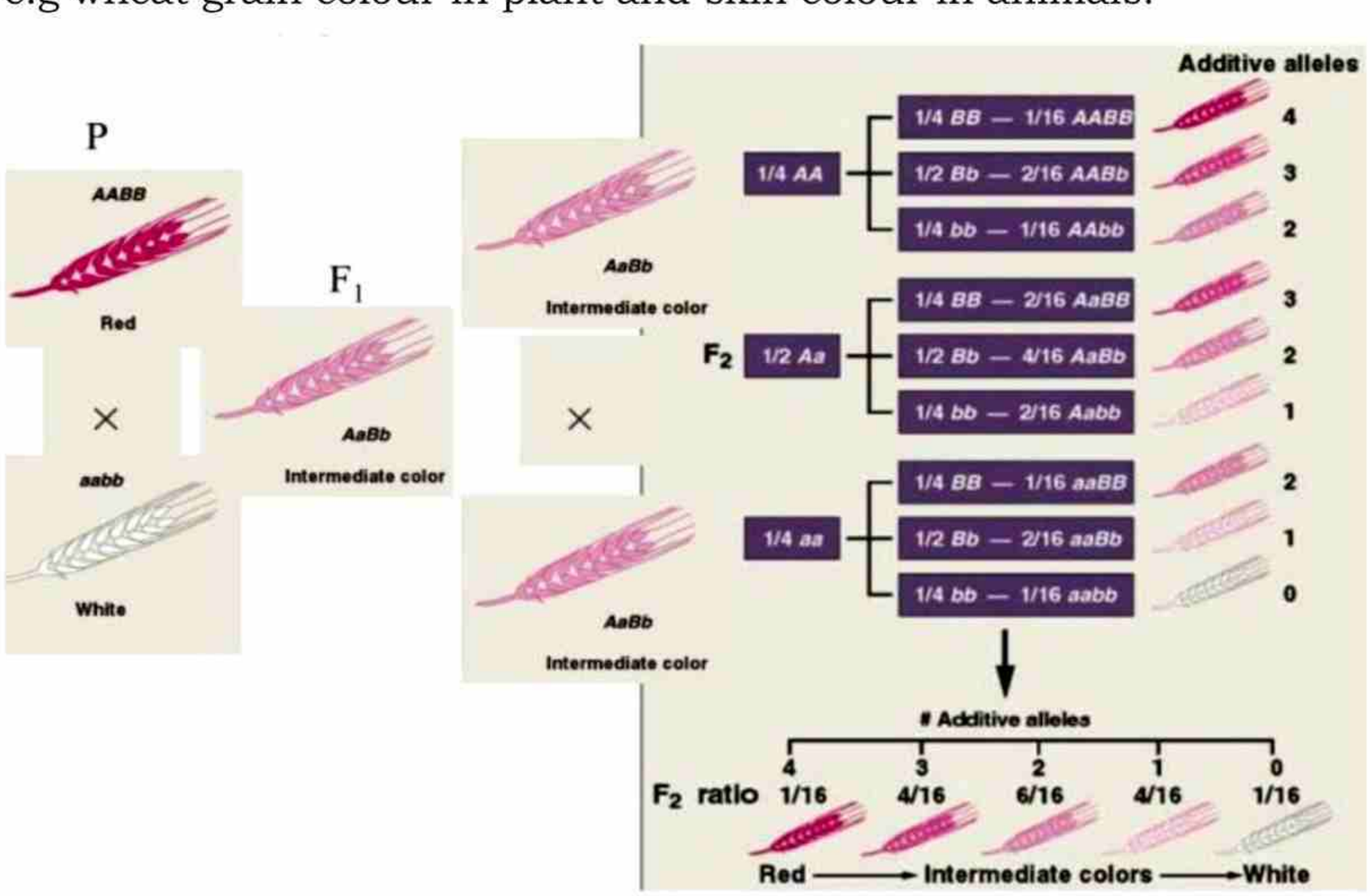


Fig. 23.4 Polygenic trait of wheat

Wheat grains colour trait as polygenic trait

The colour of wheat grains vary from white to dark red. It is a best example of polygenic inheritance or continuously varying trait. Usually seven different phenotypes are found in the population of wheat all over the world. These phenotype vary from dark red to white.

Nilsson-Ehle studied the genetics of wheat grain colour. When he crossed true breeding dark red with white grain producing wheat plants, All plant in F_1 generation produce light red grains. i.e intermediate between two parental shades. It seems like case of incomplete dominance, so when F_1 grains were grown to mature plants and crossed with each other, F_2 grains had exactly seven shades of colour in the ratio of 1 dark red: 6 moderately dark red: 15 red: 20 light red: 15 pink: 6 light pink: 1 white as given in chart below.

Phenotypes In wheat grain colours

Phenotype	Dark red	Moderately dark red	Red	Light red	Pink	Light pink	White
Ratio	1	6	15	20	15	6	1

It was found that the grain is controlled by three different gene pairs. i.e Aa, Bb, Cc at three different loci, Each individual would contain six alleles for this trait. Allele A, B, C are for the production of red pigment while a, b, c does not produce any pigment. If a wheat plant contains ABC in the combination of **AABBCC** all produce red pigment so they produce Dark red grains. If the genotype will be **aabbcc** none of them produce red colour so the wheat grain colour will be white. The other genotype will be developed different colours of grains as phenotype.

	ABC	ABc	AbC	Abc	aBC	abC	aBc	abc
ABC	AABBCC	AABBCc	AABbCC	AABbCc	AaBBCC	AaBbCC	AaBBCc	AaBbCc
ABc	AABBCc	AABBcc	AABbCc	AABbcc	AaBBCc	AaBbCc	AaBBcc	AaBbcc
AbC	AABbCc	AABbCc	AAbbCC	AAbbCc	AaBbCC	AabbCC	AaBbCc	AabbCc
Abc	AaBbCC	AABbcc	AAbbCc	AAbbcc	AaBbCC	AabbCc	AaBbcc	Aabbcc
aBC	AaBBCC	AaBBCc	AaBbCC	AaBbCc	aaBBCC	aaBbCC	aaBBCc	aaBbCc
abC	AaBbCC	AaBbCc	AabbCC	AabbCc	aaBbCC	aabbCC	aaBBCc	aabbCc
aBc	AaBBCc	AaBBcc	AaBbCc	AaBbcc	aaBBCc	aaBbCc	aaBBcc	aaBbcc
Abc	AaBBCc	AABbcc	AAbbCc	AAbbcc	AaBbCc	AabbCc	AaBbcc	aabbcc

It was found that all the six allele code for red pigment (AABBCC), colour of grain will be dark red. When all six alleles do not

produce red (aabbcc) the colour of grain will be white. When a grain has one allele for red light (Aabbcc or aaBbcc or aabbCc) the colour of gram will be light pink, if plant contain two alleles of red pigment (AaBbcc or aaBbCc or AabbCc) the colour of grain will be pink. If the plant has three Pigments of Red colour (AaBbCc or AABbcc or AabbCC) will be light red. In the same way for alleles colour dose (AABBCC & aaBBCC or AAbbCC) will express red and five dominant alleles dose (AABBCc or AABbCc or AaBBCC) will produce moderately dark red grains. It showed that the phenotype of grain colour depend upon the presence of colour producing alleles i.e. A, B and C. The expression of these genes are also influenced by environmental factors like light, Water and nutrients.

Inheritance of Human Skin Colour

Another example of polygenic trait is human skin colour trait, which is found in variable shade therefore it is continuously varying trait. Human skin colour develops by the presence of a pigment melanin. If a person produces high quantity of melanin, its complexion (skin colour) will be dark or vice versa. This trait is controlled by three to six gene pairs, greater the number of melanin producing gene darker will be the skin colour. These genes are working in the following manner:

Locus 1	d^1d^1	d^1D^1	d^1D^1	D^1D^1	D^1d^1	D^1d^1	D^1D^1
Locus 2	d^2d^2	d^2d^2	d^2D^2	D^2d^2	D^2d^2	D^2D^2	D^2D^2
Locus 3	d^3d^3	d^3d^3	d^3d^3	d^3d^3	D^3D^3	D^3D^3	D^3D^3
Total number of dark-skin genes	0	1	2	3	4	5	6

Fig.23.5 Polygenic trait of human

Gene A is responsible for permanent survival, proliferation and migration of melanocytes

Gene B is responsible to synthesize tyrosinase, involve in the conversion of tyrosine into melanin. It means that it is involved in the synthesis of melanin.

Gene C is responsible for determination of either proper black or dark brown type of melanin i.e. eumelanin will synthesize or red-brown type of melanin i.e. phenomelanin will produce.

Each of the above ABC has & two forms, the dark skin alleles are represented by capital letters (ABC) and light skin alleles are represented by small letters (abc). These alleles are not completely dominant over each other. In heterozygous condition they exhibit intermediate phenotype i.e. incomplete dominance, the gene a, b and c act as light-skin alleles in the genotype they inhibit melanin production.

There are seven different shades of skin colour ranging from very Light (aabbcc) to very dark (AABBCC), mostly human beings have the intermediate skin colour (AaBbCc) this genotype develops mulato i.e. an offspring of intermediate skin colour belongs to black and white parent. When individual of mulato cross with each other i.e. AaBbCc x AaBb Cc, each parent can produce eight different types of gametes, when these gametes fertilize there will 64 chances of zygote formation by which offspring of seven colours can be produced.

Epistasis

We have already discussed that the effect of non-locus on other gene to interfere in their phenotype is epistasis. The gene which interferes and masks the phenotype of the non-locus gene is called epistatic gene or interfering gene and the gene which expression masked by epistatic gene is called hypostatic gene.

Examples of Epistasis in Plants and Animals

Colour pigments trait in Foxgloves Petals

In foxgloves plant petal colour is determined by three genes. M which expresses to Synthesis an enzyme to develop Anthocyanin which expresses as purple pigment, mm produces no pigment it seen albino with yellowish spot on petal, while another gene D is an

enhancer of anthocyanin due to this gene expression more anthocyanin produce and petal become darker, dd does not enhance. The third gene which is located at another gene locus, W prevent pigment deposition except in the spot as a result white spotted petals are produced whenever ww allow pigment deposition in petals.

M (MM, Mm) → Purple
mm →white (no pigment)
W (WW, Ww) → spots

D (DD, Dd) → enhancer of purple
dd → no enhancer (light)
ww → Uniform colour (no-spot)

According to the result of di-hybrid cross performed by Mendel if genes of 2 traits are heterozygous in both parents they produce offspring with the phenotype ratio of 9:3:3:1 but there was no epistatic genes, but In the case of foxgloves plant di-hybrid cross where both are heterozygous for both traits. Produce 12: 3:1

DdWw x DdWw

Gametes DW Dw dW dw x DW Dw dW dw

	DW	Dw	dW	dw
DW	DDWW White spotted	DDWw White spotted	DdWW White spotted	DdWw White spotted
Dw	DDWw White spotted	DDww Dark red	DdWw White spotted	Ddww Dark red
dW	DdWW White spotted	DdWw White spotted	ddWW White spotted	ddWw White spotted
dw	DdWw White spotted	Ddww Dark red	ddWw White spotted	Ddww light red

Dominant Epistasis: white spotted : Dark red : light red

12 : 3 : 1

The mechanism of interference shows that **W** prevents deposition of pigment in flower, only in spots where as **w** allows deposition in the all cells of petals. On the other hand **D** allele allows to synthesize large amount of anthocyanin (red pigment whereas allele **d** synthesize little amount of anthocyanin.

Coat Colour in the Labrador retriever
Example of Epistasis in Animal

Labrador is an excellent type of dog its coat colour is one of the best example epistasis in mammals. These dogs are found in three colours due to their coat colour, i.e. Black, chocolate and yellow. This coat colour Inheritance is autosomal i.e. their genes are located at autosome it means it is not related with their sexes: the **B** is for Black colour **b** is for Chocolate colour both are located at same gene locus but the gene of yellow colour **E** is located at other gene locus.

The Black Coat colour (B) is dominant over chocolate (b). The Chocolate puppy must be homozygous i.e. both parent donates recessive allele. Its genotype well be (bb) but if any puppy have BB in Bb genotype to offspring will always be black, yellow coat colour gene is located at different gene locus this gene also have two alleles **E** dominant **e** recessive produce yellow it requires two doses of ee it means homozygous recessive will interfere in the expression of Black and chocolate to produce yellow coat colour. It shows that the colour gene is recessive epistatic gene. However, homozygous dominant EE or heterozygous dominant will not interfere to the puppies will be either black or chocolate according to parental gene combination. If a Black Labrador which is homozygous for both gene pair (BBEE) is crossed with a yellow (bbee), all offspring will be black with BbEe genotype. If these black offspring interbreed produce offspring of all three coat colours i.e. Black, Chocolate and yellow.

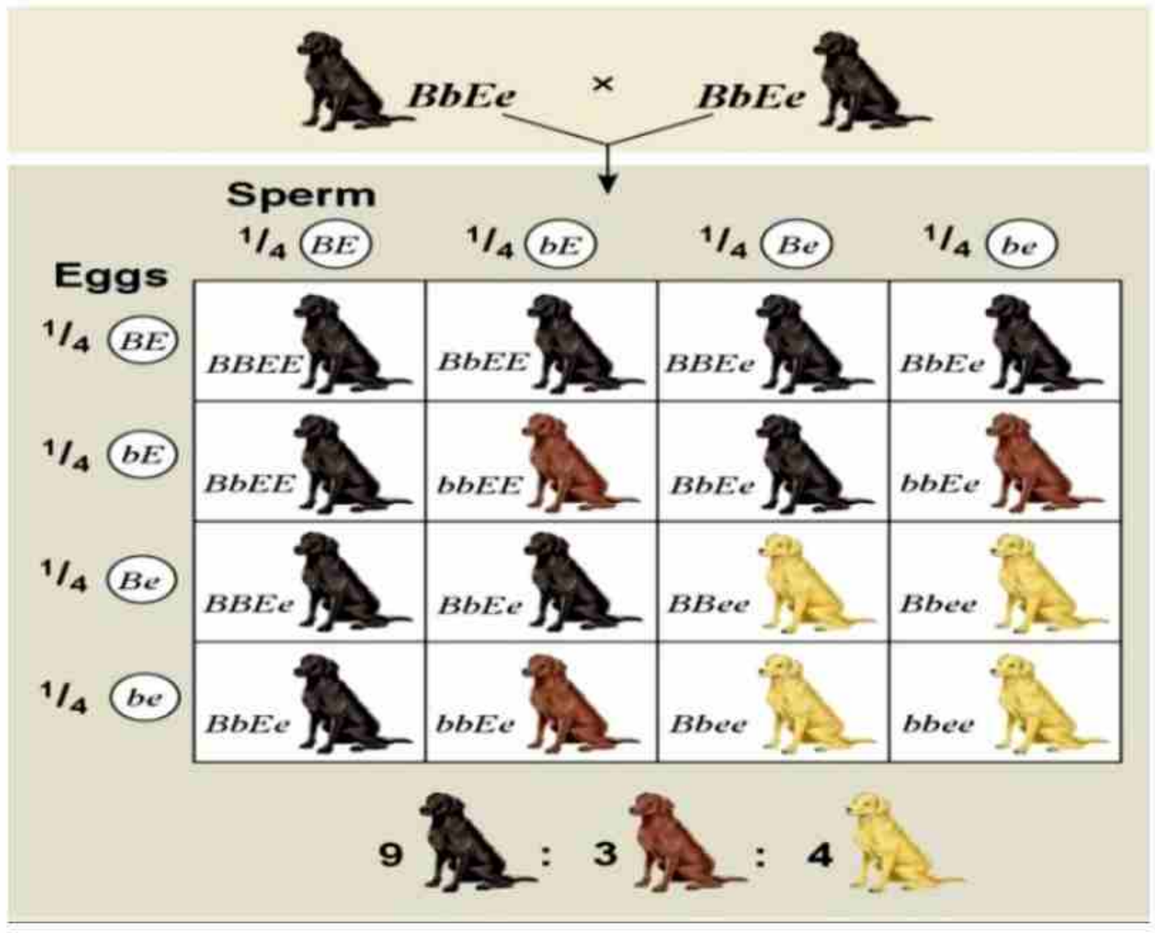


Fig.23.6 Dominant Epistasis

Gene Linkage and Crossing Over

According to careful estimates, there are thousands of genes located on four (04) pairs of Chromosomes present in the cells of Drosophila. It means that each chromosome contain a large number of genes, similarly chromosome of all organism have many genes, located at single chromosome. It was found that a chromosome may contain maximally 4000 genes. According to chromosomal theory of inheritance each genes are inherited by chromosomes. It means that genes located at a single chromosome tend remain together during inheritance. This tendency of gene in a chromosome to remain together is called **Linkage** and the genes which are present at some chromosome and inherit together called **Linked gene**, the genes, which are located on autosome called autosomal linked genes and their inheritance called **autosomal inheritance** or **autosomal linkage**. Similarly if they are located on sex chromosome (X or Y) their linkage called **sex-linkage** and their inheritance is called **sex-linked inheritance**. All the linked genes present on the same chromosome at the time of inheritance called **linkage group**. therefore the number off linkage groups in an organism are equal to number of homologous chromosomes present in an organism.

The linked genes are present on same chromosomes therefore they are considered to be inherited together in the offspring so always parental combination of characters are found in offspring and assorted traits do not segregate independently. Linkage between genes can be detected by test cross of di-hybrid organisms. It is a cross where a heterozygous organism of two traits is **back crossed** with its recessive parent. If the results will come in the following ratio, then the linkage will be determined easily i.e. if four phenotypic combinations (parental and non-parental) occur in offspring then there will be no linkage between the genes. If this ratio is deviated and more parental types with less non-parental type appear which shows **partial linkage**, if only parental type appears it shows **complete linkage**. In Mendelian di-hybrid cross, where linkage was not considered as phenomenon the result shows the parental and non-parental combination is the ratio of 9:3:3: 1. In case of linked genes of di-hybrid cross the result will be only parental combination with a ratio of 3:1.

T.H. Morgan was the geneticist who observed karyotype of Drosophila, he was of the contributor of **Chromosomal theory of Inheritance**, also studied 85 pairs of contrasting trait inheritance in *Drosophila melanogaster*. In Drosophila he observed two assorted traits whose genes are linked together (that is located at same chromosome). The dominant gene **V** for normal wings and its recessive allele **v** for vestigial wings, another trait where a dominant gene **B** for Gray body colour is dominant over black colour gene (**b**), Both are located at same chromosome.

As they are linked, they tend to be inherited together i-e. **V** with **B** and **v** with **b**. It implies that when a homozygous **VVBB** fly is crossed with a homozygous **vvbb** fly all offspring will have **VvBb** i.e. Normal wings and Gray body colour. When this heterozygous fly is crossed with homozygous recessive **vvbb** and the genes remains completely linked as well as no crossing over occur then only two parental type in offspring will appear equally i.e. Gray body with normal wings and black with vestigial winged.

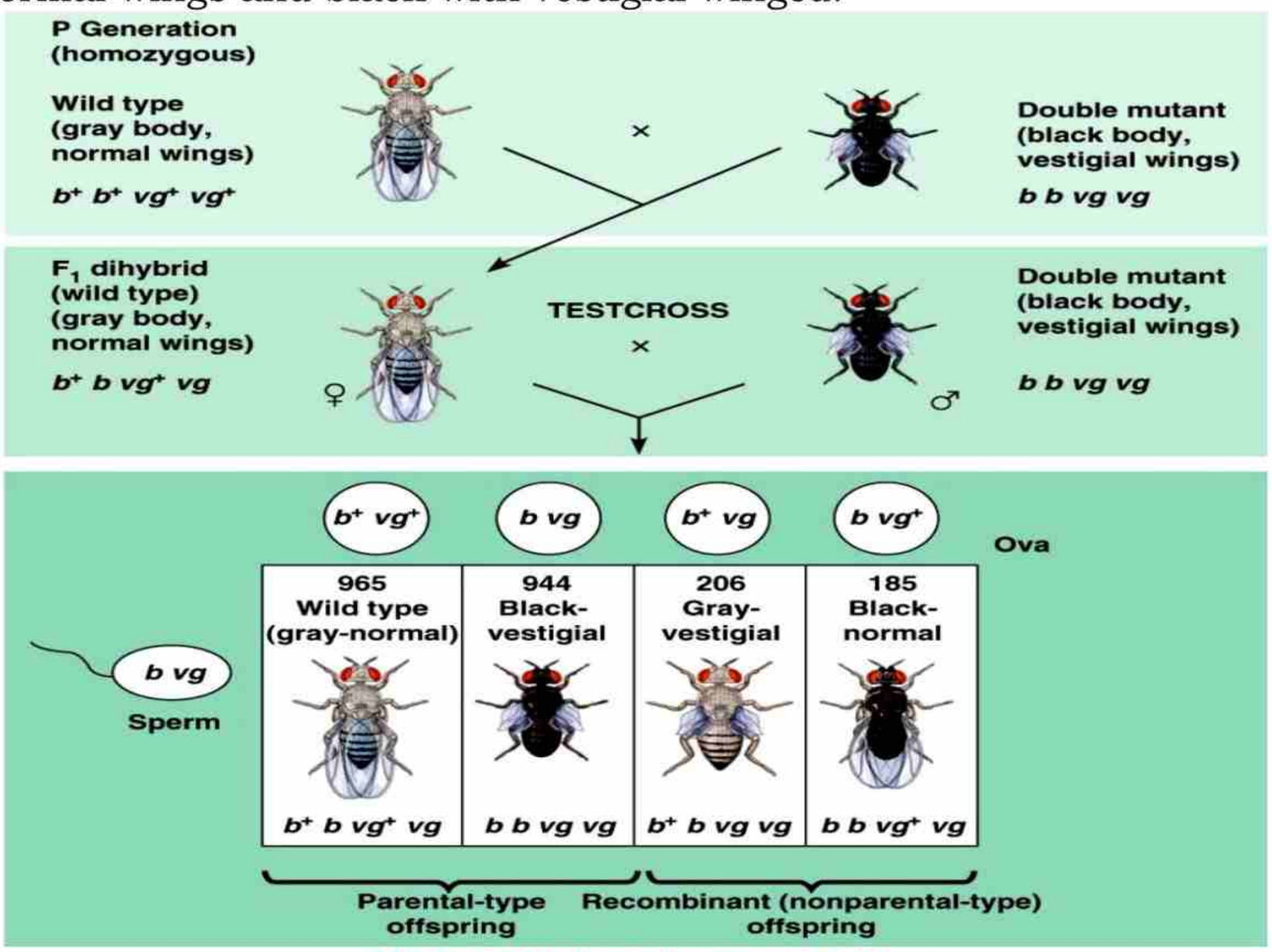


Fig.23.7 Linkage in Drosophila

Crossing Over

The linkage is also not an absolute and it not necessary the genes of a chromosome remain attached with each other and transmits together. If Linkage remain continue so the inheritance of a trait remain continue and the offspring will be like one of the parent only. The gametes in animals and spore mother cells (S.M.Cs) divide by meiosis to produce gametes, and spores respectively. During meiosis, the homologous chromosomes pair up, this pairing of homologous chromosomes called **Synapsis**. Soon after meiosis they attach and form cross bridges between their non-sister chromatids, they sometimes exchange their segments, this process of exchange of chromosomal segment between non- sister chromatids of homologous Chromosome is called **crossing over.**

After separation the chromosomes carry some genes with each other and new combination of gene develops on a chromosome which develops variety of gene and new combination between parental combinations occurs. The recombinant Chromatids resulting from crossing over may bring alleles together in a new combinations so, when gametes, are formed gametes a variety in gametes develop. Therefore this process leads to genetic variability during sexual reproduction. Take an example to understand the process of crossing over, where a pair of homologous chromosomes carries gene **T** and **B** on both chromosomes where as another gene homologous has **t** and **b**. **Chiasmata** is formed between their non-sister chromatids and crossing over also takes place as alleles of non-sister chromatids are different, so exchange between their segment cause recombination of their alleles.

Allele **b** cross over to chromosome containing allele **T** and allele **B** cross over to chromosome containing allele **t**. These chiasmata open and sister chromatids also separate from each other to become an independent chromosome. At the time of gametes formation 4 types of gametes are formed two with parent combination i.e. **TB** and **tb** and two with non-parental (recombinant) combination i.e. **Tb** and **tB**. If crossing over will not occur only two parental types of gametes formed. The parental types of gametes produce offspring, with parental combination of characters while non-parental (recombinant)

combinations produce offspring with non-parental (recombinant) characters.

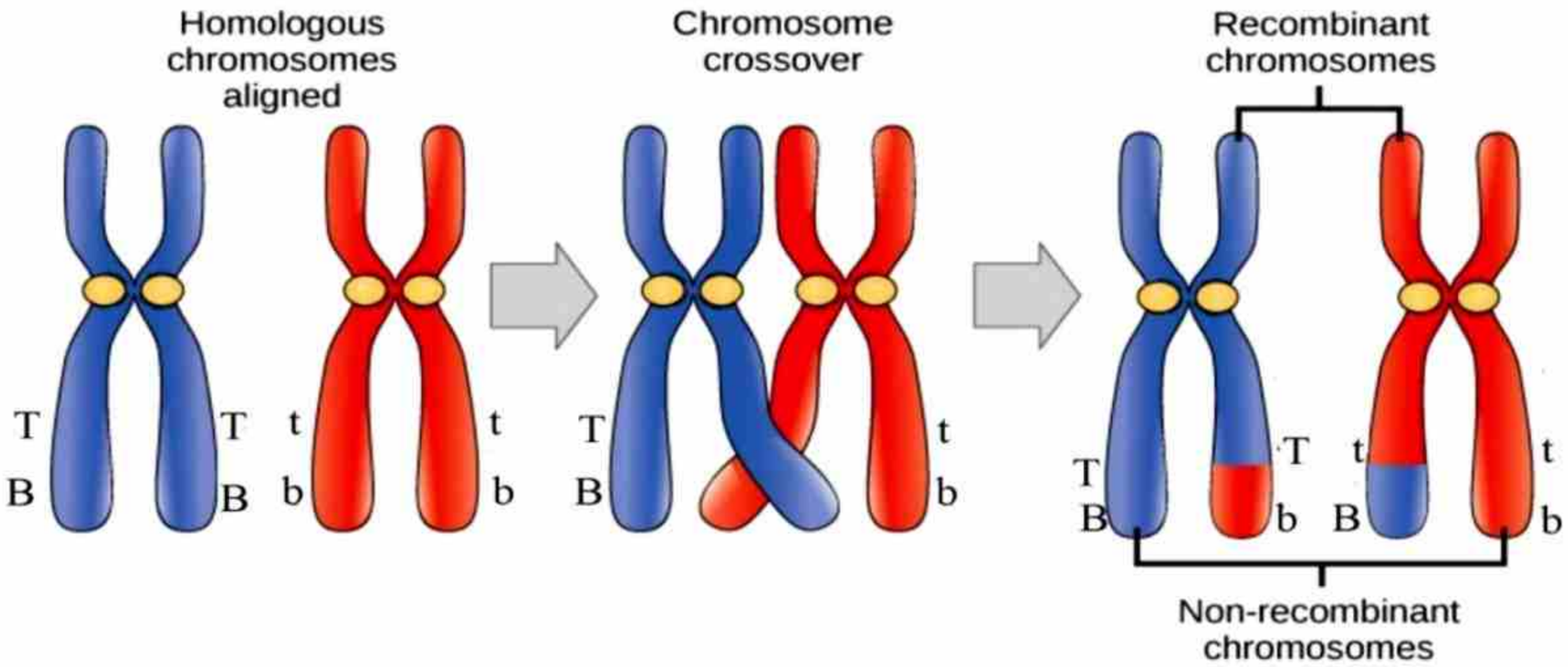


Fig.23.8 Crossing over

Sex Determination

It was found in early year of last century that in the animals and plants most of the chromosomes are found in the form of homologous pair but a pair of chromosome may or may not be homologous in the members of same species. W. Sutton found the simplest situation of chromosomal difference in Grass-hoppers, where he found male have one chromosome less than female i.e. the females have 24 and male have only 23. It means the female has 12 pairs of chromosomes in their Somatic cell (2n) whereas 12 chromosomes (n) in each egg.

On the other hand male of Grasshopper have 11 pairs with a single chromosome in somatic cell (2n) whereas by spermatogenesis produces two types of sperms one type have 11 chromosomes (n) and other with 12 chromosomes (n). Fertilization of egg (12 chromosomes) have two chance, either with sperm having 11 chromosomes (n), or with the sperm have 12 chromosomes (n). If a sperm with 11 chromosomes fertilizes the egg, a male baby will develop or the other sperm (12 chromosomes develop female baby on fertilization this odd chromosome, which determines the sex of the individual is formed as **sex-chromosome**. The other chromosomes which are similar in male and females are **autosomes**.

XX and XY sex-determination in Drosophila and Mammals

Sex- Determination Drosophila

T.H. Morgan, a Nobel Prize winner (1933) selected. *Drosophila melanogaster* (Black-bellied dew lover), common fruit fly, can be seen hovering around over ripe fruit, for his experimental work. He observed the karyotype of this fly and noted that the male and female Drosophila has differences in one pair of chromosomes as shown in following Fig. 23.8

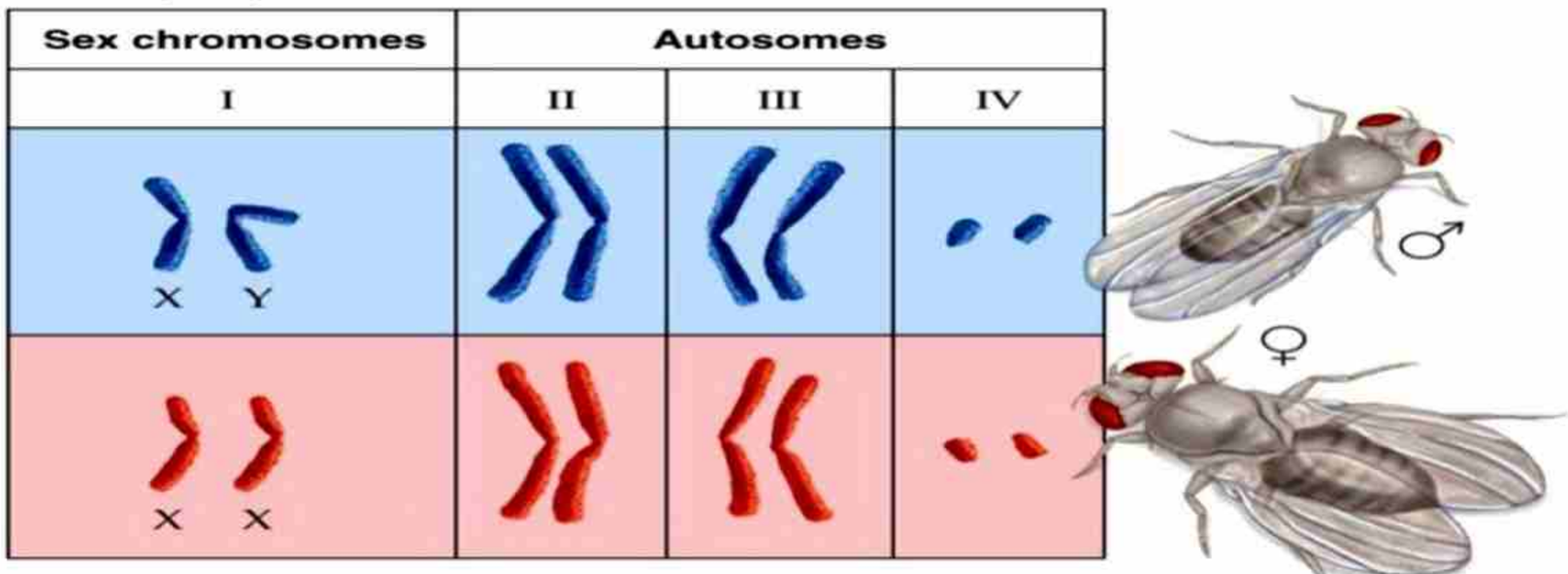


Fig. 23.9 Karyotype of Drosophila

This shows that there are three pairs of chromosomes which are same in male as well as in female fly. These chromosomes are called **autosomes** but the difference lies in 4th pair. The female has both the chromosome of 4th pair similar and rod shaped (Homologous). On the other hand male has both the chromosomes different from each other (Heterologous) one chromosome is rod shaped and other is hook shaped. This 4th pair designated as **sex-chromosome** which decide the sex in Drosophila.

Moreover, the rod shaped sex chromosome, two of the female and one of the male are alike designated as **X-chromosome**. The hook shaped unlike sex-chromosomes is designated as **Y chromosomes**. So, In Drosophila, individual having **xx** will be a female and that receive **xy** will be a male

Sex-Determination in Human

In human beings and majority of animals, the case is same as Drosophila. The difference in male and female is not of one whole chromosome as Grass-hopper, but of the shape of one chromosome in one sex.

In man each cell either somatic or germ cell has 46 chromosome (2n) of which 44 i.e 22 pairs are similar in both sexes called **autosomes**. The 23rd pair differ in female consist of similar chromosomes (homologous) but in male the 23rd pair differ in shape, one of the two chromosomes is like sex-chromosomes of female of but the second is much smaller than the other. The two chromosomes of female's 23rd pair and one of male which are similar are called **X-Chromosome**, while the unlike, smaller chromosome of male's 23rd pair is called **Y chromosome**. So, the human female possesses 44 + XX chromosomes, whereas the male is 44+ XY chromosomes in their Karyotype.

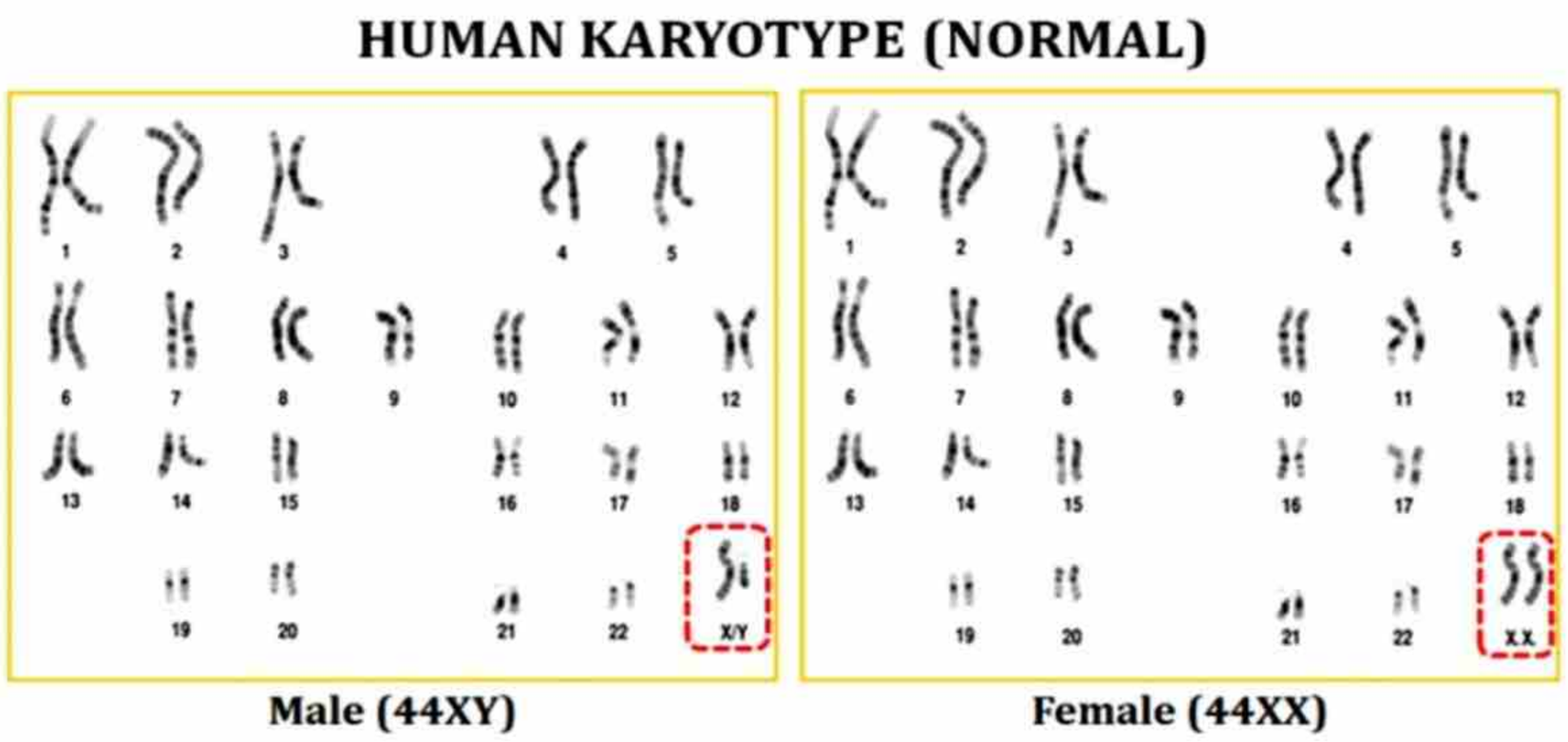


Fig.23.10 Karyotype of human male and female

The above stated situation that the male is **heterogametic** i.e. produces two types of sperms i.e. X and Y containing and the female is **homogametic** i.e. produce only one type of ovum containing only X.

Other Patterns of Sex Determination

(i) XO-XX Type

As we have discussed that in some animal only one chromosome work as sex-chromosome, and this pattern on sex-determination was found in Grass-hopper. The protenor bug also has same where male has only one sex-chromosome i.e XO. This sex chromosome is X-chromosome and other sex-chromosome is missing entirely in male. Therefore male of protenor bug is heterogametic i.e.

produce two types of sperms one type of sperm has X Chromosome while the other type do not contain sex- Chromosome. The gamete without sex chromosome is called Nullo gamete. Female of this bug have one X chromosome in all ovum therefore it is called homogametic, so sex of the offspring depend on the kind of sperm that fertilizes to ovum. If an x-carrying sperm fertilize the baby will be female, if the nullo-sperm fertilize the ovum the zygote will carry XO, so a male baby will develop from this zygote.

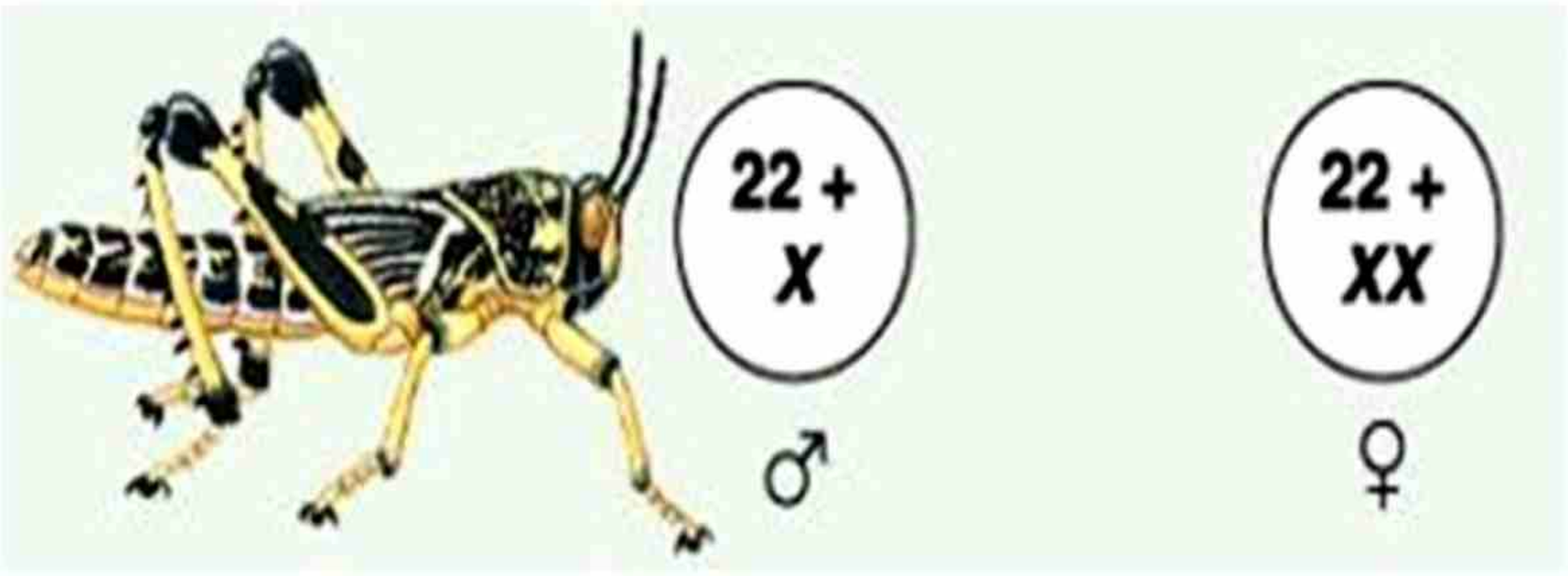


Fig.23.11 Karyotype of grasshopper

ii) ZZ-ZW Type

In some organisms like birds, butter fly and moths the conditions of sex-determination is different from the above. J. Seiler in 1914 discovered that in moths the reverse of XX-XY System of sex-determination is present. In this system the female is heterogametic because she contains heterologous sex-chromosome therefore she produce two types of eggs some contain Z as sex chromosome and some contain W as sex chromosome in equal proportion.

On the other side all male produce same type of gametes have Z chromosome as sex-chromosome. It shows that the female which produce two variety of ovum become responsible for sex-determination in offspring, when a Z chromosome carrying egg is fertilized by sperm which always contain Z, male baby will produce but when a W carrying egg is fertilized by sperm, a female offspring is produced.

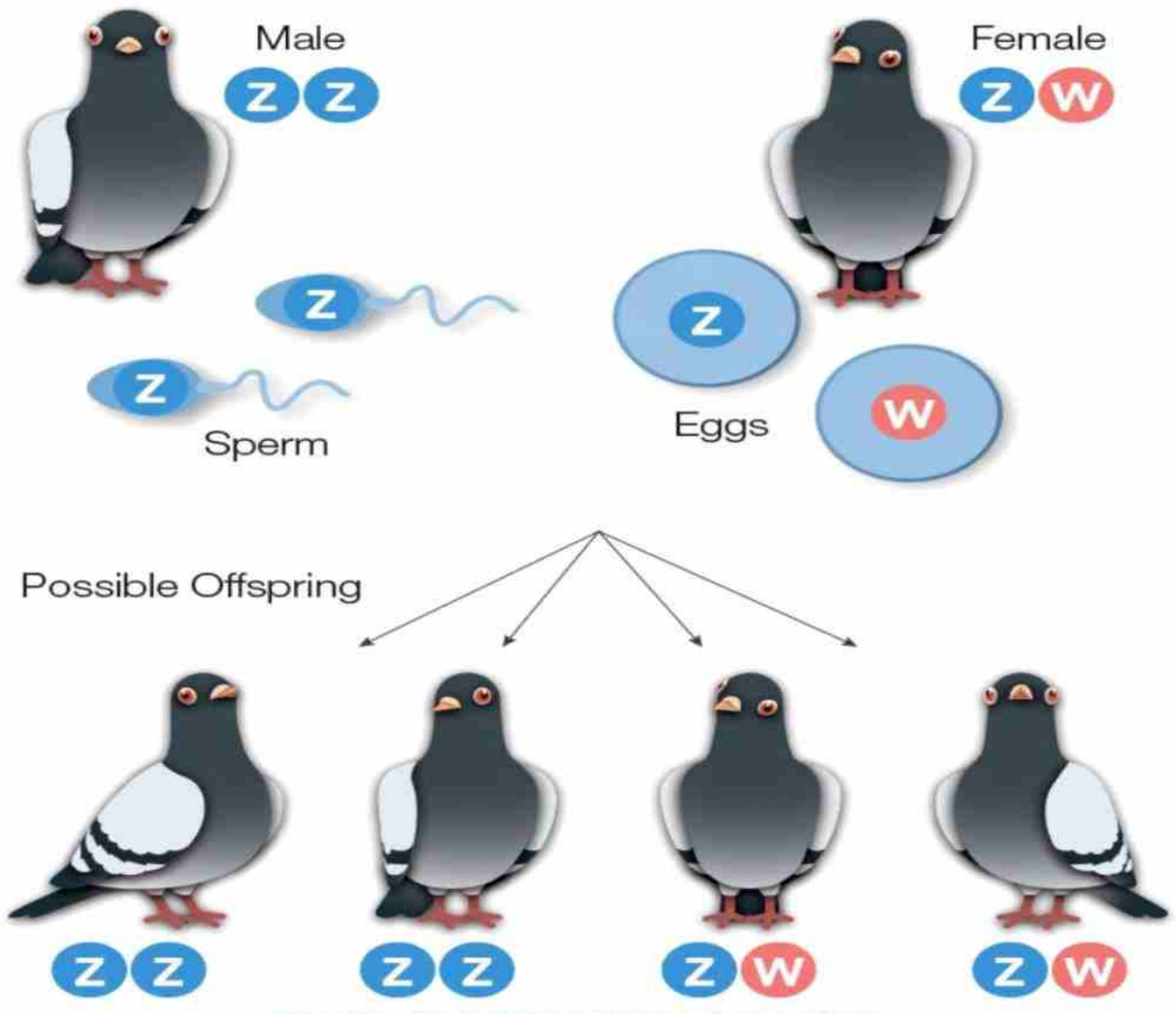


Fig.23.12 ZZ and ZW trait in birds

	Male baby		Female baby
Sex ratio	2	:	2

Genetic problem

1. Draw a pedigree of 3 generations in a human family to show how many offspring will be male and female?
2. A moth produce four babies, how many male and female babies will produce in their next generation show it by develop pedigree.

Sex- Linkage

According to chromosomal theory of inheritance, the genes are located at chromosome. The genes are located at same chromosome called linked genes because they usually inherit together in a linked manner if crossing over does not take place. The genes which are located at autosomes called autosomal linked gene and they inherit

through autosomes from parents to offspring. This type of inheritance called autosomal linked inheritance. On the other hand, the genes which are located at sex-chromosome are called sex-linked genes. The sex-chromosome in human or Drosophila are of two types X and Y. The alleles which are located at X-chromosomes called X-linked and in the characters which are inherited through the X-chromosome are called **X-linked inheritance** whereas the alleles located at Y-chromosome called Y- linked, and their inheritance called **Y-linked inheritance**. Some traits are controlled by that type of genes which have alleles found on both X and Y, such traits are called **X-Y linked** or **Pseudo autosomal** because they behave differently from sex-linked traits they have just autosomal mode of inheritance. On the other hand Y chromosome is not completely inert. It does carry a few genes which have no contrasting alleles on X-chromosome. The genes on Y chromosomes of human express characters of maleness e.g. bobbed gene of Drosophila are pseudo autosomal because they have pattern of inheritance like autosomal genes.

Sex-Linked Inheritance in Drosophila

T. H. Morgan (1910) performed various breeding experiments with wild type red-eyed Drosophila. He noticed a white eyed mutant. This was male and turned out to be a true breeding strain of white eyed flies. He crossed this white eyed male with homozygous red-eyed female.

The F_1 and F_2 population followed the simple Mendelian ratio. But when white eyed female was crossed with red-eyed male, the result

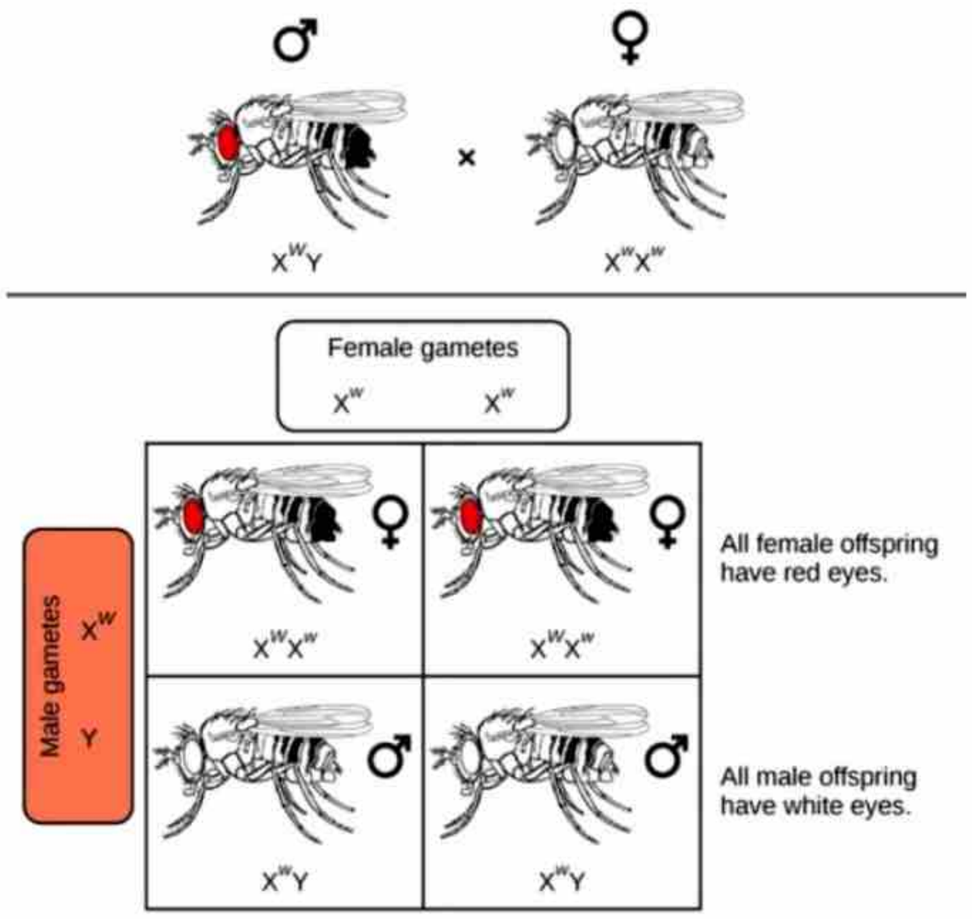


Fig.23.13 Sex linked trait in Drosophila

was not same as before. To examine the details of various cross-made by T. H. Morgan. Here the case in represented in the form of figures of Cross, where R for red-eyed and r for recessive white eyed flies.

Cross- I

When red-eyed (X^RX^R) female is crossed with white eyed flies (X^rY) male the F_1 generation shows all red flies, the case in male and female are same.

The F_2 generation shows red-eyed and white eyed flies in ratio of 3:1. (All females are red but the chances of red eyed and white eyed type in male are 50% : 50%). In the some case genotypically females are also of two types, although both are red eyed.

The one type of female is homozygous i.e. unable to produce white eyed offspring while the other type of female are heterozygous (carrier for white eyed genes) i.e. can produce white eyed offspring

Cross-I			Cross-II		
Red eyed Female	X	white eyed Male	white eyed Female	X	Red eyed Male
X^RX^R		X^rY	X^rX^r		X^RY

Cross-II

When Red eyed male (X^RY) crossed with white eyed female (X^rX^r) the result were found different from cross I. In F_1 both types of flies were produced that is red eyed and white-eyed. Moreover all the red-eyed were female, while all the white eyed were males. In F_2 generation again red and white eyed appeared in equal ratio where half of them male and females are red as well as white eyed.

On the basis of these results T. H. Morgan obtained in the above crosses he concluded that gene of eye colour trait in Drosophila is present on X-chromosome. The Y chromosome does not carry gene (allele) of eye colour.

Y-Linked Inheritance or Holandric Traits

Y chromosomes is different from X-chromosome in respect of morphology and genetically. It is not completely inert it was only inert for those traits which are located on X-chromosome. In

Drosophila and human being it carries few genes which have no counterpart on X-chromosome these genes are called Y- linked gene.

The Y-linked traits are called holandric traits

The alleles of holandric gene are only located at Y-chromosome not on X-chromosome. The Y-linked genes are hemizygous, only located on non-homologous region of Y-chromosome.

They express phenotypically in males, inherit from father to son female do not inherit Y-chromosome so the Y-linked traits cannot pass to them. In human some Y-linked traits porcupine man (Straight hairs on the body), hypertrichosis growth of hairs in the edges of pinna, webbing of toes etc.

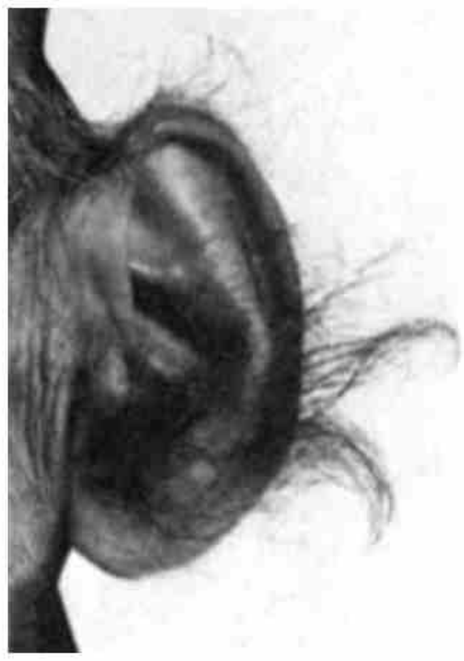


Fig.23.14 Y-linked trait in human

Sex-Limited and Sex-Influenced Traits

We have already studied about sex-linked traits and sex-linked inheritance but some traits are associated with sex of organism i.e. maleness or femaleness there traits are called sex-related traits. This phenomenon of inheritance shows that the genes are not necessary located on sex-chromosomes. These traits may controlled by autosomal or sex-linked genes. There are of sex-related traits i.e. sex-limited and sex-influenced Traits.

Sex-Limited traits

The type of genes which are present in both sexes of a sexually reproducing organisms but expressed in only one gender (Sex) and turned off in other gender. It is due to anatomical differences in the member of a species e.g. The genes which have horn controlling gene but only expressed in male and female have horn controlling gene but only expressed in male sheep. Another example of sex-limited trait is beard growth in human. It is limited only to men. A women does not grow a beard herself she can pass the genes to her son the purpose of sex-limited gene is to resolve sexual conflict.

Sex-Influenced Trait

Another type of sex-related traits in that sex-influenced trait, it is an autosomal trait but influenced by sex. These traits are controlled by an allele which is expressed as dominant allele in one but recessive, in other. If a male has one recessive allele it will expressed that character, but in the case of female it requires two recessive to show the same result e.g. **soft facial hairs in female** Vs **coarse facial hairs in male,** another example is baldness which is found in male not in female. It is an autosomal dominant trait in male but autosomal recessive in females, if a male will be heterozygous for this trait he will be bald but a woman should be homozygous for recessive allele to develop baldness.

Sex-Linkage Inheritance in Man

Human have same pattern of autosomal and sex chromosome. They have XX in female and XY chromosome in male as sex-chromosome. X has many gene on it to control **X-linked traits** like colour blindness, muscular dystrophy hemophilia, congenital deafness, diabetes insipidus etc. some of them are due to recessive alleles and other are due to dominant alleles. Their pattern of inheritance different from each other.

In human genetic studies takes place through mode of inheritance and pedigrees studies because experimental controlled mating is not possible in them.

X-linked Recessive allelic Inheritance:

The human female which has one X-linked recessive allele of abnormal character called carrier but does not contain any symptoms of this disorder. The male only possess a single X-chromosome if this chromosome carries a recessive allele he will be affected and will be abnormal for that trait. The offspring of carrier female will have 50% chances to receive this abnormal recessive allele, all female children of affected father will be carriers, the male

children of an affected father will not affected at all if their mother is homozygous for normal allele. Example haemophilia and colour blindness.

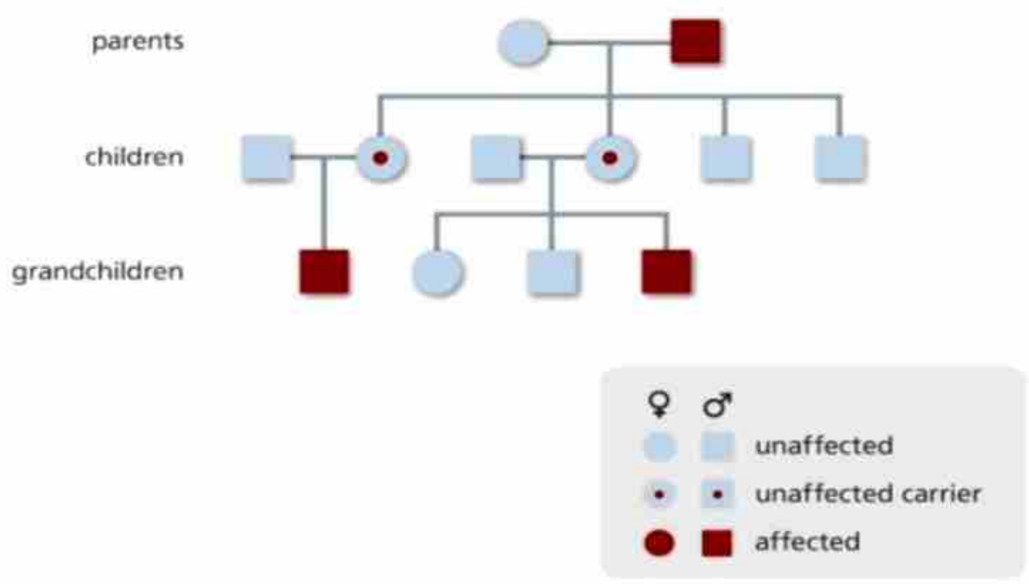
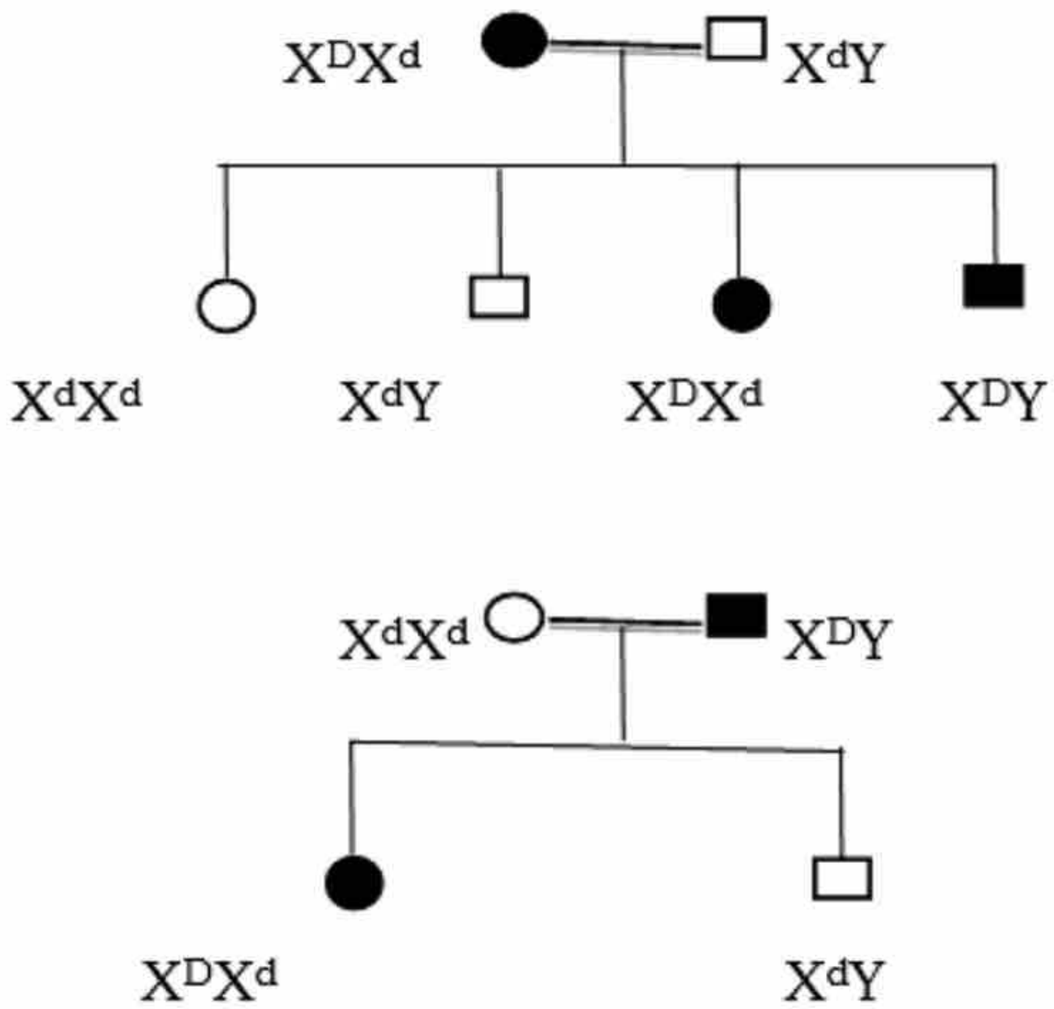


Fig. 23.15 Pedigree of X-linked recessive trait

X-linked Dominant Inheritance

The dominant alleles which are located at X-chromosome are responsible for these types of disorders. In female the affected female may be homozygous or heterozygous. The male and female offspring of a heterozygous affected female has 50% chances of this disorder.

On the other hand if a father has this disorder their all female children will be affected but all male children will be normal e.g. Vitamin D resistant rickets-hypophosphatemia or Rett syndrome



Genetic Inheritance of Haemophilia

Haemophilia is X-linked recessive human disorder. In these haemophilic persons blood does not clot after injury because the haemophilic persons are unable to synthesize blood clotting factor. There are three types of haemophilia i.e. A, B and C, the A and B are X-linked recessive traits while haemophilia C is an autosomal recessive trait. The chance of X-linked A and B are more in male than female while C affects equally due its autosomal location. The chances of haemophilia is more in male because it is hemizygous in male i.e. control by single allele while in female two doses of alleles are required to develop haemophilia i.e. homozygous recessive. The gene of haemophilia inherits in zig-zag manner from maternal grandfather through a carrier daughter to grandson. It never passes direct from father to son.

Genotype of normal mother = X^HX^H

Genotype of haemophilic father = X^hY

P_1 ♀ Normal female x haemophilic male ♂

X^HX^H X^hY

gametes X^H X^h Y

X^HX^h X^HY

Normal daughter but Carrier of haemophilic gene — Normal son

P_2 ♀ Normal female but carrier x Normal male ♂

X^HX^h X^HY

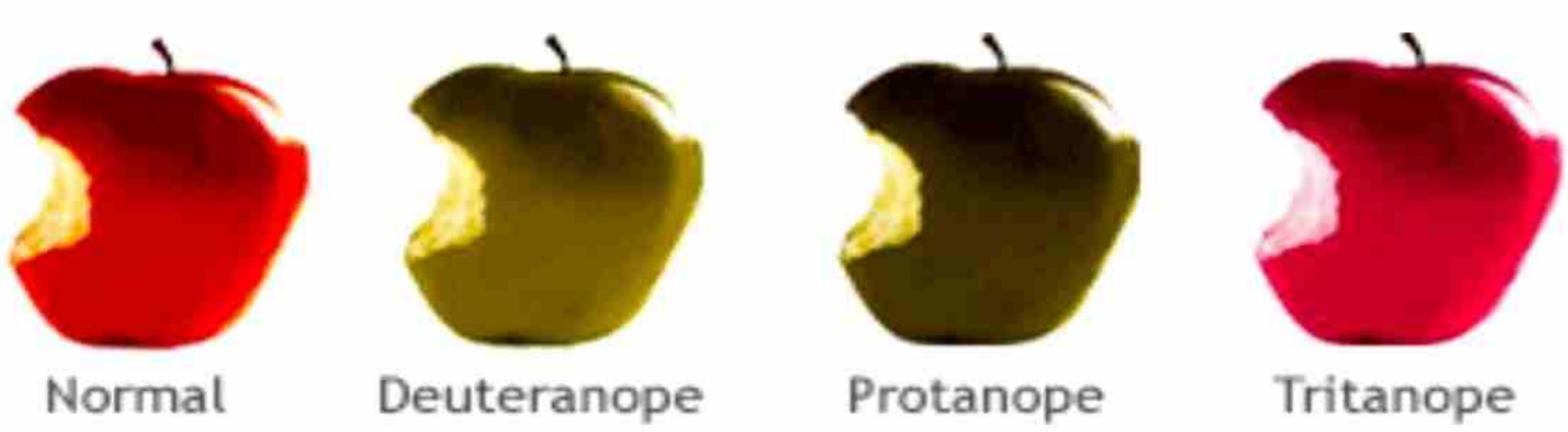
gametes X^H X^h X^H Y

	X^H	Y
X^H	X^HX^H Normal	X^HY Normal
X^h	X^HX^h Normal but carrier	X^hY Haemophilic

Inheritance of colour blindness

Human eye has two types of neurons Rod and Cones. Rods are responsible for vision in low light, while cones are responsible colour distinction there are three basic colours normally which develop all colours, the distinct vision of these three colours called to normal trichromatic vision which is due to three different kind of cones located in the retina, each cone in sensitive to only one of these primary-colours i.e. red, green and blue.

Each type of cone has specific light absorbing proteins called **opsins.** These proteins produced by expressing specific genes. The genes for red and green opsins are located on X-chromosomes whereas the gene for blue is located at autosome chromosome no-7. If mutation occurs in these opsins genes develop other recessive alleles for these genes which cause colour blindness in the form of dichromacy and monochromacy.



Fig,23.16 Dichromacy in human

Dichromacy: It is a condition of colour blindness where a person can distinguish two colours clearly but cannot perceive one of the three, whose gene become mutated and its opsins does not synthesized properly i.e. missing. There are three types of
i) Protanopia is red blindness
ii) Deuteranopia is green blindness
iii) Tritanopia is blue blindness

Monochromacy: It is a condition of colour blindness where a person can recognize only one. It is true colour blindness. In blue monochromay only blue colour can be recognized by person but both red and green cone cells opsins are absent. It is X-linked recessive

trait. It is also called red-green colour blindness the inheritance pattern of colour blindness is also like haemophilic pattern of eye colour trait in drosophila. It also work in zig-zag (**criss cross inheritance**) manner and more common in male than female.

Fig.23.17 Normal and Monochromacy

Inheritance of Muscular Dystrophy

It is type of muscle disease caused by mutated allele (gene), the person have this gene have muscle weakness with passage of time which ultimately decrease its mobility with the passage of time. It is sex-linked recessive disorder, the normal gene code for protein called **dystrophin** synthesized in normal person, but missing in the patients of **Duchenne** patient due to recessive alleles, the absence of dystrophin causes leakage of calcium into the cell the symptoms of **Duchene muscular dystrophy** appear in childhood where child begins to have difficulty in standing or rising for standing. Ultimately it become unable to move up to the age of 12 so he or she required wheelchair, with the passage of time they feel difficulty in breathing usually become unable to survive after the age of 20 years, therefore affected male cannot survive for marriage only carrier female survive which can inherit this gene to male baby. This inheritance pattern is similar as haemophilic pattern.

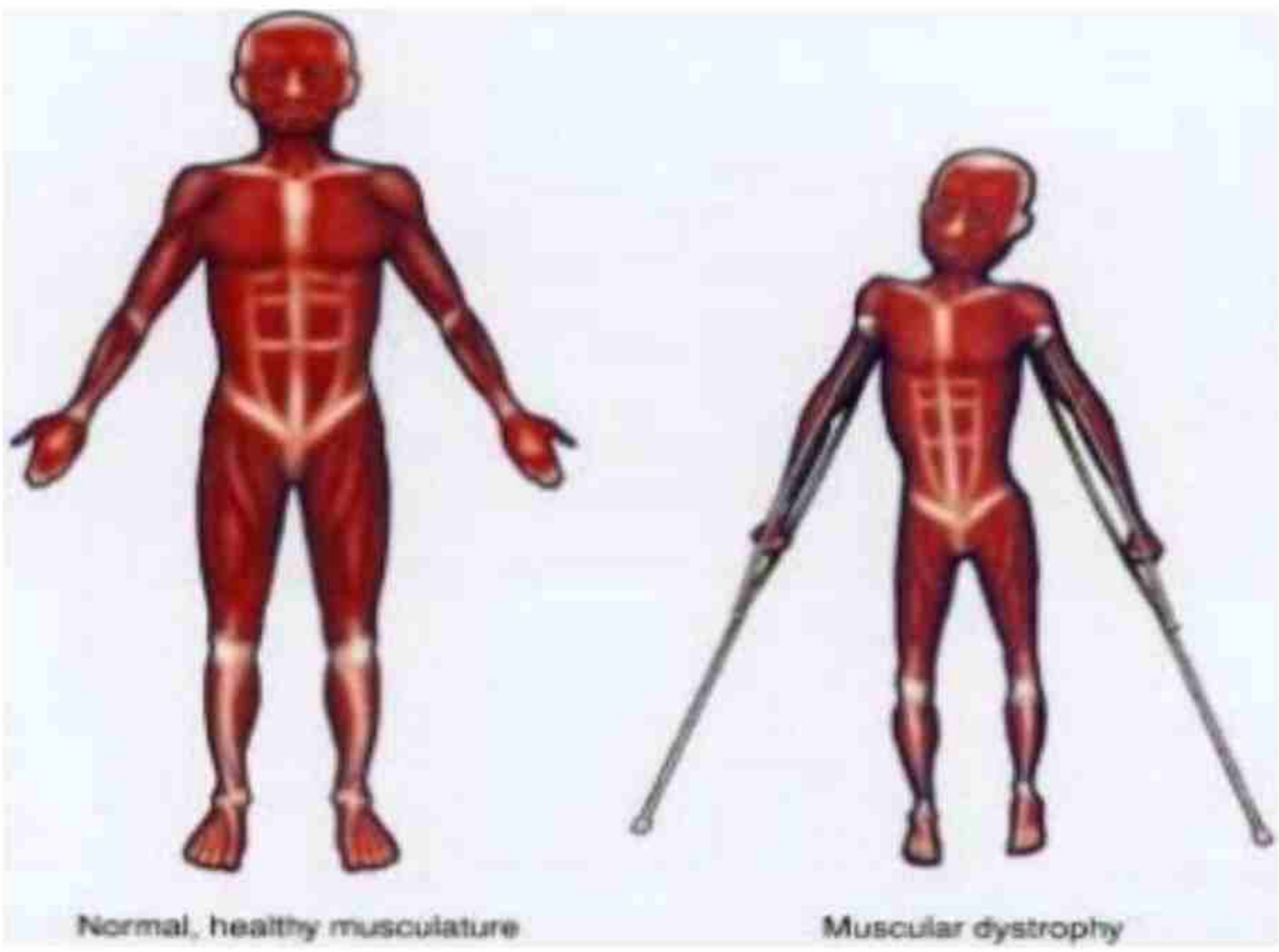


Fig.23.18 Muscular dystrophy

Symbols for pedigree development

- Male
- Female
- Affected Male
- Female
- Carrier Female for sex linked inheritance
- Heterozygous male for autosomal recessive trait.
- Heterozygous female for autosomal recessive trait
- Mating or cross
- Mating or cross
- Dizygotic twins
- Monozygotic twins

SUMMARY

- The scientific study of inherited characters from parents to offspring, their pattern of inheritance and causes of variation called Genetics.
- The character which was expressed in impure condition (1st generation, F1) called Dominant and its contrasting character, which was not expressed called recessive.
- Cross between phenotypically dominant individual and homozygous recessive to find out the homozygosity or heterozygosity of dominant called test cross.
- Phenomenon of inheritance where expression of both contrasting allele blend in heterozygous condition called incomplete dominance.
- Phenomenon of inheritance where expression of both contrasting allele does not blend heterozygous condition called co-dominance.
- A trait may have more than two alternative forms, the genes which have more than two alternative forms are called multiple alleles.
- International society of blood transfusion has found more than 30 types of blood group system.
- ABO blood group system is controlled by three alleles I^A, I^B and i.
- The breakdown of R.B.C produce large amount of bilirubin pigment which accumulate in the foetus and damage the neuron.
- The phenomenon of inheritance where a single trait is controlled by two or more than two separate pairs of genes which manifest themselves in additive manner to yield variable phenotype called polygenic inheritance.
- Labrador is an excellent type of dog its coat colour is one of the best example epistasis in mammals.
- Tendency of gene to remains together in a chromosome called linkage.
- During meiosis the homologous chromosomes pair up, this pairing of homologous chromosome called synapsis.

- Process of exchange of chromosomal segment between non-sister chromatids of homologous chromosome is called crossing over.
- Chromosome which determine sex of the individual called sex-chromosome.
- Chromosomes which are similar in male and female called Autosomes.
- The alleles of holandric gene are only located at Y-chromosome.
- The Y-linked genes are hemizygous, only located on non-homologous region of Y-chromosome.

EXERCISE

1. Encircle the correct answer:

i) Which of the following would cause phenotypic variations among organisms of the same genotype?
(a) Continuous variation within the species
(b) Different varieties of the same species
(c) Different sexes
(d) Exposure to different environments

ii) In which of the following examples of human inheritance is the inheritance pattern explained by multiple alleles on an autosomal chromosome?
(a) The ABO blood group system
(b) Cystic fibrosis
(c) Down's syndrome
(d) Haemophilia

iii) What are the phenotypes of the parents of a colour-blind son and a non-carrier daughter with normal colour vision?

	Father	Mother
(a)	Carrier	Normal
(b)	Colour-blind	Carrier
(c)	Colour-blind	Colour-blind
(d)	Normal	Carrier

iv) In the F_2 generation of a dihybrid cross, the phenotypes occurred in the ratio 3:1 what does this result indicate?
(a) The alleles were segregating independently
(b) Polygenic inheritance was involved
(c) Codominance was being shown
(d) The gene loci were linked

v) Two parents, both of blood group A, have a daughter of blood group O. What is the probability that their next child will be a boy who has blood group O?
(a) 0.25 (b) 0.5
(c) 0.75 (d) 1

vi) A boy is colour blind which could be the genotype of his mother?
(a) X^NX^N (b) X^NX^n
(c) X^NY (d) X^nY

vii) Number of chromosome in grass hopper female is 24. How many chromosomes are present in grass hopper male?
(a) 26 . (b) 25.
(c) 24 (d) 23

viii) The allele of holandric gene is located at?
(a) X-Chromosome (b) Y-Chromosome
(c) Autosome (d) None of these

ix) The gene which interferes and masks the phenotype of the phenotype of the non-locus gene called?
(a) Mutant gene (b) Epistatic gene
(c) Pleiotropy (d) Sex-linked

x) x. International society of blood transfusion has found more than?
(a) 10 blood system (b) 20 blood system
(c) 30 blood system (d) 40 blood system

2. Write short answer of the following:

i) Why Rh-incompatibility could be a danger to the developing foetus and mother?
ii) Why haemophilia is common in human male?
iii) What do you mean by sex-influenced trait?
iv) Differentiate between following
   a) Linkage and crossing over
   b) Monohybrid Cross and Dihybrid Cross
   c) X-linked trait and Y-linked trait
   d) Autosomes and sex-chromosome
   e) Incomplete dominance and Co-dominance
v) Why human male are heterogametic?
vi) What do you mean by dichromacy and monochromacy?

vii) What do you known about ZZ and ZW in sex determination?
viii) Why incomplete dominance is called partial dominance?
ix) Define following terms

(a) Genetics	(b) Allele	(c) Gene
(d) Karyotype	(e) multiple allele	(f) test cross
(g) Mutant	(h) Test cross	(i) Back cross
(j) Linkage	(k) Crossing over	(l) Protanopi
(m) Isoagglutinogen	(n) Erythroblastosis foetilus	

x) Why law of segregation is called purity of gametes?

3. Give detail answer of following questions:

i) Explain epistasis with reference to the inheritance of coat colour in Labrador retriever.
ii) Describe inheritance of two traits with the help of genetic cross.
iii) Describe ABO blood system in human with genetic cross.
iv) Explain sex determination in human and sex linked (x-linked) trait with genetic cross.
v) A male has co-dominant blood group marry with female whose blood group is homozygous A, both have a male child who marry with a female with recessive blood group what will be the chances of blood group in their children? Prove it with genetic cross.

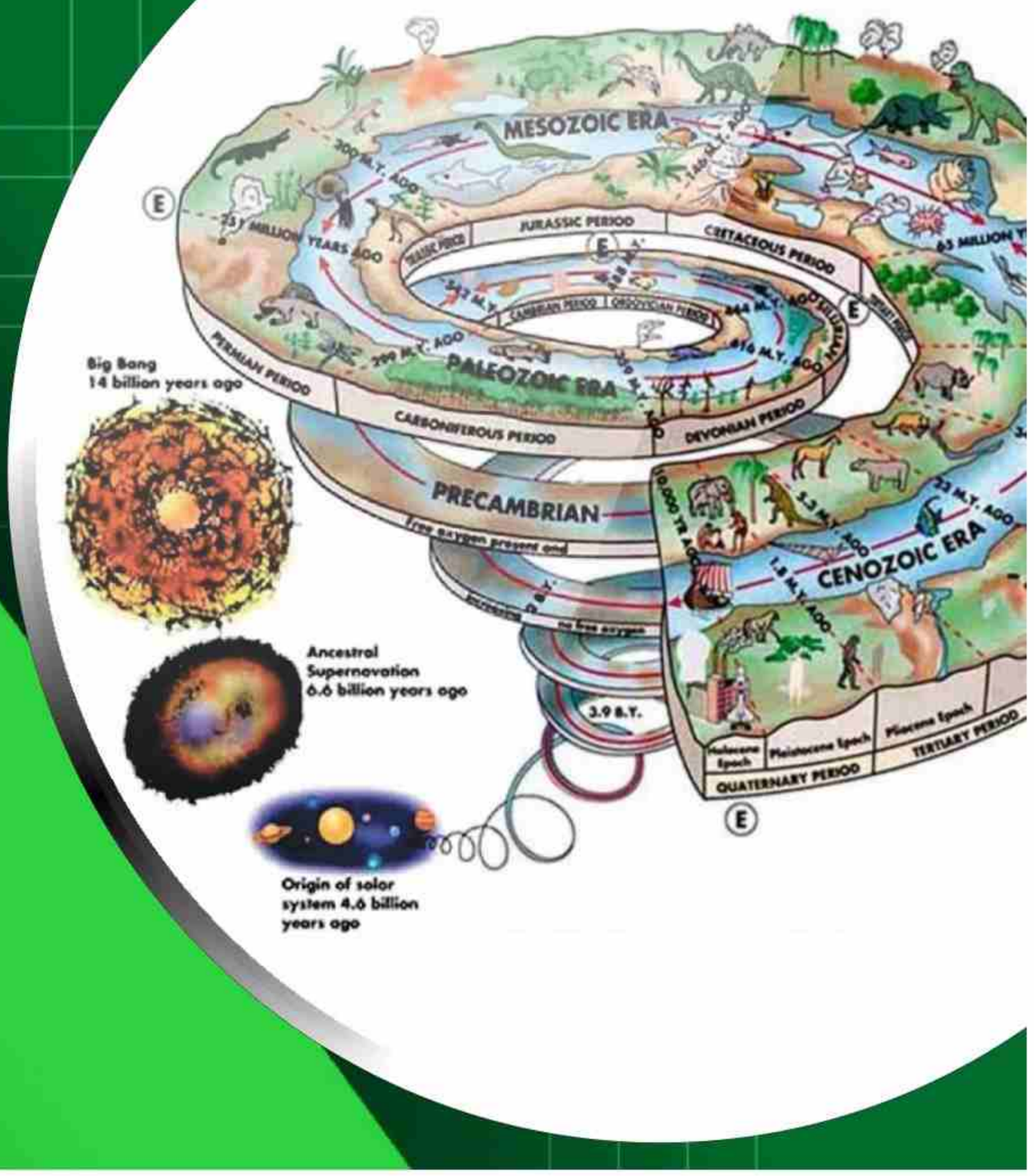
EVOLUTION

Chapter 24

Major Concept

In this Unit you will learn:

- The Evolution and The Concepts of Evolution
- Evidences of Evolution
- Evolution of Eukaryotes from Prokaryotes
- Lamarckism
- Darwinism
- Neo-Darwinism



The process and mechanism of origin of universe and the origin of living forms is of always a matter of enquiry for man. Hence there are always speculations regarding these issues from non-scientific as well as scientific point of views. Though many of us see it as contradictive matter from the religious point of view, the human interest is never ending till the exploration of truth. Without the understanding of physics, chemistry and mathematics, the biology cannot alone explore the reality and truth.

EVOLUTION

(Latin *ēvolūtiōn-*, "unfolding" or "emergence from an enclosing structure, historical development,")

Broadly speaking, evolution is a process of gradual changes and development of something such as earth, solar system, living things and living organisms etc. In Biology, the term evolution refers to a process of development of an entity in the course of time through gradual sequence of changes from simple to complex form. For instance, one might ask which is more primitive, plants or animals? Through the study of living organisms, the answer may be hypothesized.

24.1 THE EVOLUTION OF THE CONCEPTS OF EVOLUTION

The great diversity among living organisms around us made the human to think about their origin. Whether it is through their creation or origin from one another, there are two schools of thoughts. One of the schools of thoughts believes in **Divine Creation** while the other in origin through simple to complex forms.

Theory of special creation

The theory of special creation believes that living entities are created by God. They were created either at the same time or at some intervals. However, the species do not have any inter-relationship with each other from the origin point of view. They were created in the same form as present today so are supposed to be fixed and immutable. Father Suárez (1548-1613) was one of the advocates of Creationism. Carolus Linnaeus (1707-1778), a Swedish Botanist, who wrote number of books describing nature and is best known for

his great scientific work on taxonomy. Initially, he was also believer of the fixity of species.

Theory of Evolution

In contrast to the theory of special creation, the theory of evolution believes that organisms are evolved through gradual process of changes from simple to complex forms during the course of time. Thus plants and animals have developed in continuous, orderly way, under the guidance of natural laws.

George Buffon (1749-1788) was the first to implement the **geological time scale** and developed the idea that living beings evolved constantly. This concept of evolution of living organisms contradicts clearly with the concept of Divine Creation. Gradually, a number of evolutionary biologists contributed to this concept which seemed to be strictly opposing the theory of special creation. The opposition became extremely strong regarding the evolution of man. From the religious point of view, it was never acceptable; as The Holy Book, The Quran says very clearly in many surahs that Allah has created man so how I can evolve. For instance, some of the references can quote as follows:

"And We have certainly created you, [O Mankind], and given you [human] form."

(Surah Al Aaraf-11)

"And [mention, [O Muhammad], when your Lord said to the angels, "I will create a human being out of clay from an altered black mud."

(Surah-tul-Hijr-28)

"And it is He who has created from water a human being and made him [a relative by] lineage and marriage. And ever is your Lord competent [concerning creation]"

(Surah-tul-Furqan-54)

"And of His signs is that He created you from dust; then, suddenly you were human beings dispersing [throughout the earth."

(Surah Alroom-20)

24.2 EVIDENCES OF EVOLUTION

From molecular level to the gross structure of an organism, the process of evolution is supported through evidences from following different disciplines of Biology.

Evidence from Biogeography

The distribution of different species on earth provides evidence of evolution and it correlates the variations of a species and the movement of continents across the globe via plate tectonics. Let's take the example of pouched mammals (marsupials) such as kangaroos and koala found in America, Australia and New Guinea. Currently, the said geographical locations are separated from each other by Pacific Ocean. This makes impossible for said mammals to swim through such large distance. So how could end up in these locations and nowhere in between. It may be answered by the past continental positions and the fossil record of these mammals.

Fig. 24.1 Evidence from biogeography (e.g., Pouched mammals)

The scientists believe that that the existing continents were once a single piece of land termed as **Pangaea**. Slowly and gradually, it broke into different large pieces of land masses which started separating from each other. Thus, marsupials did not need a migration route, rather they rode through the continent to their current positions and diversified themselves.

Evidence from Paleontology

Paleontology deals with the extinct forms of life which are studied through **fossils**. During the course of time, those organisms were preserved somehow, partly or completely. Through such remains, the paleontologists try to reconstruct them. Let's take the example of **Archaeopteryx**, a fossil of a bird being discovered in 1861 in Bavaria, Germany. It is being estimated that Archaeopteryx lived around 150 million years ago. A careful study of this fossil revealed that it showed mixed features of birds as well as reptiles. Just like birds, it has a beak, wings, a tail, and body covered with feathers. However, like reptiles, it showed teeth, fingers and claws in fore limbs, vertebrae in tail and keel-less sternum. The presence of mixed features suggestive of the fact, that some of the ancestral reptiles were turned into early birds which later completely lost the reptilian features and transformed into modern birds.

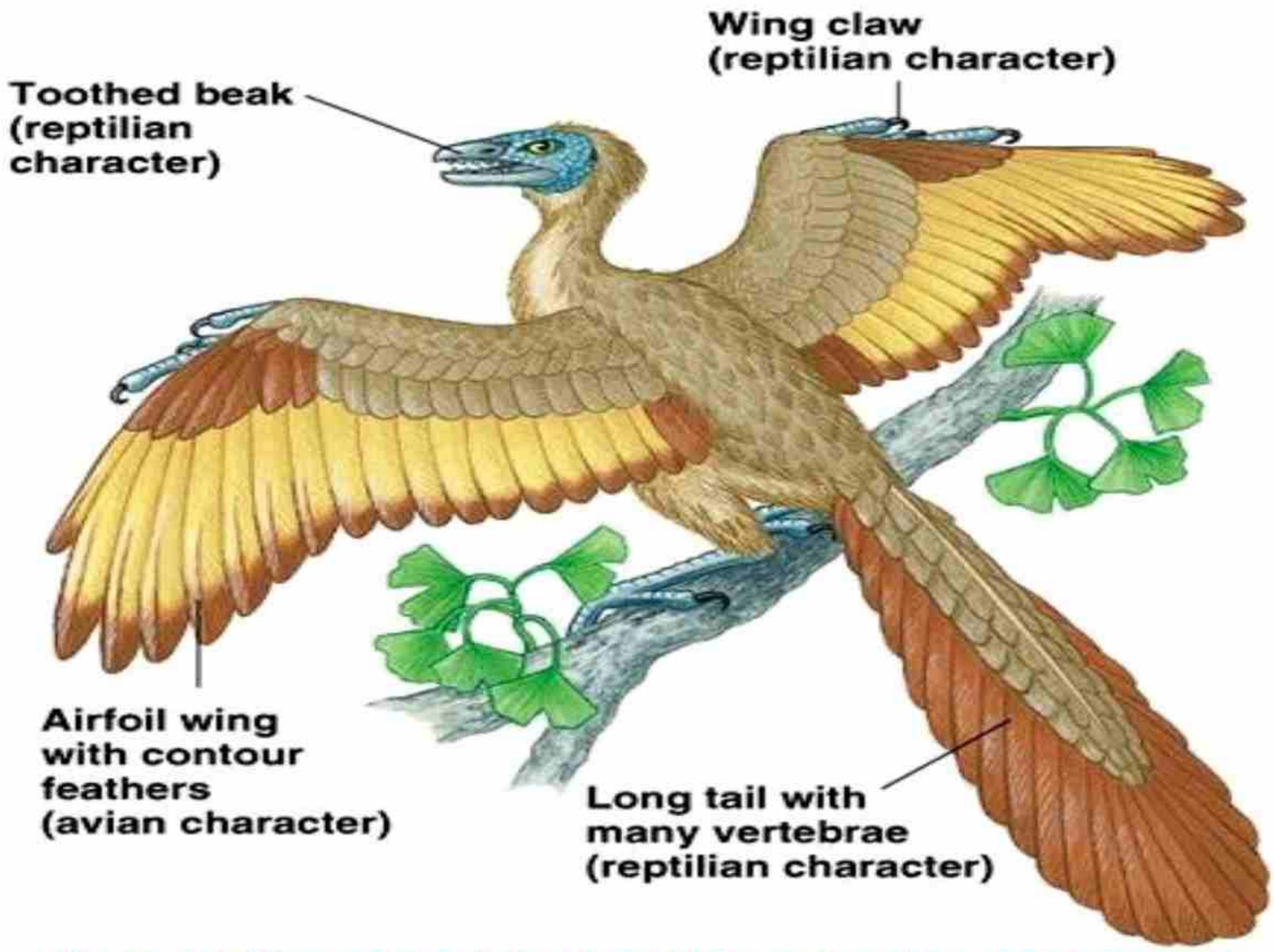


Fig. 24.2 Evidence of evolution from Paleontology (e.g. Archaeopteryx)

Evidence from comparative anatomy (homology)

Different species may show a number of internal or external organs similar to each other or vice versa they may exhibit visibly different structures but involved in the same functions. Organs which are similar in structure but differ in function are termed as **homologous organs**. For example, Arm of man, flippers of dolphin, fore-limb of a horse and wings of bat are homologous to each other. All of these mammalian organs show internally that the skeletal plans are same internally like same number and arrangement of bones, pentadactyl hand, etc. suggesting a common origin. However, they differ in function as per requirement of the habitat and other features. Biologically, this is termed as **divergent evolution** since the two or more species share common ancestry. If species descended from common ancestors, homologies make sense but if all species originated separately, it is difficult to understand why they should share homologous similarities. Without evolution nothing forcing the tetrapods all to have pentadactyl limbs.

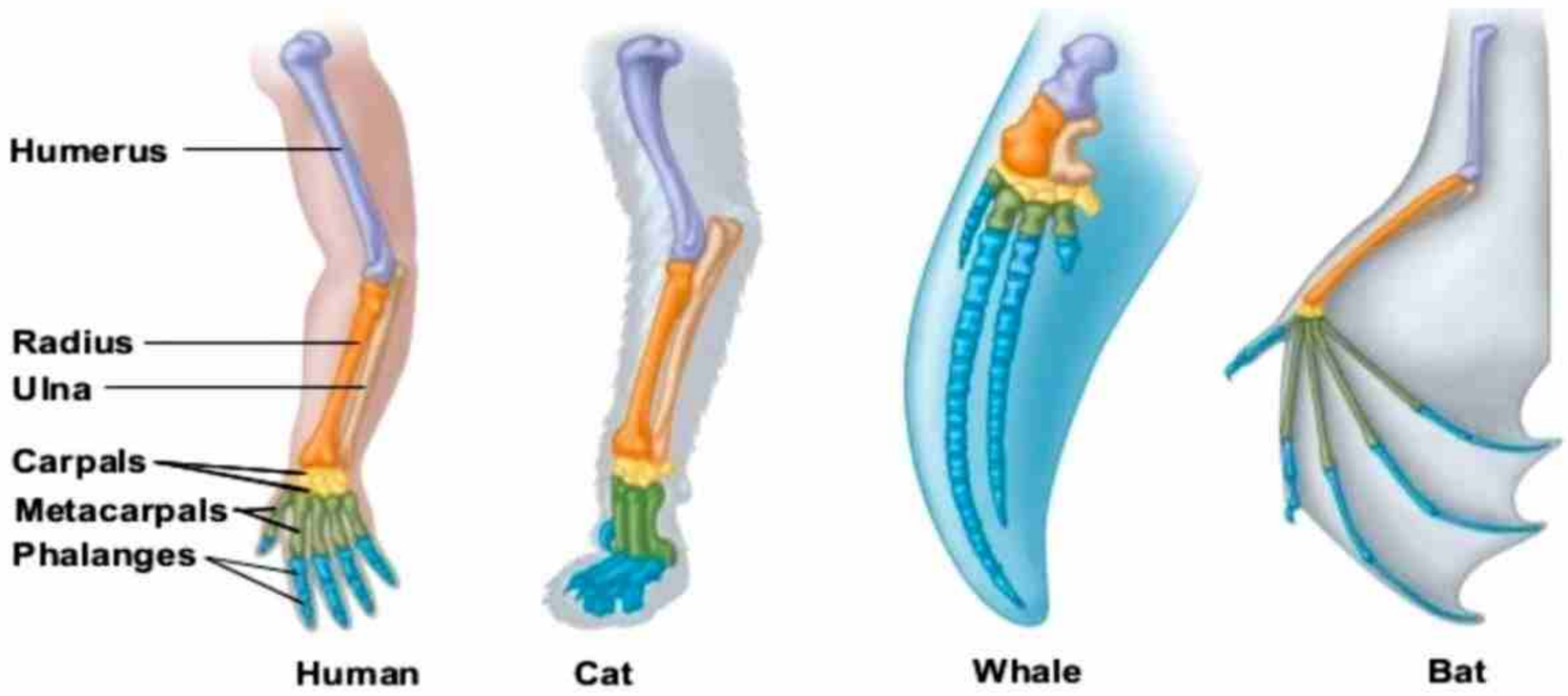


Fig. 24.3 Evidence of evolution from homologous organs

On the other hand some species show organs with similar in function but differ in their anatomical features. Such organs are known as **analogous organs**. For example, wings of an insect, bat and birds both are involved in flying however they have no anatomical resemblances. That shows different ancestry. This is termed as **convergent evolution**.

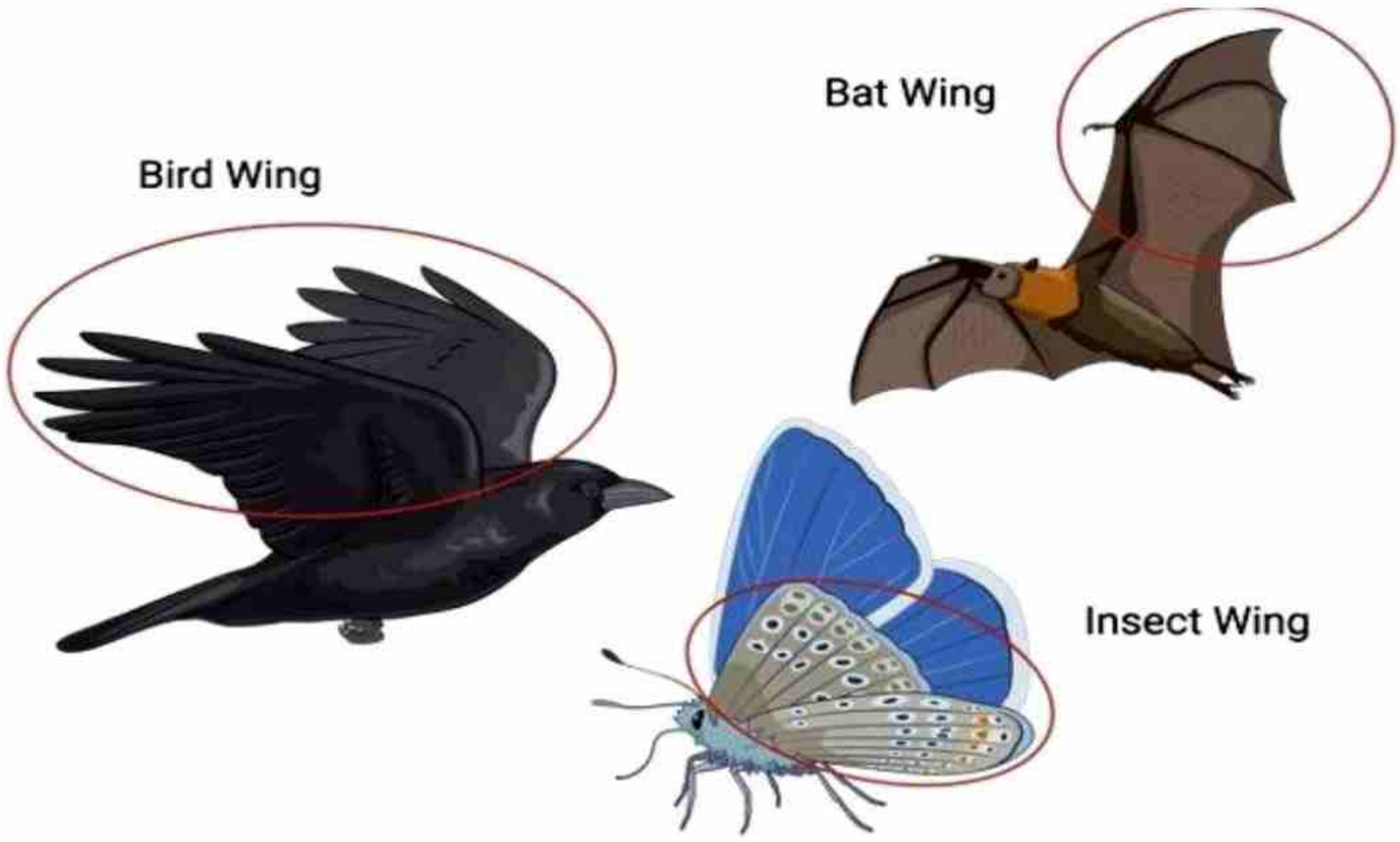


Fig. 24.4 Evidence from analogous organs

Evidence from molecular biology

Molecular biology is concerned with the study of molecules of cell and its organelles. It does provide evidence in favour of evolution. For example, genetic code may be considered in this case as good example. The translation between base triplets in the DNA and amino acids in proteins is universal in all living organisms. It can be confirmed by isolating mRNA for hemoglobin from a mammal and injecting it into bacterium E. coli which normally does not have hemoglobin. But when injected proper mRNA, it starts producing mammalian hemoglobin. Thus, it is evident that the machinery for decoding the message must therefore be common to mammal and E. coli.

A very good example in favour of evolution being observed in antibiotic resistance developed by pathogenic bacteria. If they do not adapt the lethal effect of the antibiotics, they would have been extinct so as a protection, pathogenic bacteria have to develop resistance against them through the process of natural selection. They undergo appropriate mutations in their genes to cope with the effects of antibiotics. This, on the other hand has put the pharmaceutical companies into a constant challenge to develop and improve the new and much effective, wide spectrum as well as specific antibiotics.

24.3. EVOLUTION OF EUKARYOTES FROM PROKARYOTES

Scientists agree on the fact that our planet earth was once covered with water (marine). Gradually, during the course of billions of years, the water receded and the land beneath appeared. So the life forms originated in water, especially in hot springs called hydrothermal vents. It is mentioned in The Holy Quran (sura Al-Anbiya, 21:30):

"And We made every form of life (on earth) appear from water, so do they not believe (even after being aware of these facts mention in the Quran)"

It is assumed that the vents supplied the energy and raw material for the origin and survival of early forms of life. It is now known that a group of bacteria (archaebacteria) can tolerate the extreme temperature of the hydrothermal vents. Such organisms were having a metabolism of catabolic in nature to obtain energy of the complex compound present around them. With the gradual depletion of the complex energy rich compounds in the environment, there became a great need of developing mechanisms for anabolic activities of their own. As a consequence, the evolving bacteria explored new ways of source of energy for their survival. This accounts for the existence of different ways of respiratory mechanisms correlated with existing diversity of nutritive methods among them. Thus some of the heterotrophic bacteria transformed into autotrophic ones. Initially, the autotrophs had to depend upon simple inorganic substances which gave rise sulphur-bacteria and iron-bacteria.

Since the amount of the energy obtained was very small as compared to their requirements so there developed need to evolve much more efficient ways such as photosynthesis. This account for the gradual accumulation of oxygen in the environment to be later consumed by other organisms. It is believed that the prokaryotes may have arisen more than 1.5 billion years ago. Following are two different hypotheses regarding the evolution of eukaryotic cells.

i) Membrane invagination Theory

It suggests that the cell membrane of prokaryotic cells invaginated to enclose the genetic material. This accounts for the

development of true nucleus while the other portions enclosed other necessary materials to transform into different organelles.

ii) Endosymbiotic Theory

It was suggested by Lynn Margulis. According to this hypothesis, the eukaryotic cell might have evolved when a large anaerobic amoeboid prokaryote ingested some aerobic bacteria (mitochondria) and rather than digesting started living with it in endosymbiotic relationship. Likewise, some of such eukaryotic cell, endocytosed autotrophic photosynthetic bacteria and transformed into ancestral autotrophic plant like organism.

The endosymbiotic theory seems more powerful in dealing with the evolution of eukaryotes since both mitochondria and chloroplast have following similar features like prokaryotes;

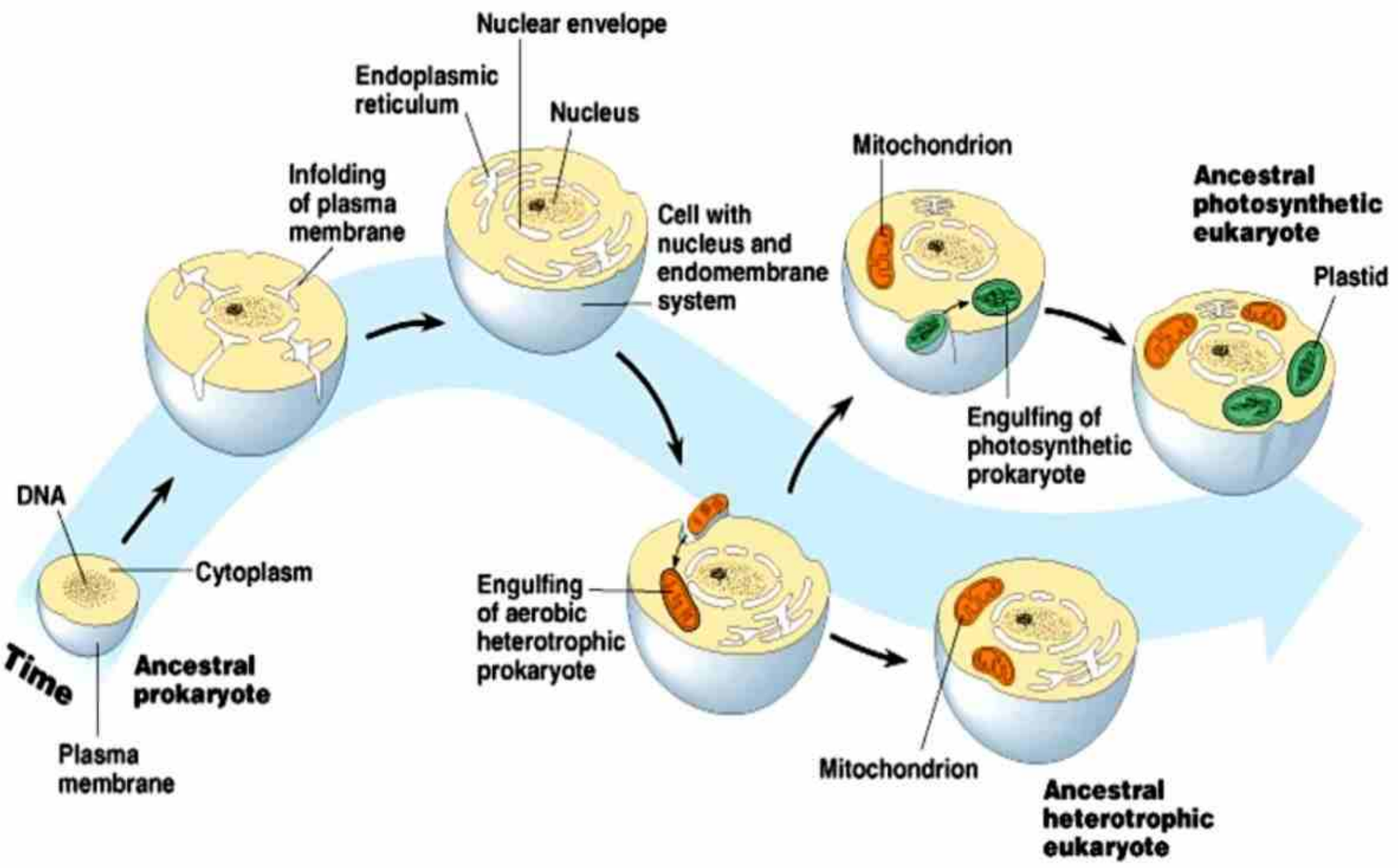


Figure: 24.5 Endosymbiotic Theory

i) Circular DNA molecules
ii) Ribosomes
iii) Metabolism
iv) Binary fission way of reproduction.

Primitive eukaryotes lived singly but later forms arose in the form of colonies also which account for the multicellularity, tissue and higher levels or organization, etc. among the eukaryotes which ultimately led towards the evolution of higher organisms like plants and animals.

24.4 LAMARCKISM

Jean Baptiste de Lamarck or simply known as Lamarck, a French biologist (1744-1829) was one of the proponents to the idea of evolution. He like many others of that era believed that evolution has taken place in accordance with the natural laws. His theory is known as Lamarckism or Inheritance of Acquired Characters. He discussed in detail his theory of evolution in his book *Philosophie Zoologique* in French in 1809. In view of Lamarck, the process of evolution is like a ladder of life proceeding from simple to the complex level of organisms with view of modification of characters of organism during its life time. His proposed theory of acquired characters consists of following postulates: i) Use and disuse of the organs, and ii) Inheritance of acquired characters.

i) Use and disuse of the organs

In view of Lamarck, an organism under the influence of internal or external factors, may either frequently use or disuse its one or more organs. During its persistence efforts of doing so, the organs under discussion are either developed more and become stronger due to more usage, or become weaker due to disuse. Thus as a consequence of constant effects of use or disuse generation after generation, the cumulative effect is seen either as either stronger or degenerating organ. He stated the example of existing giraffe with long neck and longer fore-limbs. According to him, the ancestral giraffe had short neck and fore-limbs. They fed upon the vegetation on ground. Somehow, either due to flooding of the ground or else, the ground vegetation disappeared forcing the ancestral giraffe to feed upon the foliage of trees very high above the ground level. So they had to gradually lift up the neck to pluck the leaves. Thus as a result of continuous efforts of stretching the neck and fore-limbs, the muscles developed stronger and stronger generation after generation, finally transformed into existing giraffe with long and high neck and

longer fore-limbs. He termed such adaptive features as "acquired characters".

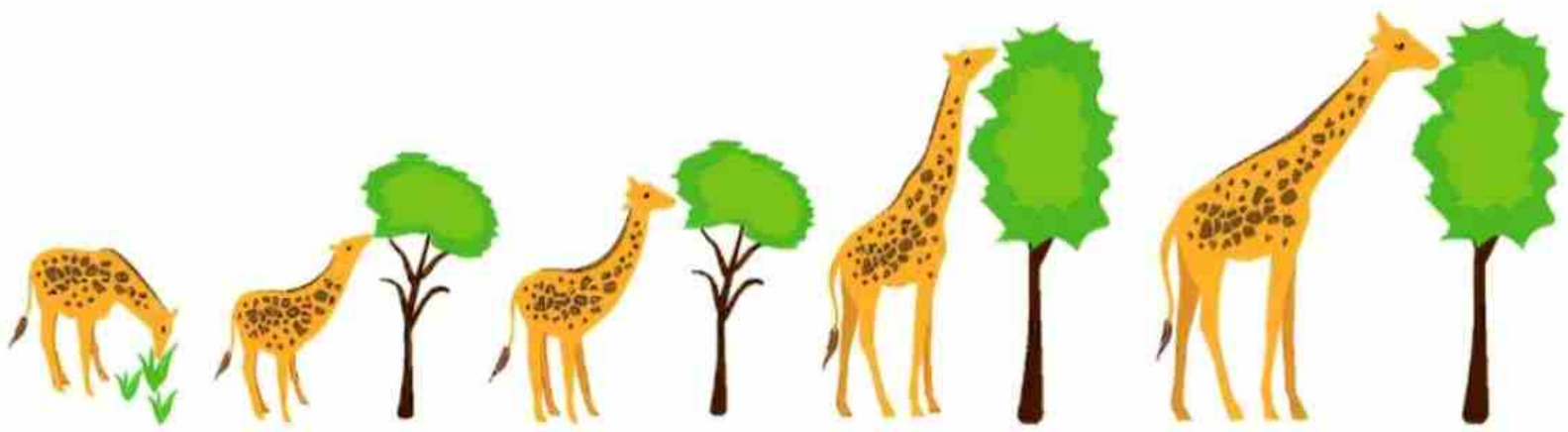


Fig. 24.6 Evolution of giraffe neck

ii) Inheritance of Acquired Characters

Lamarck believed that the characters acquired during the lifetime of individual due to use or disuse of organs was inherited to their offspring. Thus, individuals of the new generations were having stronger muscles of neck and fore-limbs. Finally, as a continuous inheritance, the outcome is the existing giraffe.

Extra Reading Material

Hypothesize whether Lamarck was criticized in his days for advocating the ideas of evolution or for the mechanism he proposed.

Lamarck's theory of inheritance of acquired characters was criticized especially by August Weismann and Cuvier on its genetic basis while on the other hand Charles Lyell and August strongly supported and promoted the ideology of Lamarck. Although Lamarck's ideas were rejected, interest in his ideas has recently resurfaced.

He may not have been correct with his long-necked giraffe example, but on a fundamental level, he was describing "epigenetics" which deals with the study of behaviours, environmental exposures on other external factors may alter how DNA is read and used to express certain proteins

Drawbacks of Lamarckism

Though theoretically seems plausible, yet Lamarck theory has no experimental support. Also the idea of development of acquired characters has no genetic basis and it seems that they influence on the somatic cells rather than the germ cells involved in inheritance. So how could be the acquired characters are inherited to the next generation without affecting the germ cells. As a fact, it is also noted that organs are not modified by the wish of the organism. Also, Lamarckism fails to account for the genetic variability found in the species.

24.5 DARWINISM

Charles Darwin (1809-1882), an English biologist, a geologist and a naturalist is well known for his contribution on evolution. His proposal of origin of species from a common ancestor is generally a widely accepted fact. Though he got education in medicine and surgery, he was never interested in the field of medical. He was much interested in studying nature as got admitted to the Christ College, Cambridge in 1928. In 1831, he decided to go on a five years trip on a ship H.M.S. Beagle heading towards South America.

24.5.1 Darwin's observations during his voyage

His voyage on HMS Beagle started in December 1931 from Plymouth, England. After crossing the Atlantic Ocean, most of his trip was sailing around South America, then proceeding ahead and crossing the Pacific Ocean, they crossed Australia. The journey continued back through the Indian Ocean up to the Cape Town, South Africa and then heading back to South America, finally back to Plymouth, England.

Since most of his trip was sailing around South America, he collected and studied offshore species of both plants and animals. During his studies, Darwin collected a variety of bird specimen, particularly finches in **Galapagos Island**. He observed that the finches of the Galapagos Island were similar to the finches on mainland but each had adaptations in beak in terms of size and shapes to obtain easily and effectively the locally available food.

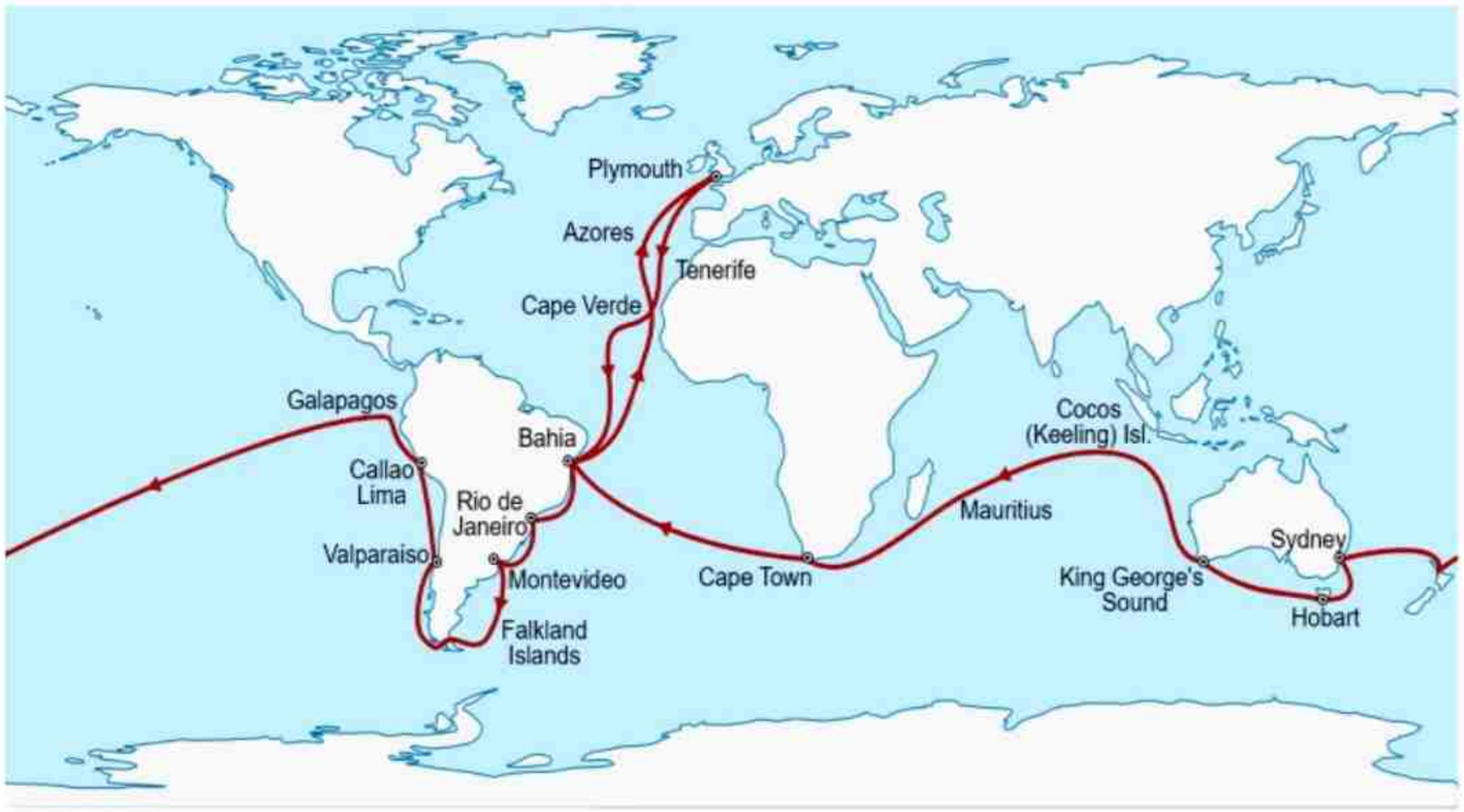


Fig. 24.7 Map showing the journey of the ship HMS Beagle

Through his observation and collection, Darwin was much convinced about the process of natural selection as tool for the process of evolution. He thought that new species could have originated as a consequence of gradual accumulation of such adaptations due to existing geographical or other types of barriers.

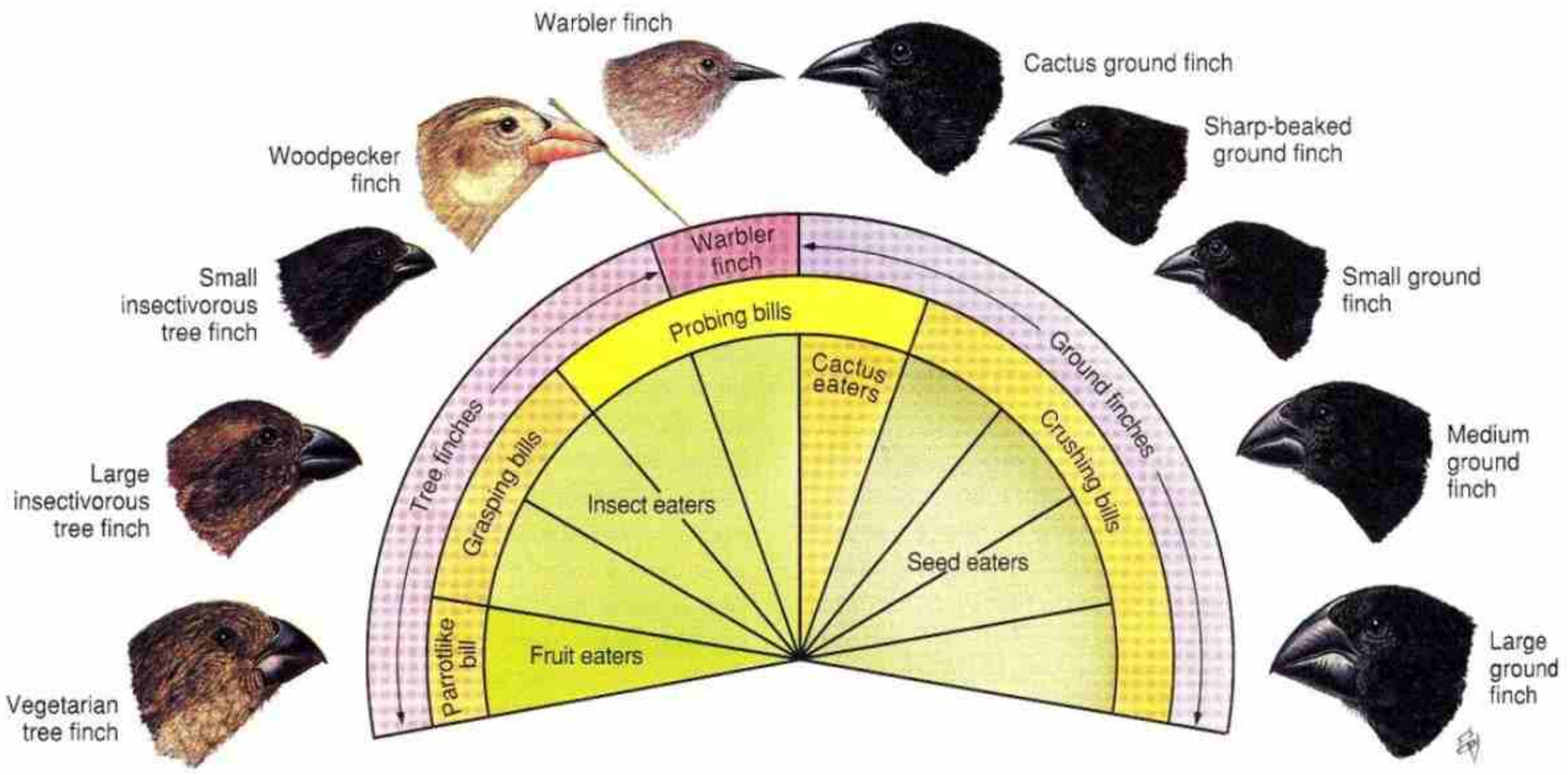


Fig. 24.8 The finches studies by Darwin on Galapagos island

24.5.2 Theory of Natural Selection

Even though the Darwin's journey ended in 1836, he felt himself in uncomfortable position to put forward his theory of evolution until 1842. During this period, he collected ample evidences to support his proposal of natural selection and the origin of species. Initially, he prepared a brief sketch which later turned into a detailed description of the process on evolution. Meanwhile, keeping in view of the sensitivity of the issue, he discussed it with his friends and colleagues before final publication.

According to the Theory of Natural Selection, all living species are descendants of ancestral species and are different from present day ones due to the cumulative change in the **genetic composition** of a population. Darwin considered "Natural Selection" is the mechanism of evolution through which heritable traits that help organisms survive and reproduce become more common in a population over time. Darwin's theory of Evolution is based upon following two key points: i) Descent with modification, ii) Natural Selection and adaptation.

i) Descent with modification

Like other evolutionary biologists, Darwin considered that living organisms are related to each other through common ancestry. The existing diverse forms of living organisms are descent of previous simpler forms and gradually adapted to the changing conditions. Thus the history of life is like a tree, with number of branches coming out of the trunk terminating at existing species. The point of junction of twigs is symbolically representing actually the common ancestors of these branches. Gradually going down towards main trunk representing the common ancestor of all forms of life.

ii) Natural Selection and adaptations

The process of Natural Selection actually operates to select the organisms with better adjustments with their environment. Such organisms have better opportunity for survive and reproduce than the inferior ones. It is comprised of following four stages.

Over production: Each individual species has power to reproduce to increase its number. Due to limited life span, limited available resources, etc. each species tries to over produce its number of

offspring because not all the offspring survive before reaching to the sexual maturity and able to reproduce.

Struggle for existence: During the life time, the individuals of a species have to struggle for the available resources of food, better living conditions, predators, parasites, diseases, etc. Thus not all individuals survive through such struggle, a number of them are vanished. In fact not all of the survivors would be able to reproduce. This causes some other decrease in their number also. They do have to struggle against other closely related species also. The struggle within the individual of the same species is termed as intra-specific struggle while with the other species is termed as inter-specific struggle. Meanwhile, all of them have faced the natural catastrophes also. This is environmental struggle.

Genetic Variations: The individuals of a population differ slightly from each other to ensure their survival and chances of reproduction. Otherwise, for example an epidemic may sweep out the entire group. Thus differences of individuals of a species are termed as variations. It ensures the chances of survival and reproduction and ultimately the longer existence of species as whole. The characters of individuals are genetically termed as traits. The traits making better chances of survival are termed as adaptive traits.

Survival of the fittest: The individuals of a species having the most favourable traits would have greater chances of survival and reproduction than the others. In terms of genetics, it can be said that organisms with better set of genes would have greater chances of survival. Such organisms are considered as fittest. According to Darwin, they would have better chances of survival as they pass their genes through inheritance to their offspring. The whole process is termed as Natural Selection which provides opportunity to the fittest one to survive and reproduce. In a sense, natural selection increases the chances of inheritance of better alleles while decreasing the less favourable alleles. In view of Darwin, the process of natural selection was a way of the origin of new species through a very slow but gradual process of accumulation of changes. Formation of new species is termed as speciation.

24.5.3 Ideas of Charles Lyell, James Hutton, Thomas Malthus in the early development of Darwinism

Darwin was inspired by findings of a number of other researchers regarding the process of fossilization and its correlation with the evolution. Following were important to understand the concept of Darwin regarding evolution.

Contribution of Charles Lyell

He was a great geologist of his time. His theory of uniformitarianism inspired Darwin. According to Lyell, the geologic processes that were around at the beginning of time were the same ones that were happening in the present as well and that they worked the same way. He believed the Earth developed through a series of slow changes that built up over time. Darwin thought this was the way that life on Earth also changed. He theorized that small adaptations accumulated over long periods of time to change a species and give it more favourable adaptations for natural selection to work on. Lyell was a good friend of Captain Robert FitzRoy who piloted the HMS Beagle when Darwin sailed to the Galapagos Islands and South America. FitzRoy introduced Darwin to Lyell's ideas and Darwin studied the geological theories as they sailed.

Contribution of James Hutton

He was a famous geologist by whom Darwin was inspired. Actual idea of fossilization was put forwarded by Hutton before Lyell. He the first to publish the idea that the same processes that formed the Earth at the very beginning of time were the same that were happening in the present day. These "ancient" processes changed the Earth, but the mechanism never changed. Even though Darwin saw these ideas for the first time while reading Lyell's book, it was Hutton's ideas that indirectly influenced Charles Darwin as he came up with the idea of natural selection. Darwin said the mechanism for change over time within species was natural selection and it was this mechanism that had been working on species ever since the first species appeared on Earth.

Contribution of Thomas R. Malthus

Thomas R. Malthus was an economist and one of the persons who fascinated Darwin with his theory on human population.

According to Malthus, the human population was growing faster than the food production could sustain. This would lead to many deaths from starvation and forces the population to eventually level out.

Darwin applied these ideas to populations of all species and came up with the idea of "survival of the fittest". Malthus's ideas seemed to support all of the studying Darwin had done on the Galapagos finches and their beak adaptations. Only individuals that had favourable adaptations would survive long enough to pass down those traits to their offspring. This is the cornerstone of natural selection.

24.5.4 Role of Alfred Russell Wallace in motivating Charles Darwin to publish the Theory of Natural Selection

A. R. Wallace was one of the contemporaries of Charles Darwin. He collaborated with Darwin on the theory of evolution. Wallace supplied Darwin with birds for his studies and helped him a lot in publishing the theory of evolution. In fact, Wallace actually came up with the idea of natural selection independently, but at the same time as Darwin. The two pooled their data to present the idea jointly to the Linnaean Society of London in 1858. It wasn't until after this joint venture that Darwin went ahead and published the ideas in his book "The Origin of Species."

24.5.5 Why the theory of natural selection attributed to Darwin?

Even though both Wallace and Darwin contributed the Theory of Natural Selection equally, Darwin gets most of the credit today. Wallace has been relegated to a footnote in the history of the theory of evolution. Actually, Wallace was the person who motivated Darwin to publish the book “On the origin of species” in 1859. Besides, Darwin later also speculated about evolution of humans on which he published “Descent of Man”. Wallace diverged Darwin at this point.

24.6 NEO DARWINISM

It is interesting to note that Darwin’s Theory of Natural Selection was put forwarded in 1859, the same time when Gregor John Mendel was formulating his Laws of Inheritance during 1856-63 which remained neglected about three decades until rediscovered at the turn of 20th century. So, the Darwin’s study was lacking a

concrete genetic basis. As discussed earlier in view of Darwin, in an individual, accumulation of fittest phylogenetic variations is the major driving force of **speciation**, hence the natural selection is the survival of the fittest in the environment. Neo Darwinism is a modified theory of Darwinism explaining the origin of species on a genetic basis, hence the main driving force of **Neo Darwinism** is genetic variation. Consequently, the main difference lies in the variation type and type of natural selection. The main force driving speciation is the gathering of genotypic variations in a gene pool. Neo Darwinism is also referred to as the Modern synthetic theory of natural selection. In this case, reproductive isolation has a major part in speciation allowing differential amplification of the fittest genes in a gene pool. Thus, natural selection of the most suitable genes is associated with the origination of new species.

POPULATION GENETICS:
It is the branch of biology that deals with the process of origin of variations and their inheritance. It plays a very important role in linking evolution and genetics so as to develop possible account for the origin of life as well as origin of species. It begins at the individual level and then cumulates the data at the population level.

24.6.1 Hardy-Weinberg Theorem

Hardy-Weinberg Theorem is the principle being proposed collectively in 1908 by an English mathematician, Godfrey Hardy and a German Physician, Wilhelm Weinberg to demonstrate mathematically the gene frequencies of different alleles in a given population. According to this theorem, the frequency of dominant allele would not tend to increase. The genetic variation in a population will remain constant from one generation to the next in the absence of disturbing factors. When mating is random in a large population with no disruptive circumstances, the law predicts that both genotype and allele frequencies will remain constant because they are in equilibrium.

Hardy-Weinberg Equation

From their principle, they deduced an equation to calculate the allelic frequencies and genotypes in a population to show the

equilibrium and termed as Hardy-Weinberg equilibrium. For example, in Drosophila the allele for gray body color *(B)* is dominant over the allele for black body *(b)*. In the absence of any other allele for body color, the sum of their frequencies must be equal to one. Now mathematically, if we designate *B* allele with *"p"* and its recessive *b* allele with *"q"* then the equation would be $p + q = 1$. Simply, knowing the frequency of one either *p* or *q* is known, we can determine the value of the other. From this assumption, the following equation can be derived to obtain the offspring genotypes.

$$p^2 + 2pq + q^2 = 1$$

(Frequency of *BB*) + (Frequency of *Bb*) + (Frequency of *bb*) = (all individuals of population)

Problem:

The frequency of two alleles in a gene pool is 0.19 (*A*) and 0.81 (*a*). Assume that the population is in Hardy-Weinberg equilibrium, then

(a) Calculate the percentage of heterozygous individuals in the population.

Solution:

H-W Equation: $p^2 + 2pq + q^2 = 1$

According to the Hardy-Weinberg Equilibrium equation, heterozygotes are represented by the $2pq$ term. Therefore, the number of heterozygous individuals (*Aa)* is equal to $2pq$ which equals $2 \times 0.19 \times 0.81 = 0.31$ or 31%

(b) Calculate the percentage of homozygous recessives in the population.

Solution:

The homozygous recessive individuals (*aa*) are represented by the q^2 term in the H-W equilibrium equation which equals $0.81 \times 0.81 = 0.66$ or 66%

Factors Affecting Hardy-Weinberg Theorem

i) Mutations:

It introduces new genes into population

ii) Selection:

Either due to natural or artificial selection, some species may be given greater opportunity to reproduce and increase the number of their offspring which can affect the frequencies of alleles.

iii) Non-random mating:

The process of mating should be non-random in a given population and the population size should be large enough.

iv) Gene flow:

It refers to the exchange of genes between different populations of the same species. It may be either due to migration of individuals from one population to another of the same species or to the transfer of gametes. In the absence of natural selection and genetic drift, gene flow leads to genetic homogeneity among demes within a metapopulation, such that, for a given locus, allele frequencies will reach equilibrium values equal to the average frequencies across the metapopulation.

Since all of these disruptive forces commonly occur in nature, the Hardy-Weinberg equilibrium rarely applies in reality. Therefore, the Hardy-Weinberg equilibrium describes an idealized state, and genetic variations in nature can be measured as changes from this equilibrium state.

24.6.2 Genetic Drift (Neutral Selection)

It refers to the changes in allelic frequency in a population from generation to generation. It occurs when allele frequencies grow higher or lower by chance and typically takes place in small populations. Although genetic drift occurs in populations of all sizes, its effects tend to be stronger in small populations. This is also named as neutral selection because most of the variations within and between species are due to random genetic drift of mutant alleles that are selectively neutral.

Example:

In order to make genetic drift clear, let's take an example of a small population of ten rabbits, two of which are white (genotype bb) while eight are brown (genotypes BB or Bb). Both alleles B and b are present in equal frequencies i.e., p=0.5 and q=0.5. Thus if 10 of the individuals reproduce randomly, the probability of having an offspring with alleles B or b is 0.5. Suppose, if (purely by chance) 5 circled rabbit reproduce among themselves (the rest died/caught by hunter, etc.) so the frequency of allele B and would change to 0.7 and o.3 respectively as shown in the Fig.24.10. Now further supposing that only two of the five of the second generation, the b allele will be completely lost.

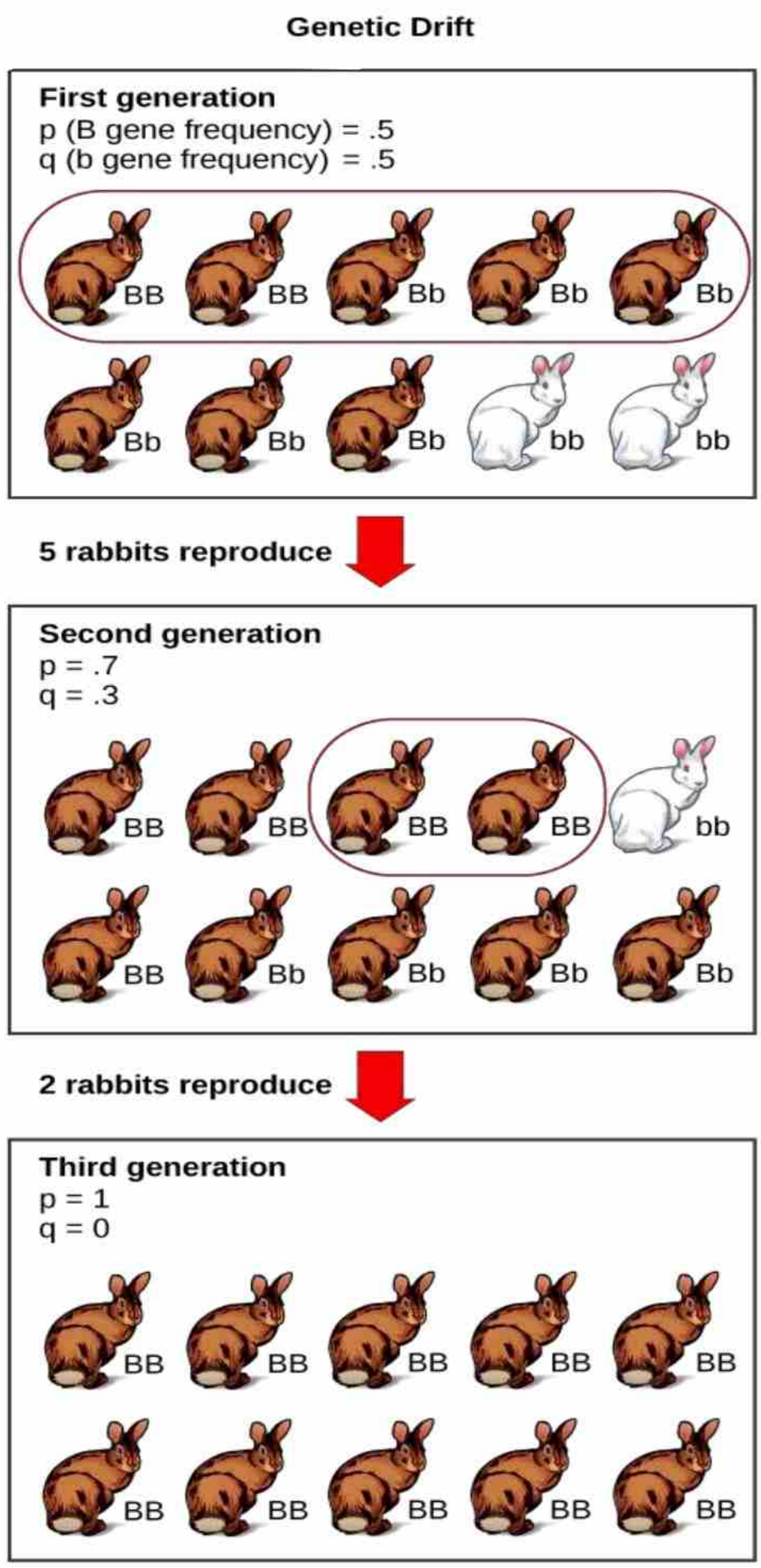


Fig. 24.10 Genetic drift

There are two types of genetic drift

i) Bottleneck effect: In this kind of genetic drift, the size of the population is decreased due to some natural catastrophes like volcano eruption, earthquake, flood, fire, etc. As a consequence, a number of individuals would be eliminated leaving behind few live individuals to reproduce.

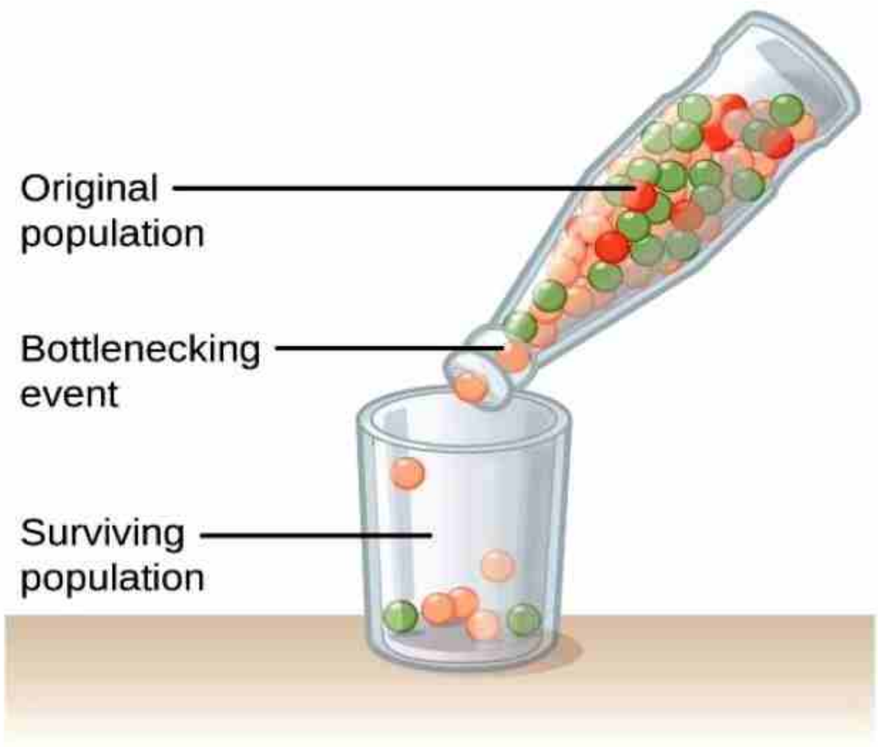


Fig. 24.12 Bottle-neck Effect

ii) Founder effect: In this kind of genetic drift, a new small population separated from the larger one due to some geographical or physical barriers starts reproducing within itself. As a consequence, the allelic frequencies will be different from their original stock.

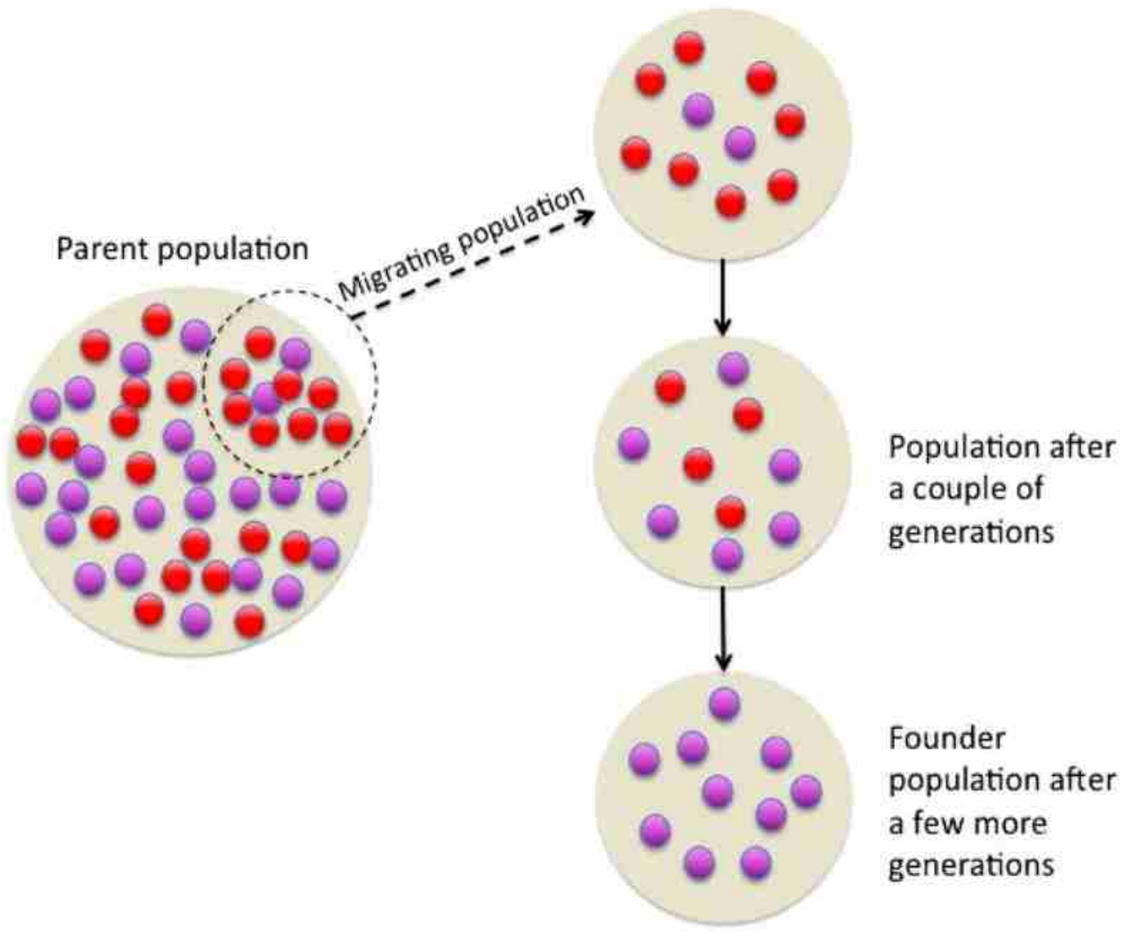


Fig. 24.13 Founder's Effect

24.6.3 Speciation and its mechanism:

It is the biological process of formation of new species of living organisms. It occurs when a group of individuals within a population develop distinct characteristics and becomes reproductively isolated from the rest.

There are different ways for speciation process, viz., allopatric speciation, sympatric speciation, peripatric speciation and parapatric speciation.

Sympatric speciation: In this case, one of the populations of a species occupying the same geographical area becomes distinctly different features so that it is unable to mate with its original stock. There could be different reasons for sympatric speciation such as polyploidy, habitat differentiation and sexual selection. It is more commonly observed among plants than animals.

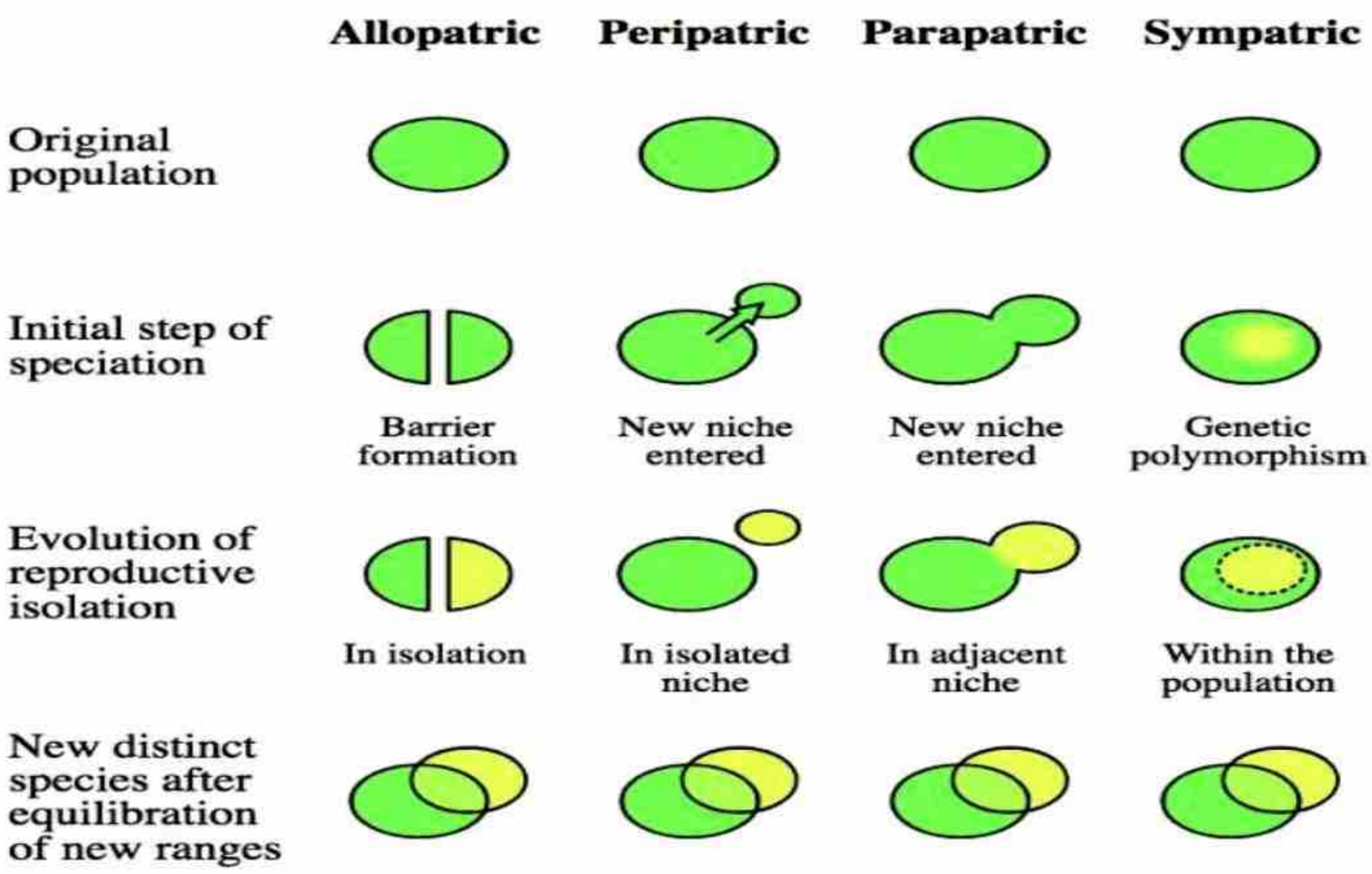


Fig. 24.14 Types of speciation

Allopatric speciation: In this kind of speciation, the populations become geographically separated from each other so that they become reproductively isolated from the rest of their populations. As a consequence, the gene flow stops among them and depending upon

their environmental factors during the course of time, they do genetically differ from them. It is one of the very common ways of speciation.

Peripatric speciation: When small groups of individuals break off from the larger group and form a new species, this is called peripatric speciation. Like allopatric speciation, although there is a geographical isolations exists in this kind of speciation, it differs in way that the separated group is much smaller than the original one.

Parapatric speciation: In this speciation, the populations are not geographically separated from each other, but they enter a quite different habitat within the same area of the parent species. In such case, the populations may interbreed but develop distinct features and habits. The reproductive isolation in this case is behavioral rather than geographical. For instance, it is observed in plants living on boundaries between distinct climates may flower at different times in response to their environments. Thus, they cannot interbreed with the parental types.

ACTIVITY:
Identify the homologous and analogous organs in animas.

SUMMARY

- Evolution refers to a process of development of an entity in the course of time through gradual sequence of changes from simple to complex form.
- The distribution of different species on earth provides evidence of evolution and it correlates the variations of a species and the movement of continents across the globe via plate tectonics.
- In divergent evolution, the two or more species share common ancestry.
- Organs with similar in function but differ in their anatomical features are termed as analogous organs.
- The presence of analogous organs shows different ancestry and this is termed as convergent evolution.
- Life forms originated in water, especially in hot springs called hydrothermal vents.
- Prokaryotes may have arisen more than 1.5 billion years ago.
- Membrane invagination Theory suggests that the cell membrane of prokaryotic cells invaginated to enclose the genetic material.
- Lamarck theory is known as Lamarckism or Inheritance of Acquired Characters.
- In view of Lamarck, the process of evolution is like a ladder of life proceeding from simple to the complex level of organisms with view of modification of characters of organism during its life time.
- Theory of acquired characters consists of use and disuse of the organs, and inheritance of acquired characters.
- Darwin applied these ideas to populations of all species and came up with the idea of "survival of the fittest".
- The main force driving speciation is the gathering of genotypic variations in a gene pool.
- Population genetics deals with the process of origin of variations and their inheritance.
- Genetic Drift (Neutral Selection) refers to the changes in allelic frequency in a population from generation to generation.
- In Bottleneck effect, the size of the population is decreased due to some natural catastrophes like volcano eruption, earthquake, flood, fire, etc.

- In Founder effect, a new small population separated from the larger one due to some geographical or physical barriers starts reproducing within itself.
- Speciation is the biological process of formation of new species of living organisms.

EXERCISE

1. Encircle the most appropriate response.

i) Which of the following was supporting the theory of special creation?
(a) George Buffon (b) Lamarck
(c) Darwin (d) Suárez

ii) Archaeopteryx is a connecting link between
(a) Amphibia and reptiles (b) Reptiles and Aves
(c) Aves and mammals (d) Fish and amphibia

iii) All of the following are homologous organs except
(a) Wings of bat (b) Wings of butterfly
(c) Wings of bird (d) Flippers of dolphin

iv) Which of the following are analogous organs except:
(a) Wings of insect (b) Wings of bird
(c) Wings of bat (d) Arm of man

v) Life originated in
(a) Air (b) Water
(c) Land (d) Space

vi) *Philosophie Zoologique* was written by
(a) Wallace (b) Darwin
(c) Weismann (d) Lamarck

vii) Which of the following is incorrect regarding Lamarck's theory of Inheritance of acquired characters?
(a) Use and disuse of the organs inherited
(b) Continuously using some organ results in its further strengthening in offspring
(c) Continuously disuse of some organ results in its weakening in offspring
(d) Concrete support to the theory through experiments

viii) The theory on human population which inspired Darwin was proposed by
(a) Malthus (b) Lyell
(c) Hutton (d) Wallace

ix) Theory of Natural Selection was lacking any support from
(a) Biogeography (b) Genetics
(c) Comparative anatomy (d) Molecular Biology

x) Which of the following cannot be the disruptive force for Hardy-Weinberg Theorem?
(a) Selection (b) Non-random mating
(c) Mutation (d) Random mating

2. Write short answers of the following questions.

i) Differentiate between the following:
a) Special Creation and Evolution
b) Lamarckism and Darwinism
c) Invagination theory and Endosymbiotic theory
d) Bottle-neck effect and Founder's effect
e) Convergent and Divergent evolution

ii) How the homologous organs support the theory of evolution?
iii) What are analogous organs? Give example.
iv) How Alfred Wallace contributed Charles Darwin regarding the Natural Selection?
v) What do understand by the "descent with modification"?
vi) How Neo-Darwinism differs from Darwinism?
vii) How the sympatric speciation differs from parapatric speciation?
viii) Justify Lamarck as an early proponent of evolution.
ix) What is genetic drift?
x) List out the factors affecting allele frequency

3. Write detailed answers to the following questions.

i) State and explain the contribution of Lamarck in organic evolution.
ii) Discuss the process of origin of single cell Eukaryotes.
iii) How biogeography and paleontology provide evidences in support of evolution?
iv) What is speciation? Explain different ways of speciation.
v) Describe the Theory of Natural Selection.

MAN AND HIS ENVIRONMENT

Chapter 25

Major Concept

In this Unit you will learn:

- Biogeochemical Cycle
- The Flow of Energy
- Ecological Succession
- Population Dynamics
- Human Impacts on Environment
- Environmental

25.1 BIOGEOCHEMICAL CYCLE

Every living organism requires nutrition to survive, and the env ironment offers these nutrients.

These nutrients circulate in cycles through ecosystems. The movement and exchange of elements and essential compounds required for life between organisms, the environment, reservoirs of water, and the Earth's crust are known as “Biogeochemical cycle”. These cycles refer to a wide range of biological, geological, and chemical activities that contribute to the balance and sustainability of ecosystems.

The protoplasm of living organisms contains a variety of elements, an ecosystem depends on a continuous supply of these substances. As a result, these elements follow a typical path from the environment to the organism and back to the environment within the atmosphere. Carbon, hydrogen, oxygen, and nitrogen are found in almost all chemicals connected with metabolic activities; these elements are required for life to exist. Phosphorus and nitrogen possess independent cycles, whereas carbon, hydrogen, and oxygen are bound together and form the carbon, hydrogen, and oxygen cycle.

25.1.1 Primary Reservoirs of Nutrients

The nutrient cycle is a system where matter and energy are transferred between living organisms and non-living environments.

The nutrients which are present in the natural reservoirs are consumed by living organisms, especially plants, and from plants to animals. These organisms release these nutrients back into the environment by their death and decay and other metabolic wastes. This

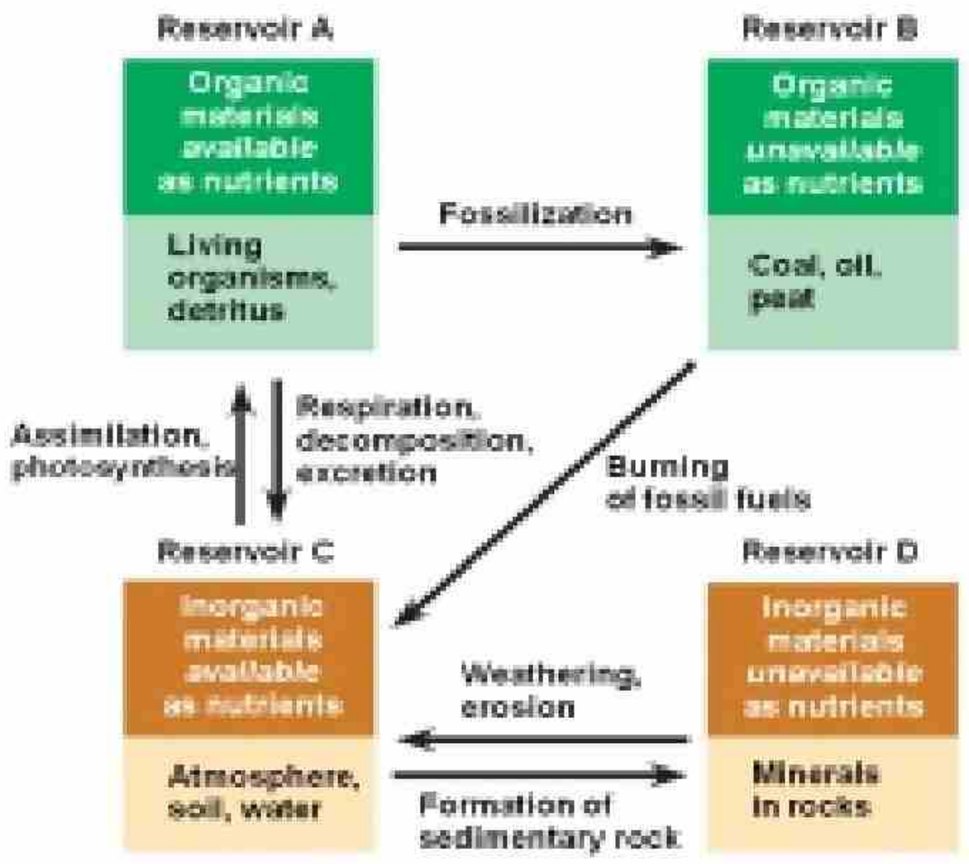


Fig: 25.1 Nutrients Cycle

movement of nutrients is called the nutrients cycle, in this way, the nutrients remain constant if equilibrium between them does not disturb.

Nature has different types of reservoirs of nutrients but all reservoirs must have the following two characteristics.
1. It must contain some inorganic or organic material for exchange.
2. They must have some material that is directly available for the use of living organisms on the basis of the above characteristics. The nature has following types of reservoirs.

Type-I: Living organisms and detritus provide organic material for respiration, decomposition, and excretion known as reservoir A.

Type-II: Coal, oil (fossil fuel), peat → provide gaseous nutrients like CO_2 on combustion reservoir B.

Type-III: Atmosphere, soil, water → provide inorganic materials like $CO_{2,,}$ many inorganic ions like SO_n^{-2}, PO_4^{-3}, Fe^{+3}, Mg^{+2}, Ca^{+2}, etc. used in the assimilation reservoir C.

Type-IV: Minerals in rocks reservoir D provide inorganic materials, the majority of inorganic materials are available for metabolism.

25.1.2 Water Cycle

The water cycle, also known as the **hydrological cycle**, is a continuous process through which water circulates between the Earth's surface, the atmosphere, and bodies of water. It involves a series of physical and chemical processes that result in the movement, distribution, and transformation of water throughout the world. Water is a very important abiotic factor in our ecosystem. It plays a very significant role in the ecosystem and is vital for the existence of life. The protoplasm of cells contains 70-90% water. It is always available in the form of circulation.

The water cycle is the continuous circulation of water on the earth and is found in different positions in the **atmosphere**. The most important process in the water cycle is the radiation from the sun which causes evaporation of water. The water cycle begins with the process of **evaporation.**

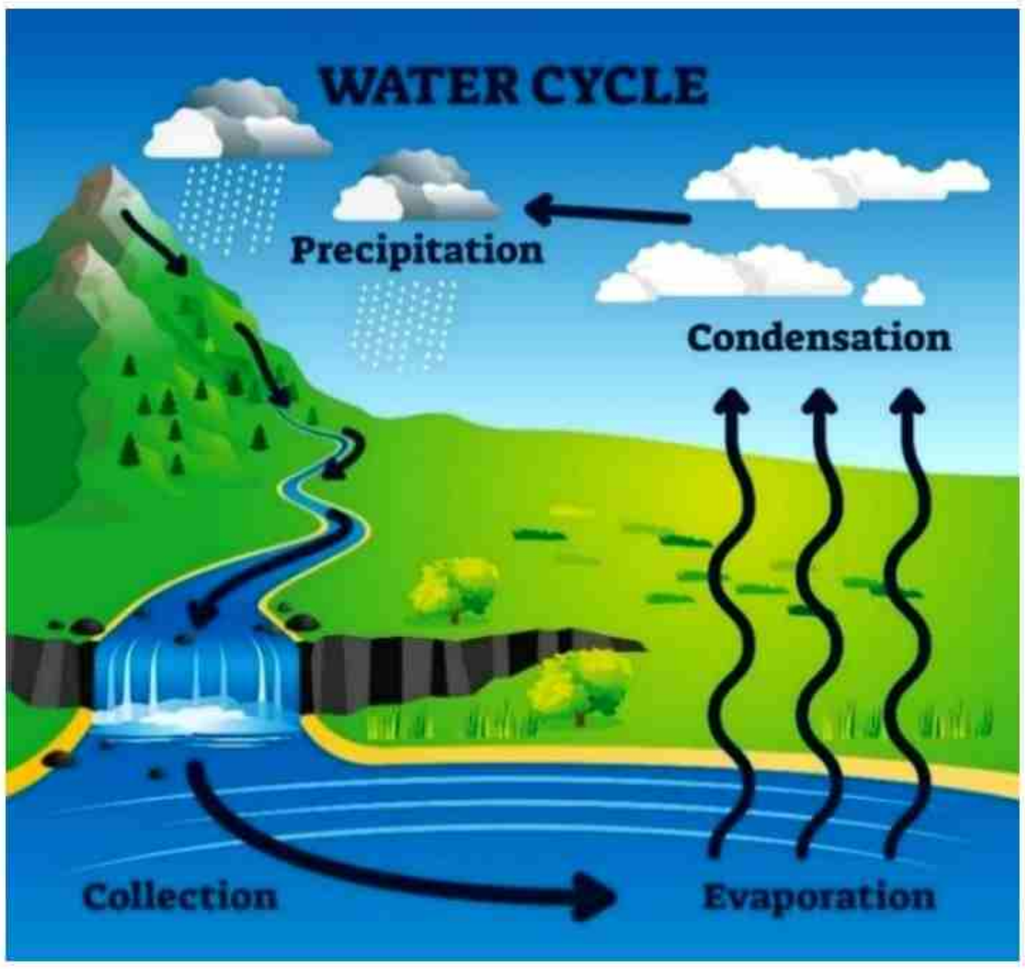


Fig: 25.2 Water Cycle

The heat evaporates water from oceans, lakes, rivers, and other bodies. Evaporation also occurs from moist soil and the surfaces of plants through a process called transpiration. As the water vapor rises higher into the atmosphere, it encounters cooler temperatures. This leads to the **condensation** of the water vapor into rain or ice crystals, forming clouds. Condensation occurs around tiny particles in the air, such as dust or aerosols, which serve as nuclei for the water droplets.

When these water droplets grow larger, remain suspended in the air, they fall back to the Earth's surface as precipitation. Precipitation can take various forms, including rain, snow, sleet, or hail, depending on the temperature and atmospheric conditions. It can occur over both land and water bodies. Water is present everywhere in the world in different forms. About 2.1 % of water exists as ice in the Polar Regions and permanent glaciers. Water in liquid form is found in the oceans, rivers, and lakes. Ocean is the main reservoir for water which holds more than 97 % of the available water.

The remaining amount of water is in the form of fresh water. It is found as atmospheric water vapors, groundwater, soil water, or inland surface water. A great amount of water is absorbed into the

soil and from underground channels. Water is again returned to the atmosphere through evaporation.

Living organisms get water from the environment. Animals get water by drinking while plants can get it by absorption from the soil. This water is used in the formation of various substances in the body. It is ingested or consumed by heterotrophs. Animals release water by respiration, evaporation from the body surface, and excretion through the discharge of wastes. Plants (autotrophs) use water during photosynthesis and release water by transpiration, the majority of it is evaporated back into the atmosphere from the leaves of plants after being absorbed by their roots. During photosynthesis, a little quantity is mixed with carbon dioxide to create high-energy molecules. These eventually degrade during cellular respiration and are released back into the environment.

25.1.3 Aquifers and Water Table

Aquifers are transparent underground layers of rock, sediments, or soil that hold and transmit water. They play a significant role in the Earth's hydrological cycle because they serve as natural underground reservoirs that contain huge amounts of freshwater. Aquifers develop over time as rainwater or surface water seeps into the earth and slowly penetrates through the porous layers of rocks or sediments. Because they have the essential permeability to retain and share water, sandstone, limestone, and destroyed volcanic rock are the most common types of rocks that produce aquifers. When water enters an aquifer, it is trapped within the pore spaces or gaps of the rocks or sediments. Wells or natural springs can be used to acquire water when pressure forces it to the surface.

Aquifers are necessary for a wide range of human activities, including agriculture, industry, and domestic water supplies. Several regions depend heavily on aquifers for irrigation and as a source of drinking water. However, aquifers must be maintained in a sustainable manner to avoid overexploitation and the depletion of these vital resources. Excessive pumping or aquifer pollution can cause water level depletion, saltwater incursion into coastal areas, and water quality degradation. Understanding aquifer features, recharge rates, and vulnerabilities is critical for effective water resource management. Aquifer planning, water level monitoring, and

the implementation of sustainable practices are all critical for sustaining the long-term supply and quality of groundwater from aquifers.

The water table, on the other hand, refers to the upper boundary or surface of the saturated zone within an aquifer. It represents the depth at which the soil and rock layers are fully saturated with water. The water table fluctuates depending on factors such as precipitation, evaporation, and the rate of groundwater extraction. In areas with abundant rainfall, the water table may be closer to the surface, while in arid regions, it may be deeper underground. The water table is significant because it determines the availability of groundwater in a particular area. Wells and groundwater extraction activities are typically bored or found below the water table to ensure access to an adequate supply of water. However, excessive pumping or overuse of groundwater can lead to a drop in the water table, resulting in a lowered water level and potential depletion of the aquifer.

25.1.4 Nitrogen Cycle

Nitrogen is an essential element for the existence of life on Earth. All living organisms need nitrogen for their growth and development because it is the necessary component of organic compounds like proteins, nucleic acids, and amino acids. The flow of nitrogen between the earth and the atmosphere in various forms throughout the environment is known as the **nitrogen cycle**.

The nitrogen cycle is a complex biogeochemical process that ensures the availability and recycling of nitrogen in the Earth's ecosystems. Nitrogen gas (N_2) makes up about 78 % of the Earth's atmosphere, but most organisms cannot utilize it directly in the gaseous form. It begins with nitrogen fixation, where certain bacteria convert atmospheric nitrogen into ammonia (NH_3) or ammonium ions (NH_4^+). This process can occur through symbiotic relationships with plants or in the soil as free-living bacteria. In the nitrification process, the conversion of ammonia or ammonium ions into nitrate (NO_2) occurs through nitrifying bacteria. Nitrates are soluble and can be easily available for plants and other organisms in the soil. It is then absorbed by plants through their roots in a process called assimilation. Within plants, nitrate is converted into various organic

nitrogen compounds, such as proteins and nucleic acids, supporting their growth and development.

Animals obtain nitrogen by consuming plants or other animals, assimilating organic nitrogen into their own tissues. When plants or animals die, or when waste products decompose, ammonification takes place. Bacteria and fungi decompose organic nitrogen compounds, releasing ammonia into the soil. Finally, de-nitrification occurs in oxygen-deprived environments, where denitrifying bacteria convert nitrate back into nitrogen gas, completing the cycle. This essential process helps to maintain the balance of nitrogen in ecosystems, supporting the growth of plants and sustaining life on Earth.

(1) Nitrogen fixation

The conversion of free or gaseous nitrogen into nitrate compounds or ammonia is called Nitrogen fixation. There are three principal ways in which nitrogen fixation can occur.

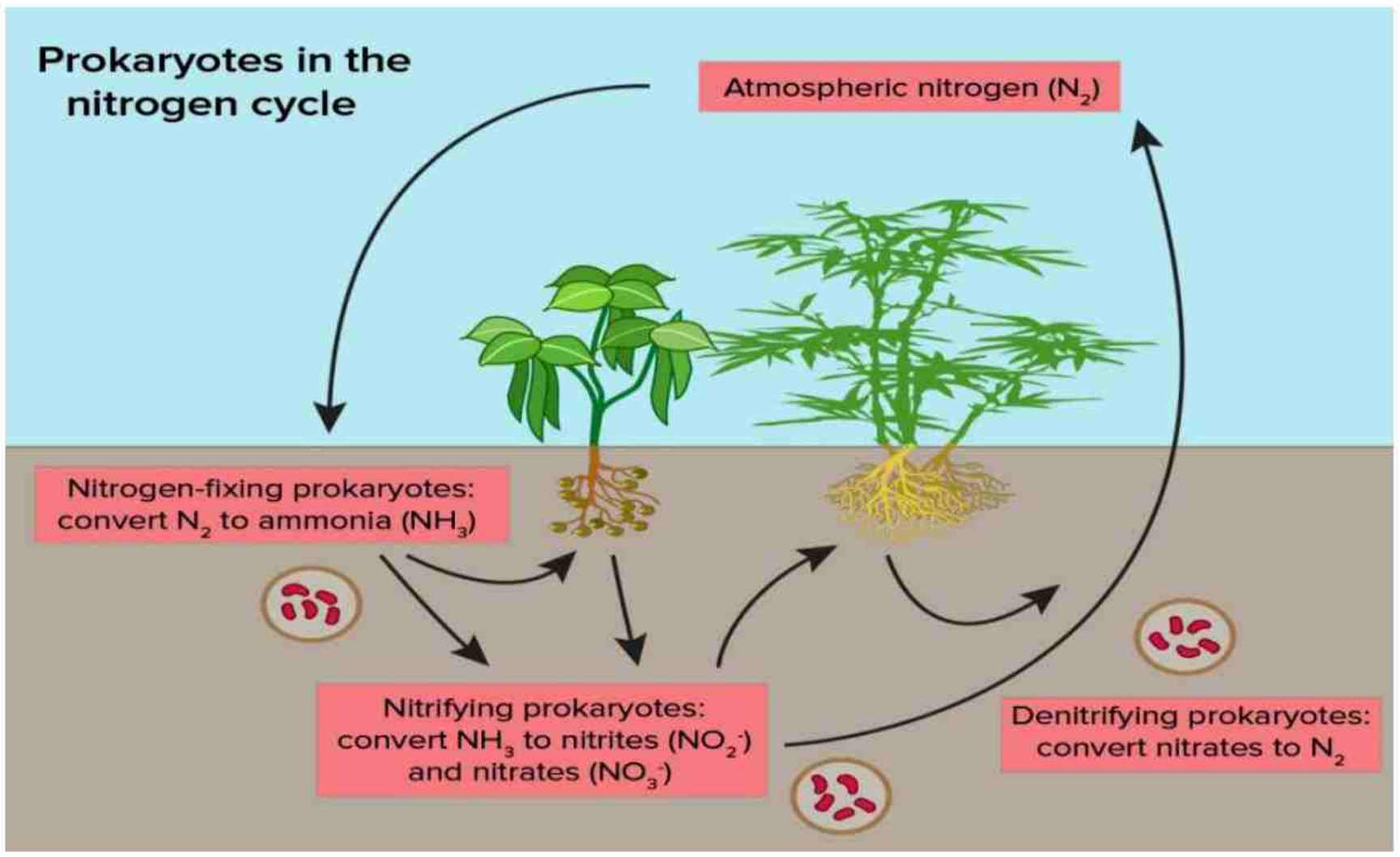


Fig: 25.3 Nitrogen Cycle

(i) Atmospheric fixation:

The fixation of nitrogen in the atmosphere is referred to as atmospheric fixation. Only a small portion (5-8%) is repaired in this manner. When lightning or thunderstorm occurs much quantity of atmospheric nitrogen is turned into nitrates or nitric acid. Nitrogen and oxygen can mix in lightning to form different nitrogen oxides. These are dissolved in rain and carried into Earth. These are deposited in the soil by the rain and then utilized by plants.

(ii) Industrial fixation:

The synthesis of nitrogen-containing fertilizers is called industrial fixation. Nowadays a large number of fixed nitrogen is artificially added to agricultural lands in the form of fertilizers.

(iii) Biological fixation:

Sixty percent of the nitrogen gas in the atmosphere is contributed by nitrogen-fixing bacteria. Nitrogen gas must be reduced to ammonia.

$$N_2 + 3H_2 \longrightarrow 2NH_3$$

This reaction can only be carried out by a small number of microorganisms called nitrogen-fixing bacteria. By killing and lysing free-living nitrogen-fixing bacteria like *Azobacter* (aerobic) and *Clostridium* (anaerobic), free-living blue-green algae in an aquatic system like *Cyanobacteria*, *Anabaena*, *Gleotrichia*, *Trichodesmium*, etc. are important nitrogen fixers. In some nitrogen-fixing bacteria's mutually beneficial relationship with plants like *Rhizobium*, the fixed nitrogen is made available to plants. The roots of many plants contain these bacteria which fixed nitrogen, increasing soil fertility, the best example is leguminous plants.

(2) Nitrification:

When ammonia (NH_3) is converted into nitrate (NO_2) compounds by nitrifying bacteria through a process called **Nitrification**. A small number of ammonia leaks into the soil, and nitrifying bacteria convert the majority of the ammonium ions into nitrates. The nitrification is completed in two steps. First ammonia is converted into nitrites (NO_2) and then it is converted into nitrates (NO_3). Two types of nitrifying bacteria carry it out. Ammonia is

converted to nitrites by the first group of bacteria, such as *Nitrosomonas*, and *Nitrococcus,* and the second phase is completed by bacteria like *Nitocystis*, *Nitrobacter* collectively known as **Nitrifying bacteria**, that's why the process is called as **nitrification**. Although bacteria are aerobic, nitrification only occurs in well-aerated soils.

(3) Denitrification:

The denitrifying bacteria are present in the soil. They reduce soil fertility by reversing the process of nitrification. Certain soil bacteria can cause nitrogen loss through their activities. In anaerobic condition these bacteria break down nitrates, releasing nitrogen back into the environment while consuming the oxygen for their own respiration. This process is termed de-nitrification, and the bacteria involved are known as denitrifying bacteria. For instance, *Pseudomonas* turns soil nitrates into gas.

$NO_3 \longrightarrow NO_2 \longrightarrow NO \longrightarrow N_2O \longrightarrow N_2$

(Nitrate) → (Nitrite) → (Nitric oxide) → (Nitrous Oxide) → (Nitrogen gas)

(4) Ammonification:

When animals and plants die, the saprophytic bacteria and fungi break down animal waste and the nitrogenous compounds in the soil to produce simple chemicals like water, carbon dioxide, amino acids, and sometimes energy. Ammonia or ammonium ions are created from amino acids. Ammonification is the process by which microbes break down organic materials to produce ammonia or ammonium molecules. Ammonification takes place in an aerobic environment in the soil. The ammonia is formed and released to the atmosphere or retained in the soil to be absorbed by plants or converted into nitrate compounds.

25.2 THE FLOW OF ENERGY

The ecosystem is the basic fundamental unit of ecology in which living and non-living things interact and influence each other. Without sunlight plants cannot prepare their food. While the on other hand animals are directly dependent on green plants for their food. Ecosystems act as energy converters. We can track the transformation of energy in the ecosystem by classifying the species in a community according to their trophic levels of feeding

relationships. Species are categorized into trophic levels based on their primary energy and nutrition sources. This trophic hierarchy is based on function rather than species.

25.2.1 Concept of Trophic Levels

Each ecosystem has different trophic levels, or groups of organisms referred to as **trophic** or **feeding levels**. **Producers** (plants, algae, and some bacteria) are the lowest trophic level (T1) use solar energy to create organic plant material through photosynthesis. The second trophic level is made up of herbivores, cows, goats, sheep, dears, grazing animals, or **primary consumers** (T2). They cannot synthesize their own organic material and utilize solar energy therefore, depends on prepared food from plants. The third trophic level (T3) is known as predators or **secondary consumers** that consume herbivores. Meat eater animals are an example of this type including humans. If larger predators, or **tertiary consumers**, are present, they represent even higher trophic levels.

Omnivores are defined as organisms that feed at multiple trophic levels and are categorized at the highest trophic level (T4) at which they do so. Humans, since are able to consume primary (grass eater) herbivores and meat (eater) carnivores' fall into this category. The fifth trophic level (T5) is occupied by **decomposers**, which include bacteria, fungi, and detritivores like worms and insects. Decomposers break down waste and dead organic material and refill the fertility of the soil, termed the fifth trophic level.

25.2.2 Flow of Energy in Successive Trophic Level

Ecosystems are energy converters; on average, 10% of the net energy produced at each trophic level is transferred to the next one. In complex natural communities, organisms whose food is obtained from plants by the same number of steps are said to belong to the same trophic level. Thus green plants occupy the first trophic level, plant eaters the second level (the primary consumer level), carnivores, which eat herbivores, the third level (the secondary consumer level), and secondary carnivores the fourth level (the tertiary consumer level). The energy flow through a trophic level equals the total assimilation (A) at that level, which in turn, equals the production (P) of biomass plus respiration (R).

Processes including respiration, growth, reproduction, defecation, and non-predatory mortality reduce the amount of energy that is transmitted across trophic levels (organisms that die but are not eaten by consumers). Because consumers may absorb high-quality food sources into new living tissue more quickly than low-quality food sources, the nutritional quality of the material that is consumed also affects how effectively energy is transferred. In terms of energy flow, decomposers are typically more significant than producers due to the slow rate of energy transfer between trophic levels. Large volumes of organic matter are decomposed by decomposers, which return nutrients to the ecosystem in inorganic form, where they are reabsorbed by primary producers. During decomposition, energy is not regenerated but rather emitted, primarily as heat. That's why things made of plastic are good for our environment since unable to decompose. Similarly, other modern things are made by humans.

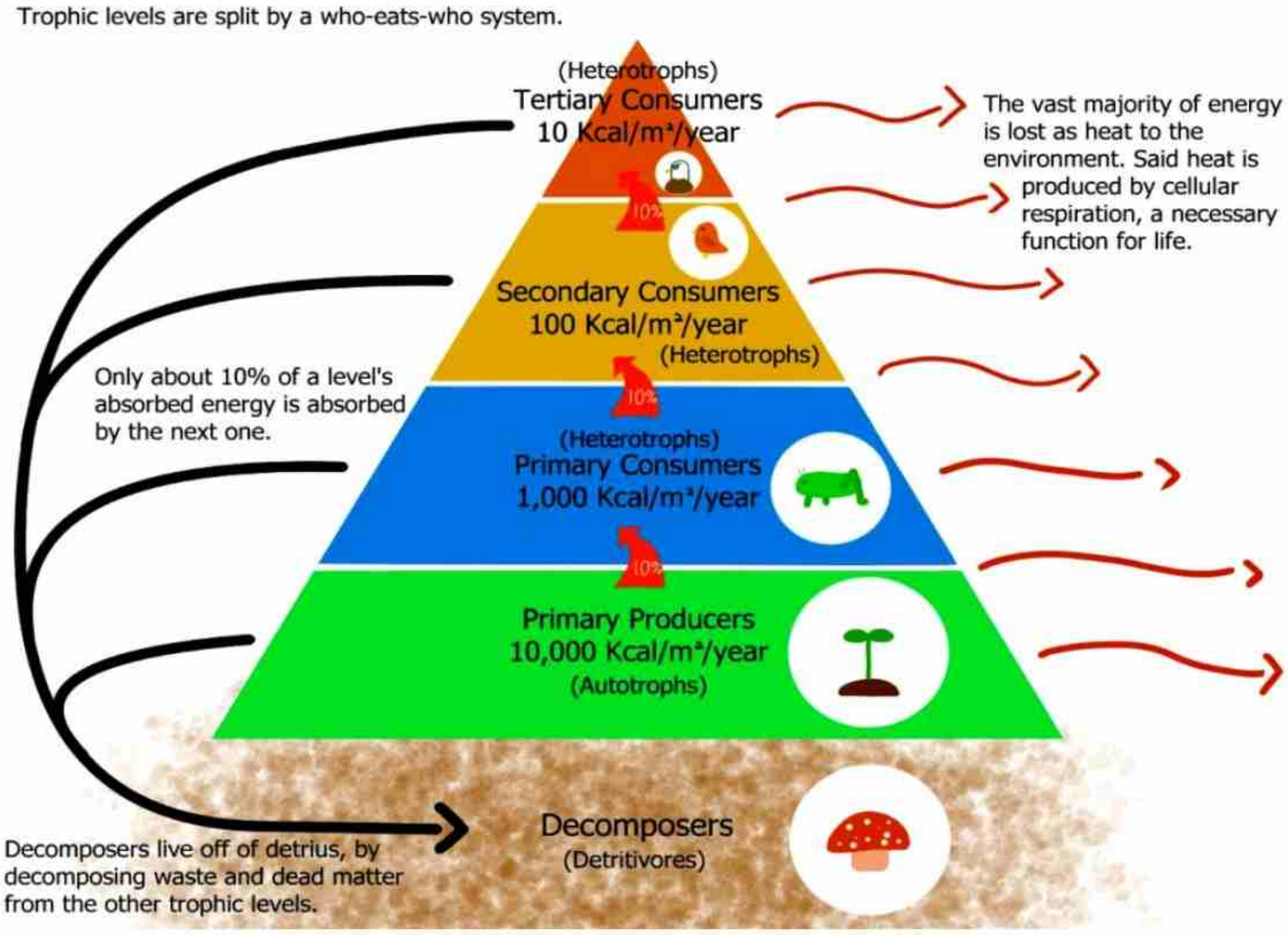


Fig: 25.4 Energy Flow in Ecosystem

25.2.3 Concept of Productivity

Productivity is crucial for an ecosystem's dynamics and stability in the context of energy flow. It deals with how quickly organisms acquire, store, and transfer energy through different trophic levels. It affects trophic relationships, population sizes, and the overall efficiency of biological systems. It also symbolizes how well available energy is converted into biomass or organic matter. Ecologists understand the energy flow, nutrient cycling, and connectivity of organisms in an ecosystem by investigating productivity. **Gross primary productivity** (GPP) and **net primary productivity** (NPP) are two important measures used to quantify the efficiency of energy conversion in ecosystems.

1. Gross Primary Productivity (GPP): It is the total quantity of energy that primary producers obtain through photosynthesis in a given area and time period. All of the energy that plants store, including the energy consumed for respiration, is included in GPP.

2. Net Primary Productivity (NPP): After primary producers have consumed some of the energy they have captured for their own respiration and metabolic requirements, the amount of energy left over is known as **net primary productivity**. The energy that is available for herbivores to consume or store in plant tissues (such as roots and stems)

23.2.4 Ecological pyramids

A visual representation of the relationships between various trophic levels in an ecosystem is provided by **ecological pyramids**. Ecological pyramids are graphs that have developed a complex design as a result of the arrangement of these data. At different trophic levels, ecologists compare the number of species, biomass, or relative energy available. Within each trophic level, they show the quantitative features of energy flow, biomass, and population sizes.

A description of the three different ecological pyramids is provided below:

Pyramid of energy: An energy pyramid shows how much energy is contained in the biomass of each trophic level. These pyramids show that more energy is lost to the environment moving from one trophic level to the next as trophic levels rise. Because some of the energy at

the lower trophic level is utilized by those species to carry out work and some of it is lost, less energy reaches each succeeding trophic level from the level beneath it. Energy pyramids provide an explanation for the lack of trophic levels. Because energy content rapidly decreases at each subsequent trophic level, food webs are short.

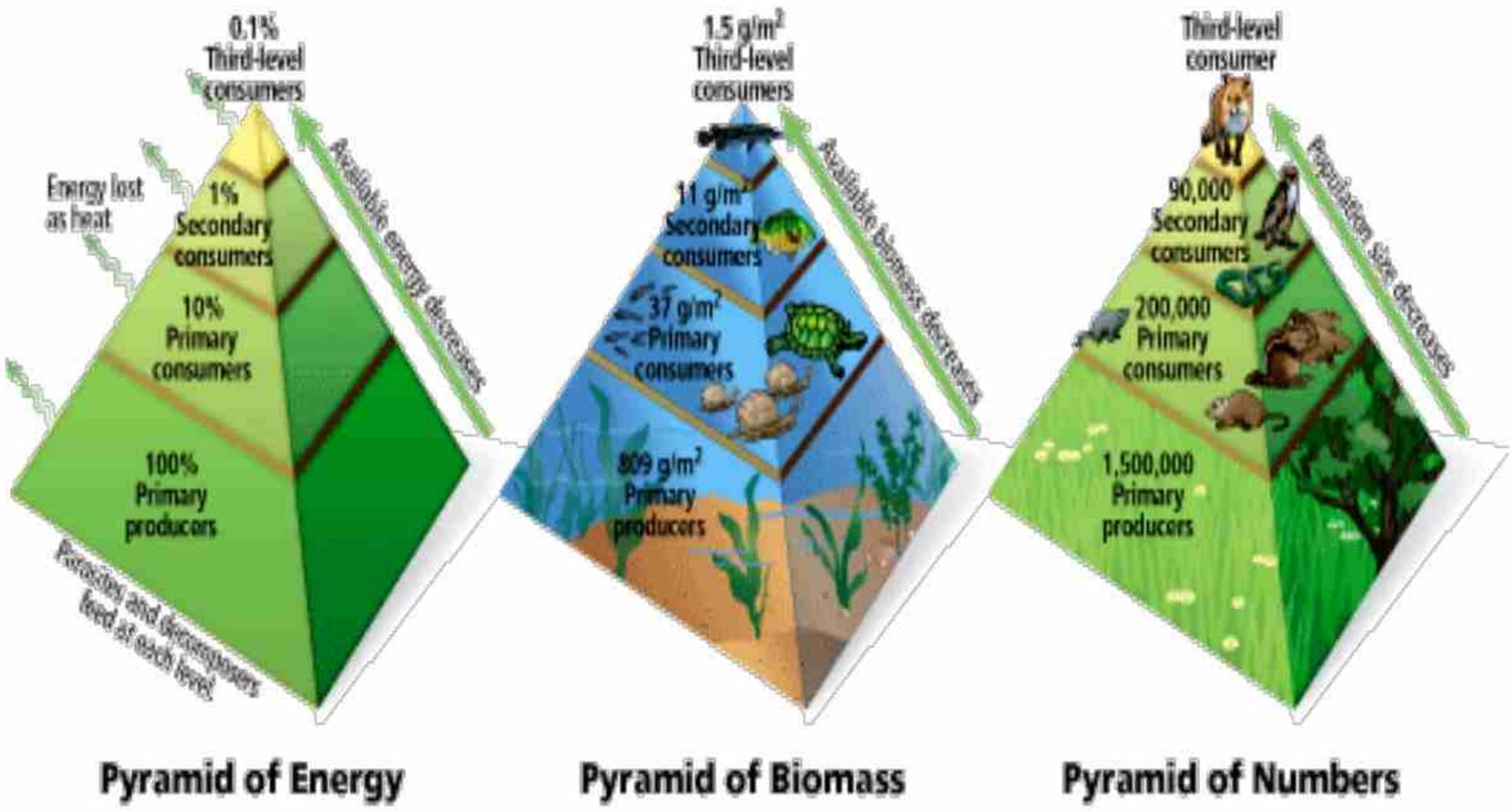


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Fig: 25.5 Ecological Pyramids

Pyramids of biomass:

The amount of biomass at each level is represented as a pyramid. Indicating the amount of fixed energy at a specific time, biomass is a quantitative estimate of the total mass or amount of living stuff. Biomass can be measured in a variety of ways, including total volume, dry weight, and live weight. Typically, the pyramids show how biomass declines across subsequent trophic levels.

Pyramids of numbers:

The number of species at each trophic level in a given ecosystem is represented by a pyramid of numbers, with larger numbers being represented by a broader pyramid. In the majority of pyramids of numbers, fewer individuals occupy each subsequent trophic level. Because of this, there are more herbivores than carnivores.

25.3.1 Ecological Succession

Ecological succession refers to the process through which an ecosystem changes and develops from a simple to a complex state over time. It occurs in response to changes in environmental conditions, such as light availability, soil composition, and moisture level. When a new environment is created, after a disturbance on a newly formed land, a community of plants and animals begins to establish itself. The term succession was first used by **Hult** in (1885), and **Clements** 1907, 1916) elaborated the principle and theory of succession. "*The process of evolution of plant communities on a bare area from birth to maturity is called* ***succession***".

The process of ecological succession involves a series of stages, known as **seral stages**, where different plant and animal species gradually replace each other. As the ecosystem matures species composition and processes change, leading to a more complex and stable community. This succession can take place over short or long periods of time, depending on the specific conditions and the rate at which species establish and adapt to the environment. The process by which species are gradually replaced over time is called **ecological succession**.

25.3.2 Kinds of Succession

Ecological successions can be divided into the following categories:

i) Primary succession ii) Secondary succession

(1) Primary succession

Primary succession occurs in areas that are barren of life and lack soil, such as newly formed land or bare rock surfaces. It begins in environments where there is no previous soil or vegetation existed. Primary succession typically follows major disturbances such as volcanic eruptions, retreating glaciers, or the formation of new islands. The process of primary succession starts with the colonization of **pioneer species**, such as lichens and mosses, which are capable of surviving in harsh conditions and can break down rocks to form soil. Primary succession is a slow and gradual process that can take hundreds or even thousands of years to reach a stable

and diverse ecosystem. It involves the creation of an entirely new community from scratch in an area that was previously devoid of life.

(2) Secondary succession

Secondary succession occurs in areas that were previously occupied by living organisms but vanished when the original ecosystem was disturbed or disrupted while the soil remained undamaged. It happens as a result of natural disasters like forest fires or storms, or due to human activities like logging or farming. Secondary succession is often faster than primary succession since the soil and some elements of the previous community are already present, supporting in the ecosystem's recovery and rebuilding.

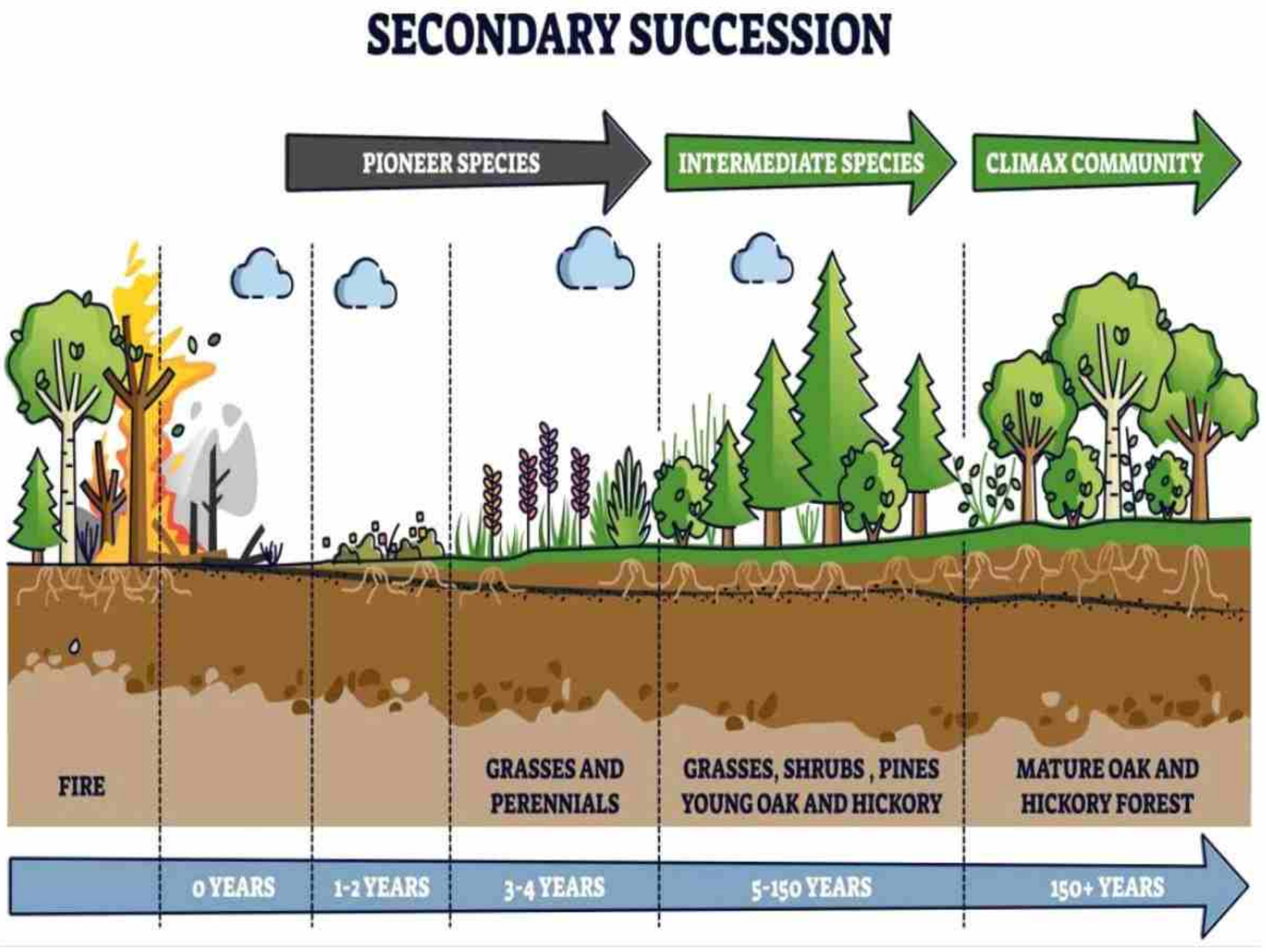


Fig: 25.6 Secondary Succession

25.3.3 Differentiate between Xerarch and Hydrarch Succession

	Xerarch Succession	Hydrarch Succession
1	It begins with lichens or blue green algae	It begins with phytoplankton
2	Initial succession is a slow process	Initial succession is quite fast
3	Succession is seen all over the area	Succession is observed in area where water is not very deep
4	The whole of the area is involved in formation of climax community	Climax community develops on the edge only
5	It reduces bare land area and converts it into fertile forested area	It fill up water body and changes it into forested land

25.3.4 Xerarch Succession

Ecological succession occurs in arid environments like deserts, mountains, or dunes known as **xerarch succession.** It describes how vegetation grows and how ecosystems adapt in response to limited water resources and harsh conditions in the environment. When there is a lack of water and organic matter for plant growth and where little or no vegetation existed, xerarch succession starts to occur. Species that have evolved specifically to survive in arid environments are frequently the pioneer species. These pioneer species tolerate high temperatures and limited water supplies and are often drought-tolerant. Lichens, mosses, and several desert plant species are examples of xerarch pioneer species.

(i) Crustose-lichen stage

When the surface is exposed to the sun, the temperature rises significantly. At this stage, the substratum's lack of water and nutrients makes the rocky habitat severely xeric. Crustose lichens, which appear on the rock surface as membranous crusts, are the first organisms to occupy the bare area. The crustose lichens *Rhizocarpus, Lacidea*, etc. are significant. They have a porous structure, which allows them to absorb more water and minerals.

Lichens produce an excessive amount of carbonic acid. That acid is produced when excess CO_2 reacts with water.

(ii) Foliose-lichens stage

This kind of lichen grows on rocks that are close to or surrounding areas where crustose lichens have already colonized. After a little amount of soil and humus has accumulated, xeric foliose and fruticose lichens, such as *Dermatocarpon, Parmelia, Umbilicaria*, and others are prominent protagonists in this stage grow on the rock surface that was previously covered by crustose lichens. These lichens cover the rocks with their delicate, leaf-like structure, covering the crustose lichens that already exist.

Additionally, they release carbonic acid, which further breaks down or loosens the rocks into tiny pieces. With the continued buildup of humus and soil particles, the habitat's ability to hold water improves.

(iii) Moss stage

Like other lichens, xerophytic mosses that is *Polytrichum, Tortula, and Grimmia* are transported to rocks and adapted to survive in extreme drought conditions and become dominant. It replaces the entire habitat and the existing foliose lichens disappear. Mostly they grow in crevices and rocks depressions where they can get more humus and moisture. These mosses significantly get more water and other mineral nutrients by competing with other lichens. They develop rhizoids to penetrate deeply into the soil of rocks. A mat could develop on the rock surface as a result of its demise and decomposition. Together with the soil, this can store more water, creating an environment that is good for growing herbs.

(iv) Herb stage

The rock is covered by herbaceous weeds, Herbaceous vegetation, which is primarily made up of annual and perennial herbs, grows rapidly as soil thickness increases. Herbs grow better in that soil which has more moisture. The roots of these plants can almost reach the level of continuous rocks below the surface, release acids, and speed up degradation. Herbs that die and foliage enrich the soil with humus. A decrease in evaporation and a small rise in

temperature are the effects of soil shading. As a result, the xeric environment starts to shift, allowing for the emergence of biennial and perennial herbs as well as xeric grasses.

(v) Shrub stage

The soil is covered in xeric vegetation. These shrubs, which are low, woody plants that are smaller than trees and have little to no trunks, can grow from seeds or spread by rhizomes from nearby places. These overpower them and make the situation inappropriate for herbs. Due to their inability to compete, shrubs have taken the place of herbs. Early shrub invasion is gradual, but once a few shrubs have grown stronger, birds move in and help with seed dispersal. As a result, there is dense growth, shading the soil and creating unfavorable conditions for herb growth, which causes the herbs to migrate.

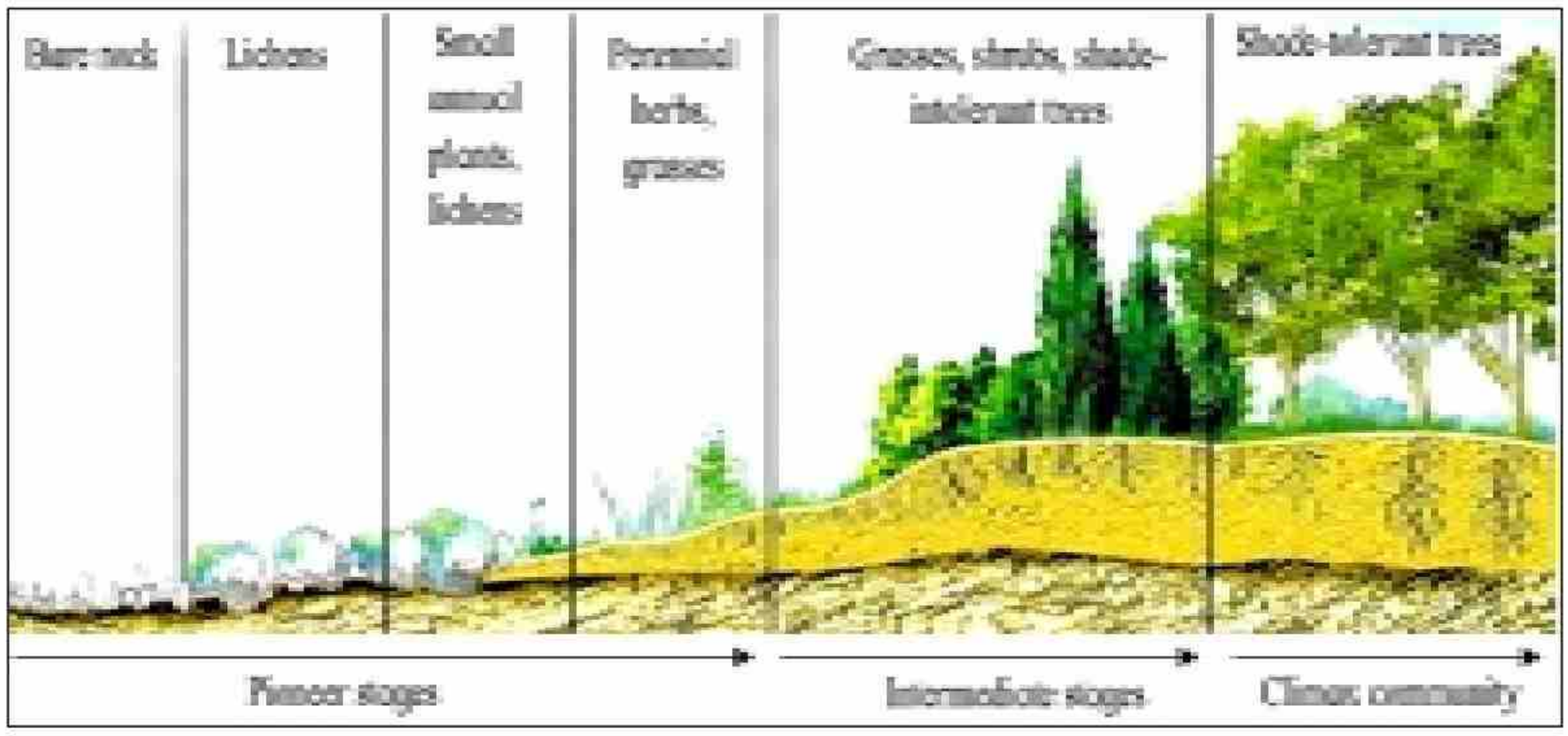


Fig: 25.7 Xerarch Succession on bare rock (Primary Succession)

(vi) Climax stage

Some shade-loving herbs and shrubs that are acclimated to humid environments also appear in the shade and create their own communities. After an extremely long period of time, the climax stage appears when perfect harmony between the plant communities and their habitat emerges. The earliest tree species are largely xeric. The xeric plants are replaced by mesophytic kinds of trees as the

weathering process started and the soil becomes deeper. Eventually, a forest might grow.

25.3.4 Hydrarch Succession in Lakes

The process of ecological succession known as hydrarch succession takes place in aquatic habitats like ponds, pools, or lakes before transforming into terrestrial communities. Below, different hydrarch succession stages are briefly described.

(i) Phytoplankton stage

Phytoplanktons are microscopic, photosynthetic organisms, primarily consisting of algae and cyanobacteria, which drift in water bodies, such as oceans, lakes, and rivers. The phytoplankton stage is essential in aquatic ecosystems as these organisms form a base for the **food chain**. They serve as primary producers, converting sunlight and nutrients into organic matter, which then becomes a source of food for other organisms, including zooplankton, small fish, and ultimately larger predators.

(ii) Submerged stage

During the submerged stage, aquatic plants like algae, submerged rooted plants, and floating leaf plants are the main inhabitants of the water body. These plants are essential to the ecosystem's early development and stabilization. The first organisms to colonize are frequently algae, and then buried rooted plants, which anchor to the substrate and help the water, become more oxygenated. As the succession develops, floating-leaved plants appear, adding to the habitat and nutrient cycling.

(iii) Floating stage

During the floating stage plants, such as water lilies, water hyacinths, or duckweeds, are prevalent. These plants have adaptations that allow them to float on the surface of the water, often with their roots submerged. Floating plants are typically able to increase in nutrient-rich environments, as they can extract nutrients directly from the water. They also contribute to the overall productivity of the ecosystem by photosynthesizing and converting sunlight and carbon dioxide into organic matter.

(iv) Reed swamp stage

This stage is also known as the amphibious stage. Even though most species are anchored in the ground now, the majority of their body parts are still above the water table. Ponds get shallower as a result of plant loss and degradation. The plants grow thick vegetation and have well-developed rhizomes. *Typha*, *Polygonum*, *Phragmites*, and *Sagittaria* are characteristic plants of this stage, and there are also animals like *Lymnea* and *Physae* as well as insects like water scorpions and huge bugs.

(v) Sedge meadow stage

A transitional stage in the ecological growth of a freshwater ecosystem is known as the sedge meadow stage of a lake. It happens after the lake has been initially colonized by floatable and submerged vegetation. Emergent vegetation, especially sedges (grassy plants), predominates in the region around the lake during the sedge meadow stage. These plants have evolved to survive in moist, marshy environments and contribute to soil stabilization. The growth of more complex plant communities and the eventual conversion of the lake into a terrestrial ecosystem are made possible by the sedge meadow stage, which is essential to future succession. It also makes it simple for organic matter to collect and contributes to the formation of soil.

(vi) Woodland stage

The woodland stage is a stage in which trees and a dense forest canopy dominate the vegetation. Tree species, including deciduous and evergreen trees, become established in the woodland stage and form a closed canopy, shading the forest floor and creating a more shady and diversified habitat.

(vii) Climax stage

The climax stage is the final stage of ecological succession in which trees eventually dominate the woodland community. The type of climax community that forms is determined by environmental conditions. Tropical rainforests occur in areas with abundant rainfall, displaying a diverse range of tree species. In areas with more moderate rainfall, such as temperate zones, a mixed forest develops, with a variety of deciduous and evergreen trees.

25.4 POPULATION DYNAMICS

A population is a group of individuals belonging to the same species who live in the same place for an extended length of time. **Population dynamics** is the study of how a species' populations evolve through time and is one of the key areas of research into population dynamics. Management of natural resources, such as fisheries, also depends on population dynamics to determine appropriate management actions. Population dynamics play a essential role in many approaches to preserving biodiversity, but little is known about it. Population dynamics is the study of both long-term and short-term variations in population numbers as well as the factors that control population size, such as:

Inflow: births, immigration

Overflow: Habitat destruction, decreased recruitment, increased mortality, and inadequate conditions.

Outflow: Culling (to pick and destroy individuals, e.g. seals, deer) emigration, natural disasters, accidents, and predators.

25.4.1 Characteristics of a Population

Characteristics of a population can vary depending on the species and the specific environment it occupies. A population's constituents depend on the same resources, are impacted by comparable environmental conditions, and are very likely to interact and reproduce with one another. However, here are some general characteristics often used to describe populations: There are population attributes including growth, distribution, carrying capacity, and viable size.

(i) Growth: Population growth refers to the increase in the number of individuals within a population over time. It can be influenced by factors such as birth rates, death rates, immigration (individuals moving into the population), and emigration (individuals leaving the population).

(ii) Density : Population density is the number of individuals per unit area or volume. It provides an indication of how crowded or dispersed a population is within its habitat. High population density can lead to increased competition for resources and a higher risk of disease transmission.

(iii) Distribution: The distribution of a population refers to how individuals are spread out within a region or habitat. Populations can exhibit different distribution patterns, such as clumped (individuals grouped together in patches), uniform (evenly spaced individuals), or random distribution (unpredictable spacing among individuals).

(iv) Carrying capacity: There is a limited number of individuals that can live in a territory. The carrying capacity is the maximum number of individuals that a particular habitat or ecosystem can sustainably support. It represents the balance between available resources (food, water, shelter) and the population's needs.

(v) Minimum or viable size: The minimum or viable size of a population refers to the smallest number of individuals required to maintain long-term survival and genetic diversity. Small populations are more vulnerable to negative effects such as inbreeding, genetic drift, and reduced adaptability. Establishing a viable population size is essential for the long-term survival of a species.

25.4. 2. Problems related to Rapid Growth of Human Population

The rapid growth of the human population presents several problems that can be explained using demographic principles. These problems have significant implications for future generations and the Earth's carrying capacity. To address these problems and mitigate their effects, sustainable population management, resource conservation, and sustainable development practices are necessary. This includes promoting education and access to family planning, adopting sustainable consumption and production patterns, investing in renewable energy sources, preserving ecosystems and biodiversity, and fostering equitable social and economic development. By considering the carrying capacity of the Earth and adopting sustainable practices, we can work towards ensuring a better future for future generations.

1. **Over-population:** Rapid population growth can lead to over-population, where the number of individuals exceeds the carrying capacity of the Earth.
2. **Strain on Resources:** The growing population requires more resources to meet basic needs, such as food, water, and energy.

Increased consumption of resources can lead to environmental degradation, deforestation, overfishing, water scarcity, and depletion of non-renewable resources.

3. **Environmental Impact:** A rapidly growing population generates a greater ecological footprint, which is the measure of the impact of human activities on the environment. Higher population densities contribute to increased pollution, greenhouse gas emissions, habitat destruction, and loss of biodiversity. These environmental impacts have far-reaching consequences, including climate change, loss of ecosystem services, and degradation of natural habitats.
4. **Pressure on Infrastructure:** Rapid population growth puts pressure on infrastructure systems, such as transportation, housing, healthcare, and education. Meeting the needs of a growing population requires substantial investments in infrastructure development and maintenance.
5. **Intergenerational Equity:** The rapid growth of the human population can compromise intergenerational equity, which refers to ensuring that future generations have the same opportunities and resources as the present generation. Unsustainable population growth and overconsumption of resources can deplete and degrade resources, leaving fewer available for future generations. This can lead to inequitable distribution of resources and compromised well-being for future populations.

25.4.3 Role of Population Welfare department controlling the Population of Pakistan

The Population Welfare Department of Pakistan plays a vital role in controlling population growth through awareness campaigns, family planning services, training, research, policy formulation, and partnerships. It aims to provide education, access to contraceptives, and reproductive health services to empower individuals and couples to make informed choices about family planning.

The Population Welfare Department of Pakistan aims to control population growth by promoting family planning, providing access to services, raising awareness, and ensuring effective policy implementation. These efforts contribute to empowering individuals

and couples to make informed decisions about their reproductive health and contribute to sustainable population management.

25.5 HUMAN IMPACTS ON ENVIRONMENT

25. 5.1 Nuclear Power

A nuclear power plant is similar to a large coal-fired power plant, with pumps, valves, steam generators, turbines, electric generators, condensers, and associated equipment. Except for the reactor, which plays the role of a boiler in a fossil-fuel power plant?

Fig: 25.8 A boiling water reactor

The use of sustained nuclear fission to generate heat and electricity is known as **nuclear power**. According to 2005 statistics, nuclear power provided 6.3% of global energy and 15% of global electricity. The scarcity of fossil fuels, which is not available in every country, is the reason behind the development of nuclear power

plants. The nuclear power industry went through a period of remarkable growth until about 1990. That percentage remained stable through the 1990s and began to decline around the turn of the century. This trend appears likely to continue well into the 21st century. The Energy Information Administration projects world electricity generation between 2005 and 2035 will roughly double.

Pakistan also has these type of plants, namely the Karachi Nuclear Power Plant (KNPP) located in Karachi and the Chashma Nuclear Power Plant (CHASNUPP), is located in the vicinities of Chashma colony and Kundian in Punjab which are very essential for the country's development, prosperity, and security purpose. The plant is run and controlled by highly professional and trained staff working there with zero incidents in other countries of the world.

Advantages of nuclear power

a) Nuclear power costs about the same as coal, so it is not prohibitively expensive to produce.
b) Because it emits no smoke or carbon dioxide, it has no impact on the greenhouse effect.
c) Generates enormous amounts of energy from small amounts of fuel.
d) Generates a small amount of waste.
e) Nuclear energy is trustworthy.

Disadvantages of using nuclear power

By using nuclear power there are two main issues with nuclear power the assurance of safe operation and the safe disposal of wastes.

(i) **Surety of safe operation:** In nuclear plants, prevention, monitoring, and action, i.e., mitigating the consequences of failures, are used to achieve maximum safety. These are (a) superior design and construction; and (b) superior performance. (c) Continuous monitoring and testing to detect equipment or operator failure; and (d) avoidance of significant radioactive releases. Up to now, there is no negative impact on our plant with respect to failure, and safety is reported.

(ii) Safe disposal of the wastes: Radioactive waste is defined as waste containing radioactive material. Nuclear waste is a source of concern because it is not biodegradable, which means it does not decompose naturally in the presence of oxygen in the atmosphere. Second, it poses a number of health risks to anyone who comes into contact with the radiation emitted by this waste. As a result, some safety measures for nuclear waste disposal should be used, such as deep ocean disposal, deep geological burial, nuclear waste recycling, reprocessing, and solidification.

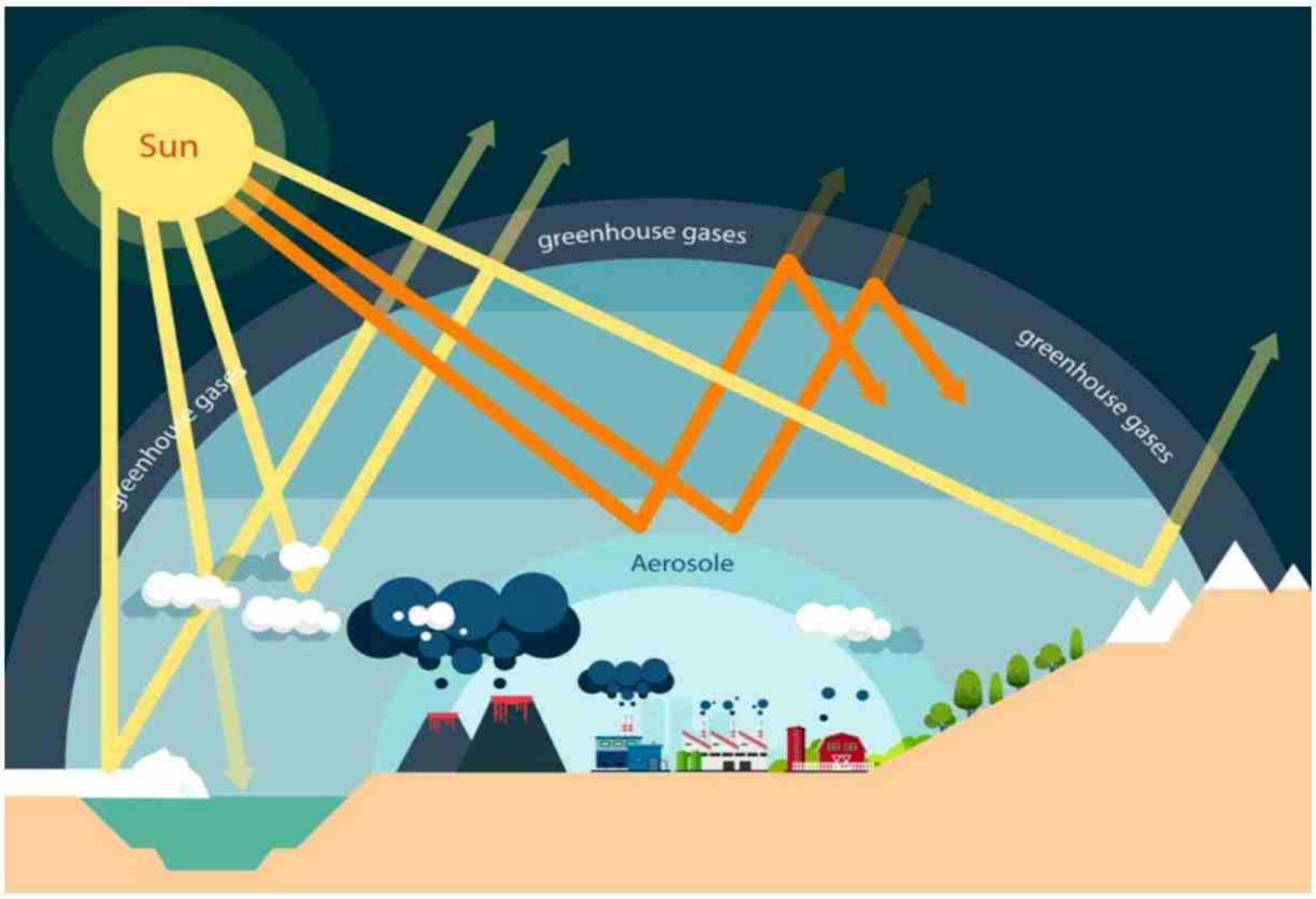


Fig: 25.9 Greenhouse effect (Global Warming)

25.5.2 Causes increasing concentration of CO_2 in the World's atmosphere

Human activities are mainly responsible for rising CO_2 levels in the atmosphere. The major sources of CO_2 emissions by humans are the combustion of fossil fuels such as coal, oil, and natural gas for industry, transportation, heating our homes, and generating

electricity. The burning of wild lands and forests increases CO_2 levels in the atmosphere. Deforestation also increases CO_2 levels.

Since the industrial revolution, the percentage of CO_2 in the atmosphere has increased significantly. Though not the primary cause, humans and other animals contribute to CO_2 levels in the atmosphere by exhaling CO_2. Furthermore, the intermittent eruption of volcanoes contributes to the increase of CO_2 in the global atmosphere.

25.5.3 Carbon Dioxide Concentration and Global Warming

The amount of CO_2 in the air is quickly increasing day by day. In comparison to 0.03% in the middle of the twentieth century, it makes up around 0.04% of the air nowadays. Why is this relevant? The increased atmospheric CO_2 levels, also known as the "greenhouse effect," are most likely what are raising the planet's average temperatures. CO_2 is one of the numerous gases of greenhouse gases.

The natural greenhouse effect that keeps the Earth's atmosphere above freezing would be insufficient without carbon dioxide. People are accelerating the natural greenhouse effect and raising the earth's temperature by releasing more carbon dioxide into the atmosphere. CO_2 levels in the atmosphere are rising as a result of various human activities, such as the use of fossil fuels in automobiles and industrial processes. CO_2 absorbs high-energy radiation, causing the atmospheric temperature to rise. This temperature increase is referred to as global warming.

Long Term effects of global warming

The Earth becomes warmer and more trapped in infrared light as carbon dioxide levels increase in the atmosphere. With only a 1.3^0C increase, the earth would become warmer than it has ever been in the past 100,000 years. According to the worst-case scenario, the warming would likely be significant towards the poles. The arctic ice that melts, as a result, might progressively flood places 150 km (or more) inland by raising the sea level by an estimated 100 m. Major agricultural areas would become drier as a result of a warming trend altering the spatial distribution of precipitation.

25.5.4 Acid Rain

Any precipitation that contains acidic elements, such as sulfuric acid or nitric acid, is referred to as **acid rain** or acid deposition. Scottish chemist Robert Angus Smith first used the term "acid rain" in 1852. Wet deposition refers to the type of acid rain that incorporates water. "Dry deposition" is the name for acid rain created from dust or gases. When atmospheric pollutants like oxides of nitrogen and sulphur react with rainwater and come down with the rain, then this result in Acid Rain. Sulphur dioxide and nitrogen oxides have contaminated the water in the atmosphere. When the gases and water vapor interact, the gases' contents turn into clouds. Even hundreds of kilometers from the pollution source, the water vapor condenses and falls to Earth as acid rain. When the acid precipitation reaches the surface of the ground, it also falls as snow or as dry micro-particles and mixes with water. Acid rain can impact the environment by destroying flora, aquatic habitats, buildings, and infrastructure.

Causes of Acid rain:

The causes of acid rain are sulphur and nitrogen particles which get mixed with the wet components of rain. These particles can be found in two ways: either man-made, i.e., as the emissions that are given out from industries, or by natural causes, like lightning strikes in the atmosphere releasing nitrogen oxides and volcanic eruptions releasing sulphur oxides. Although sulphur and nitrogen oxides are naturally produced during volcanic eruptions, forest fires, and eruptions. Humans are also responsible for producing more than half of these chemicals through the burning of coal in power plants, commercial boilers, and sizable smelters that extract metals from ores. Automobiles also release nitrogen oxides into the atmosphere. Anthropogenic sources refer to the causes of acid rain that result from human activity.

Effects of acid rain:

Animals, vegetation, and agriculture are all negatively impacted by acid rain. Each and every nutrient needed for plant life and growth is washed away. Aquatic ecosystems are impacted when acid rain builds up on the ground and enters ponds, rivers, and lakes. It

not only pollutes the water, but it also changes the chemistry in a way that makes it difficult for aquatic ecosystems to exist. Acid rain contributes to the leaching of heavy metals like iron, lead, and copper into drinking water, as well as corroding pipes. Taj Mahal, one of the Seven Wonders of the World, is largely affected by acid rain because the city of Agra has many industries that emit sulphur and nitrogen oxides into the atmosphere.

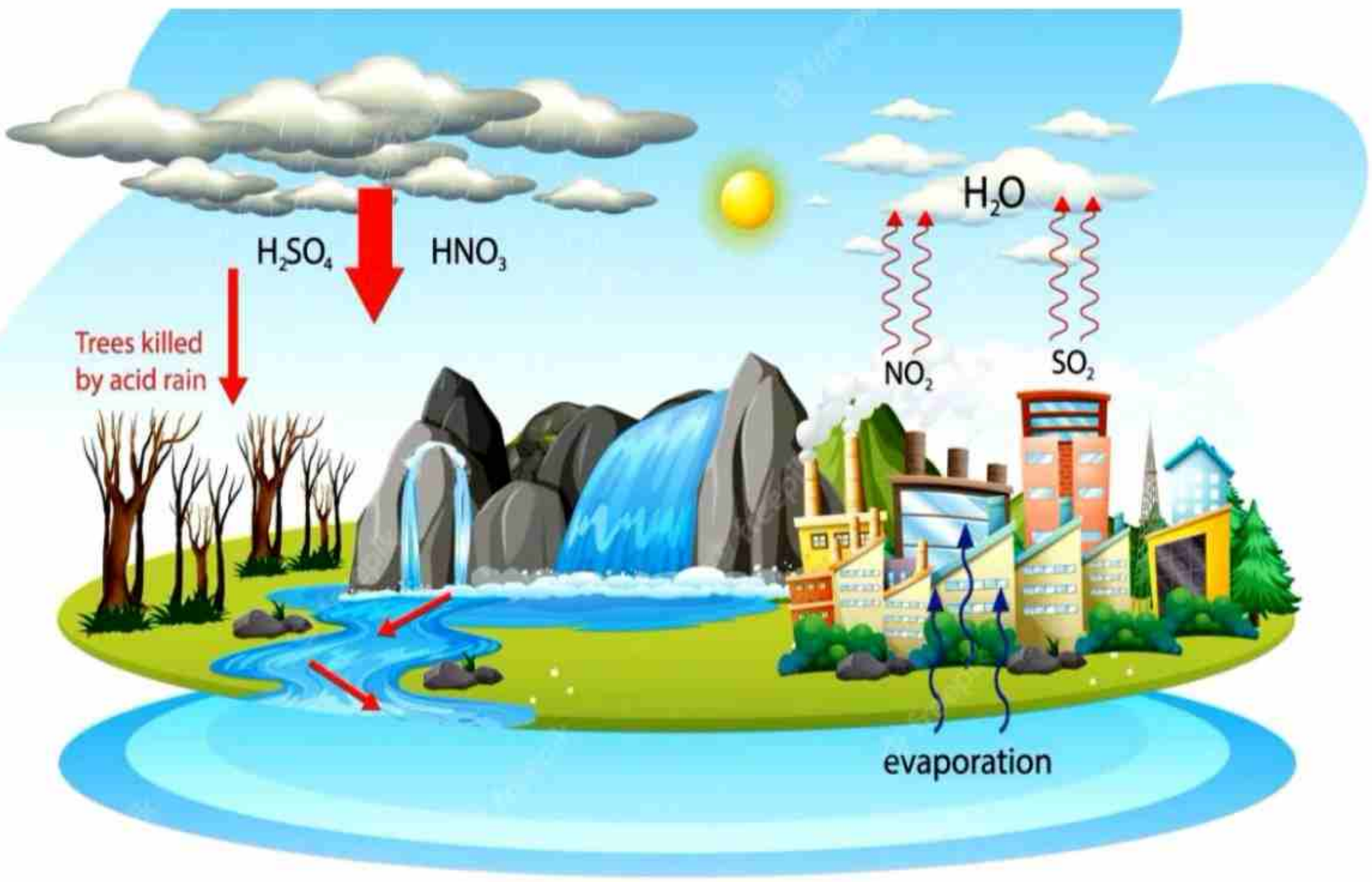


Fig. 25.10 Acid rain

Acid rain has a number of negative impacts, including the following: (a) it makes the soil more acidic; (b) it harms agriculture and forestry; and (c) it kills aquatic species and prevents their successful reproduction. (d) It also improves the properties of some metals, such as aluminum, which may be harmful to many ecological organisms. (e) Acid rain, also referred to as "stone cancer," significantly damages stone structures and monuments. India is deteriorating because of the emissions from oil refineries. (f) Acid rain has a negative impact on the nervous, respiratory, and digestive systems. Both humans and animals' are affected

25.5.5 Ozone Depletion

Ozone layer depletion is the continuous loss of ozone from the upper atmosphere as a result of human activities. This occurs when ozone molecules come into touch with chlorine and bromine atoms in the atmosphere and are broken down. The high atmosphere's ozone layer gets thinned due to ozone layer depletion. Ozone molecules can be destroyed by one chlorine molecule. It doesn't get made as quickly as it gets destroyed. Some substances emit chlorine and bromine, which then helps to deplete the ozone layer Hydrochlorofluorocarbons, methyl bromide, and halons are all ozone-depleting compounds. The most prominent chemical that depletes the ozone layer is chlorofluorocarbons, which can lead to dangerous levels of ultraviolet light pollution.

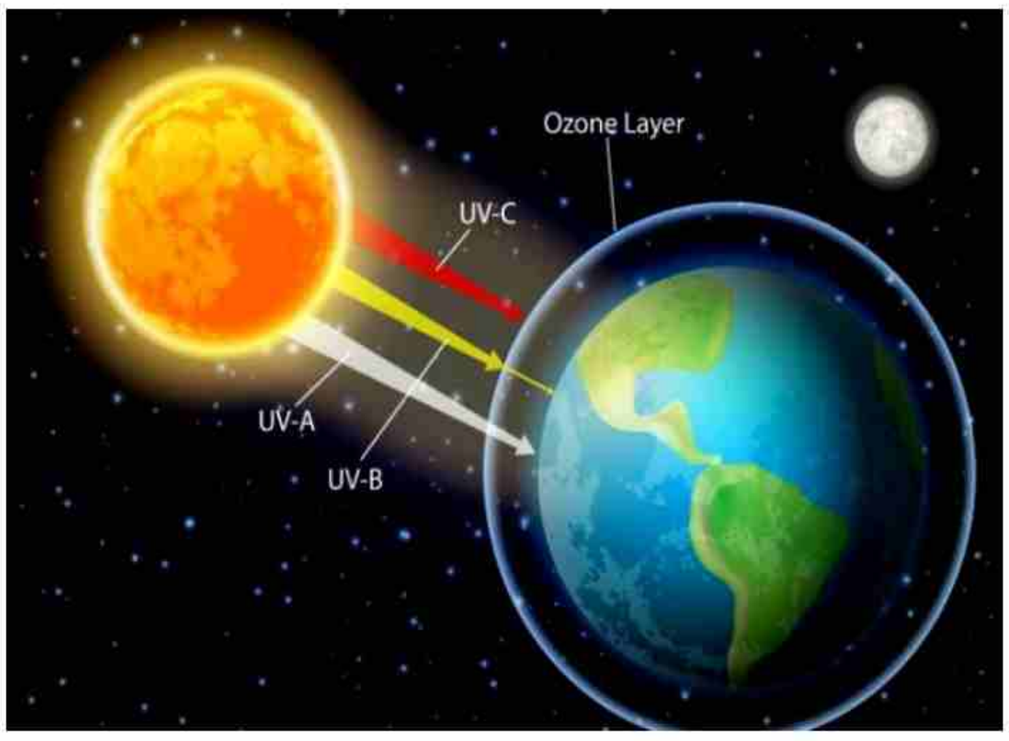


Fig: 25.11 Ozone layer depletion

Composition of the Ozone layer:

It is an atmospheric layer that is located between 10 and 50 kilometers above Earth's purest form. The blue-colored, explosive, and extremely deadly gas is ozone. Three oxygen atoms make up the molecule known as ozone or O_3. Oxides of nitrogen (NOX) and volatile organic compounds (VOC), commonly referred to as hydrocarbons, perform chemical interactions that result in ozone.

Formation of the ozone layer:

When ultraviolet energy from the Sun splits an oxygen molecule into two oxygen atoms, the resulting atomic oxygen subsequently joins with another oxygen molecule to generate ozone in the atmosphere (O_3). Oxides of nitrogen (NOX) and volatile organic compounds (VOC), commonly referred to as hydrocarbons, undergo chemical interactions that result in ozone. Both near the earth and high in the atmosphere, this reaction is possible.

Causes of ozone layer depletion:

The ozone in the stratosphere blocks off the majority of UV rays. Chlorofluorocarbons (CFCs) are a class of commercially significant chemicals that are found in the stratosphere. These have been employed as cleansers in the electronic sector; coolants (like Freon) in air conditioners and refrigerators; foam (like Styrofoam) for packing and insulation; and propellants in aerosol cans. CFCs and related chemicals are broken down into chlorine, fluorine, and carbon by ultraviolet radiation. Chlorine and fluorine can interact with ozone under certain stratospheric circumstances to produce molecular oxygen.

25.5.6 Role of the Ozone layer in protecting life on Earth

It was discovered in 1985 that the amount of stratospheric ozone had decreased over Antarctica in the springtime by more than 40% since 1977. The protective shield surrounding the Earth had a breach in it. The ozone layer is found in lower levels of the stratosphere. All ultraviolet radiation is absorbed by it, preventing it from reaching the earth's surface and protecting all organisms from the negative effects of UV radiation. The ozone layer maintains the oxygen and ozone in their regular cycles by absorbing radiation.

25.5.7 Effects of Ultraviolet Radiation on human health

UV rays can now reach the Earth's surface as the ozone layer thins. A few health problems linked to excessive UV radiation exposure in humans include sunburn, early aging of the skin, skin cancer, and cataracts. Variations in the earth's temperature and stratospheric ozone often have an impact on UV radiation. More UVB (the higher-frequency, more dangerous type of UV) is now reaching the Earth's surface as ozone levels are declining. On the other side, the penetration of UV radiation is reduced by a rise in cloud cover, pollution, dust, wildfire smoke, and other airborne and aquatic particles connected to climate change. Additionally, ultraviolet radiation affects and reduces the ability of phytoplankton to perform photosynthesis.

25.5.8 Chernobyl nuclear power incidence

The Chernobyl disaster was the result of a nuclear accident. It happened on April 26, 1986, at Ukraine's Chernobyl Nuclear Power Plant. A fire and explosion released large amounts of radioactive contamination into the atmosphere, which spread across much of the Western USSR and Europe. Aside from the 57 direct deaths in the accident, approximately 500.000 workers were affected. In 2005, the United Nations Scientific Committee on the effects of atomic radiation predicted that up to 4,000 additional cancer deaths from the accident would occur among the 600,000 people who received more significant exposures.

25.6 ENVIRONMENTAL RESOURCES AND THEIR DEPLETION

Resources are useful items that can be used by humans to meet their needs and desires in any climate. Natural or environmental resources are those that come directly from the environment of living things and can be utilized. Everywhere that humans have gone, they have changed the environment according to their needs. Living things are valuable natural resources. The Earth is a standalone entity. The smart utilization of Earth's resources will determine how long humanity will exist. Natural resources play a significant role in a country's economic growth. Without their consumption adjustment, there will be irreversible climate change, declining economic growth, and higher social, economic, and environmental costs due to lower productivity. Resource depletion is the process of using either of these types of resources faster than they can be replaced.

25.6.1 Kinds of Natural Resources

The environment is a vast collection of resources. These resources are the natural components of the world that are essential to human existence. These as renewable and non-renewable resources.

(i) Renewable Environmental Resources

On a human-time scale, resources like direct solar energy, wind, and tides that are unconditionally renewable are known as permanent resources. A conditionally renewable resource is one that

can be renewed, reproduced, or expanded in quantity by natural processes. Examples include freshwater, fresh air, fertile soil, and trees in a forest, gases in grassland, fruits, and fibers. The majority of biotic and complex resources that are obtained from living organisms are conditionally renewable resources. Natural systems that replace themselves quickly enough to keep up with consumption provide renewable resources. Living things make use of them. Natural cycles like the water cycle, carbon cycle, oxygen cycle, nitrogen cycle, etc. are continually replacing them.

(ii) Non-renewable Environmental resources

The creation of non-renewable materials occurs considerably more slowly than their environmental usage. These are depletable and once lost, they cannot be replaced. Various metals, non-metallic minerals, coal, oil, and natural gas are a few examples. Mostly they consist of minerals and fossil fuels, which cannot be renewed again. These are finite, exhaustible resources that are gradually replaced when they are used up (in stock) (e.g., coal and oil). These biotic resources cannot be regenerated because they were created by plants' photosynthetic activities millions of years ago. In modern times, neither the supply of gasoline nor the supply of iron ore is reproduced or increased. They are basically lost forever once consumed.

25.6. 2 Depletion of Environmental resources

The exhaustion of raw materials within a region is referred to as a resource of depletion. Renewable resources and non-renewable resources are commonly distinguished. The use of either of these types of resources beyond this level of replacement is commonly known as the depletion of resources. Sustainable use of resources is suggested by the experts.

Causes of resource depletion: Man is the primary cause of resource depletion; his activities consume natural environmental resources at a rate that exceeds their rate of renewal. Overconsumption or excessive or unnecessary use of resources, inequitable distribution of resources, overpopulation, slash-and-burn agricultural practices; technological and industrial development; erosion; irrigation; mining

for oil and minerals, and pollution or contamination of resources are all factors that contribute to the depletion of natural resources.

25.6.3 Conventional and Non-conventional Energy resources

There are two types of energy sources: conventional and non-conventional.

(a) Conventional energy sources

Conventional sources of energy are those that have been in use since prehistoric times. Traditional energy sources include the fossil fuels coal, natural gas, and oil. Coal, oil, wood, peat, and uranium are sources of energy (electricity), as well as fuel for fire. The benefits of traditional energy sources, such as fossil fuels, include their low production cost and the requirement for well-established technology that can produce energy continuously. The drawback of traditional energy sources is that they have a limited quantity because nuclear energy and fossil fuels will ultimately run out. Burning fossil fuels also contributes to acid rain and releases large volumes of greenhouse gases.

Fossil fuels: Coal, oil, and gas are examples of fossil fuels. They meet 95% of the electricity demand. They cannot be regenerated. Fossil fuels are so-called because they are the remains of plants and animals that lived millions of years ago.

Nuclear energy is generated by the fission of radioactive atoms. This energy is used in nuclear reactors to make electricity. U235 is the primary nuclear fuel. Nuclear energy has the advantage of emitting a large amount of energy. The disadvantages are that it produces radioactive waste and is costly.

(b) Non-conventional energy sources

Non-conventional energy sources or unusual sources of energy are new energy sources that are still not widely used. Their contribution to national power is not significant. These are: Solar and hydroelectric power (dams in rivers). Wind energy, tidal energy, and ocean wave energy, Geothermal energy (heat from deep under the ground), Thermal energy from the sea (the difference in heat between shallow and deep water), Biomass (burning vegetation to prevent methane production),

Bio-fuel (producing ethanol (petroleum) from plants), Bio-gas It is also referred to as renewable energy sources.

The benefits of non-conventional energy sources include their abundance in nature, lack of pollution, and environmentally friendly nature. The disadvantages of nonconventional energy sources are that they are often limited to producing energy only under certain conditions, such as sunny days for solar panels and windy days for windmills.

25.6.4 Protection of Environmental Resources

Natural resources are essential to our survival. The quality of our air, water, soil, and biological resources has a direct impact on our health and well-being. Our surroundings Seascapes and wildlife are inextricably linked to our culture, inspiring art, and literature. Our economy and key industrial sectors rely on healthy ecosystems both directly and indirectly. Many people believe that natural resources have intrinsic value; that is, they are valuable in and of themselves regardless of their functional value.

25.6.5 Role of government departments and NGOs

The governments of different countries control and develop the country's forests, dams, major irrigation systems, power plants, railways, ports, roads, mines, and industries. The environment ministry is in charge of planning, protecting, and coordinating environmental and forestry programs. The Ministry of Environment is in charge of assessing the environmental impact of any project that has the potential to harm the environment. Every year on April 22nd, Earth Day and Tree Plantation Week are observed to educate the public.

Role of NGOs: None Government Organizations can play an important role in environmental protection conservation and management, as well as in raising public awareness about environmental issues. They have raised public awareness of environmental issues caused by neglect and uncontrolled exploitation of natural resources. Some of the NGOs are involved in environmental empowerment, while others are involved in research work at different levels.

SUMMARY

- Water is a very important abiotic factor in our ecosystem.
- The water cycle begins with the process of evaporation.
- Aquifers are necessary for a wide range of human activities, including agriculture, industry, and domestic water supplies.
- The nitrogen cycle is a complex biogeochemical process that ensures the availability and recycling of nitrogen in the Earth's ecosystems.
- When ammonia (NH_3) is converted into nitrate (NO_2) compounds by nitrifying bacteria through a process called Nitrification.
- Ammonification is the process by which microbes break down organic materials to produce ammonia or ammonium molecules.
- The ecosystem is the basic fundamental unit of ecology in which living and non-living things interact and influence each other.
- An energy pyramid shows how much energy is contained in the biomass of each trophic level.
- The process of ecological succession involves a series of stages, known as seral stages,
- Primary succession occurs in areas that are barren of life and lack soil, such as newly formed land or bare rock surfaces.
- Ecological succession occurs in arid environments like deserts, mountains, or dunes known as xerarch succession.
- Phytoplanktons are microscopic, photosynthetic organisms, primarily consisting of algae and cyanobacteria.
- A transitional stage in the ecological growth of a freshwater ecosystem is known as the sedge meadow stage of a lake.
- The quality of our air, water, soil, and biological resources has a direct impact on our health and well-being.

EXERCISE

1. Encircle the correct choice.

i) Which one of these mainly causes the greenhouse effect?
(a) Acid rain (b) Ozone layer depletion
(c) Global warming (d) Forest fire

ii) Factors that affect the flow of energy at the trophic level are
(a) Non-predatory deaths (b) Growth & Reproduction
(c) Heat loss (d) Sunlight

iii) The main cause of the increase in the amount of CO_2 in the Earth's atmosphere is
(a) Rapidly growing human population
(b) Burning of a large number of fossil fuels
(c) Increase in the number of industries
(d) Decrease in the forested resources.

iv) All is positive for which of the following processes?
(a) Oxidation of Nitrogen
(b) Melting of ice and evaporation of water
(c) Oxidation of gold
(d) Burning of chlorine

v) Which of the following dietary requirements is involved in nitrogen balance?
(a) Carbohydrates (b) Vitamins
(c) Proteins (d) Essential fatty acids

vi) Which of the following cycle is not a gaseous type of cycle?
(a) Carbon cycle (b) Nitrogen cycle
(c) Phosphorus cycle (d) Oxygen cycle

vii) The source of carbon to plants in the carbon cycle is
(a) Carbonate rocks (b) atmospheric carbon dioxide
(c) Fossil fuels (d) all of the above

viii) Conversion of nitrates to nitrogen is called
(a) Nitrification (b) Denitrification
(c) Ammonification (d) Nitrogen fixation

ix) what is the only source of energy for all ecosystems on Earth?

(a) Water (b) Sun

(c) Animals (d) Plants

x) The pioneers in xerarch succession are the

(a) Foliose lichens (b) Mosses

(c) Crustose lichens (d) Shrubs

2. Write short answers of the following questions.

i) Why biogeochemical cycle is named so?

ii) Differentiate between nitrification and de-nitrification?

iii) How does energy flow between trophic levels?

iv) What are the major producers in a terrestrial ecosystem?

v) How does ecological succession affect the community?

vi) What are the causes of ozone layer depletion?

vii) Why should we conserve biodiversity?

viii) Differentiate between renewable and non-renewable resources.

3. Write the details answers of the following questions:

i) What is a biogeochemical cycle? Explain nitrogen cycle in detail.

ii) Describe the effects of Carbon dioxide and global warming on human health.

iii) What is succession? Describe different stages of secondary succession with examples.

iv) What factors determine the growth rate of the human population? Give their reason also

BIOTECHNOLOGY

Chapter 26

Major Concept

In this Unit you will learn:

- Cloning of Genes
- DNA Sequencing
- DNA Analysis
- Genomic Maps
- Tissue culture
- Transgenic Bacteria, Plants and Animals
- Biotechnology and Healthcare
- Scope and Importance of Biotechnology

Biotechnology is a multidisciplinary field of biology which deals with the application of biological phenomenon by using living organisms, cells and bio-molecules for the welfare of human beings. The basic aim of biotechnology is the improvement of human health, agriculture and environment. The history of biotechnology starts when farmers tried to improve their crop yields and develop better breeds of animal by cross-breeding techniques. The modern biotechnology develops **recombination DNA technology** to get the same result without any failure or chances of failure. The recombinant DNA is developed by using different techniques and this sub-branch of biotechnology is called **Genetic engineering** which deals with the manipulation in material of an organism to get desired results.

26.1 CLONING OF GENES

Gene cloning is a technique that involves the creation of multiple copies, of a specific DNA fragment, when a gene is identified and cloned it can be used for various purposes e.g., gene therapy, genetic engineering and production of different pharmaceutical products. There are two possible ways of gene cloning (a) Recombinant DNA technology (b) Polymerase chain reaction.

Recombinant DNA Technology: In this technique a series of procedures involve to join DNA segments taken different sources. It involves following steps:

i) Identification and isolation of gene of interest.
ii) Insertion of gene of interest into vector.
iii) Introduction of recombinant DNA into Host cell.
iv) Selection and isolation of Transformed cell.
v) Expressing of recombinant gene (protein synthesis).

26.1.1. Techniques of Gene Cloning by Recombinant DNA technology.

As we have discussed that recombinant DNA technology is a technique used to manipulate and modify DNA by combining DNA taken from different sources. This combination develops a new DNA molecule which was not found in nature before. This new form of

DNA is Called recombinant DNA (rDNA). When this DNA insert in an organism if it expresses, it transforms the living organism e.g., pUC19 is a recombinant gene if insert in E. coli bacteria it transforms ampicillin sustible bacteria into ampicillin resistant bacteria. This technology of gene cloning requires following techniques:

i) Identification and Isolation of gene of interest:

The gene of interest is the part of segment of DNA which is to be cloned. The gene of interest is identified from genome of an organism by using radioactive small fragment of DNA called **probe.** When it is identified it is directly cleaved from a Chromosomal DNA by using particular DNA scissors Called **restriction endonucleases** (Enzyme). This ensures, that the gene of interest in obtained and ready for furthers manipulation.

ii) Insertion of gene of interest into vector (Joining of gene of interest)

The gene of interest is ligated (joined) to another DNA entity called **cloning vector**. The cloning vector is usually a plasmid i.e., a small DNA molecule found as extra chromosomal DNA found in bacteria or sometimes yeast. The combination of the gene and the cloning vector form a new recombinant DNA molecule.

iii) Introduction of Recombinant DNA into Host cell

The recombinant DNA molecule is transferred into host cells. This process is called **transformation** and it involves incorporating the recombinant DNA into host cell's genome. It can be performed by putting host cell and recombinant DNA into same medium, the host are treated with **calcium chloride** which make their membrane more permeable for recombinant DNA. After this process, host cell reproduces into medium which produce clone of host cell and each new cell contain at least one recombinant Plasmid. In this way clone of recombinant genes are produced.

iv) Selection and Isolation of transformed cell:

The host cells which successfully take up the recombinant DNA (with gene of interest) are identified and selected. This selection

is achieved by the use of specific marker present in cloning vector. The markers develop resistance in host cell towards certain antibiotics or develop colours which make difference between transformed and non-transformed cell.

v) Expressing of recombinant gene (Protein Synthesis):

The recombinant gene, within the host cell is transcribed and translated in-vitro under suitable condition. As a result, production of specific protein occurs which is encoded by cloned recombinant DNA. This protein can be further purified and used for various applications in research medicine or industries.

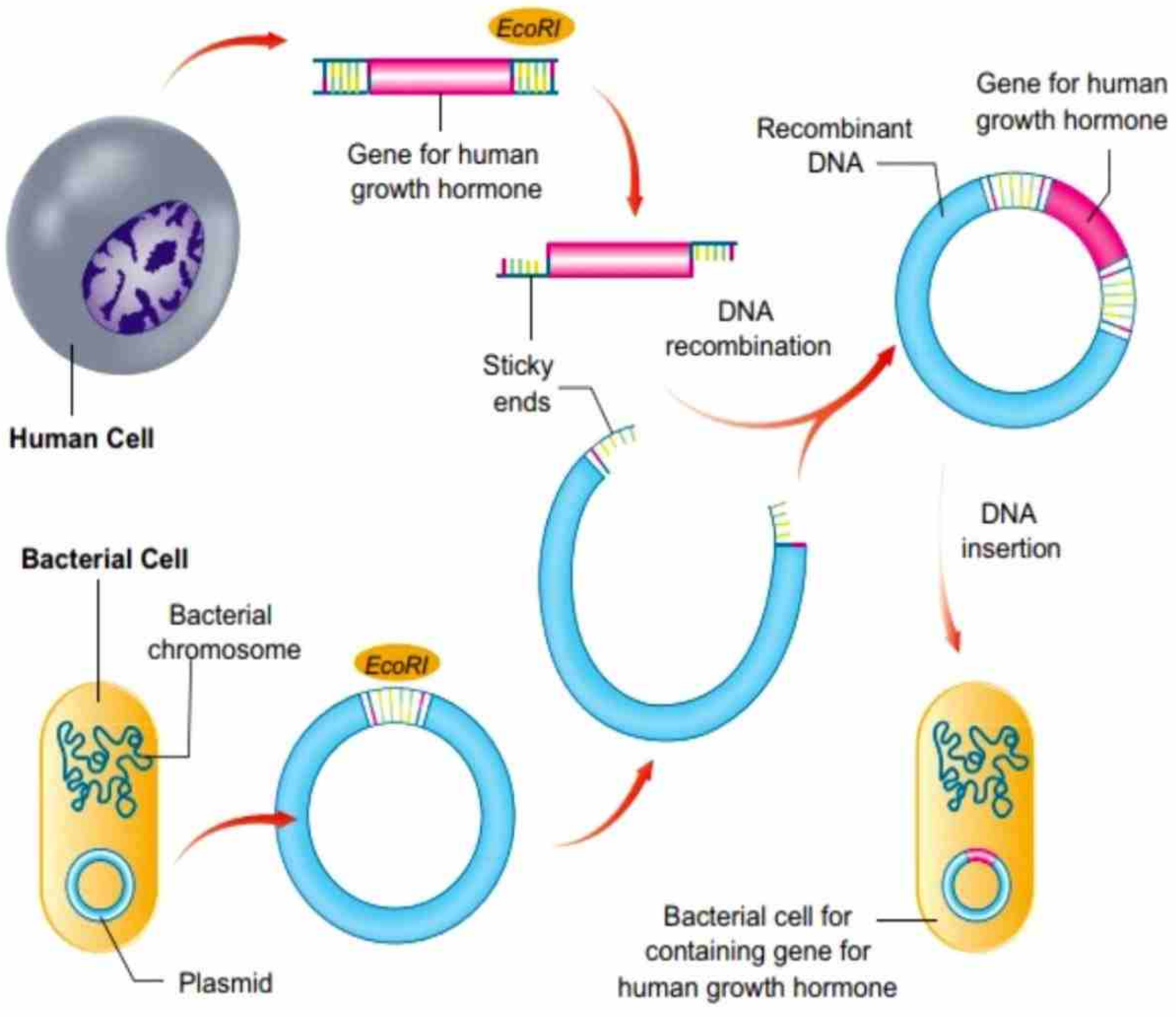


Fig.26.1 Recombinant DNA technology

26.1.2 Role of restriction endonucleases and ligases in gene cloning

Some enzymes play important role in gene cloning. They play crucial role of DNA fragmentation and pasting of fragments during development of recombinant DNA.

(a) Restriction Endonuclease and its role

They are also called restriction enzyme. They are commonly known as **(DNA) molecular scissors** because they break the phosphodiester bond at specific sequence of nitrogenous base to cut the DNA at site called **restriction site**.

Naturally these enzymes are synthesized by bacteria as defense protein to cut the DNA of invader. In this way, they restrict the activity of pathogenic DNA therefore called **restriction enzyme**. These enzymes cleave both strands of DNA molecule at or near the recognition site. These sites usually have **palindromic sequences**. A palindromic sequence is a four to eight base-pairs in DNA in which nucleotides are arranged symmetrically in reverse order. Restriction enzyme usually make **sticky ends** some of these enzymes are also make blunt end. The sticky end joins with plasmid by base pairing. Some examples of restriction enzymes are λ-Hindiii, EcoR1 etc.

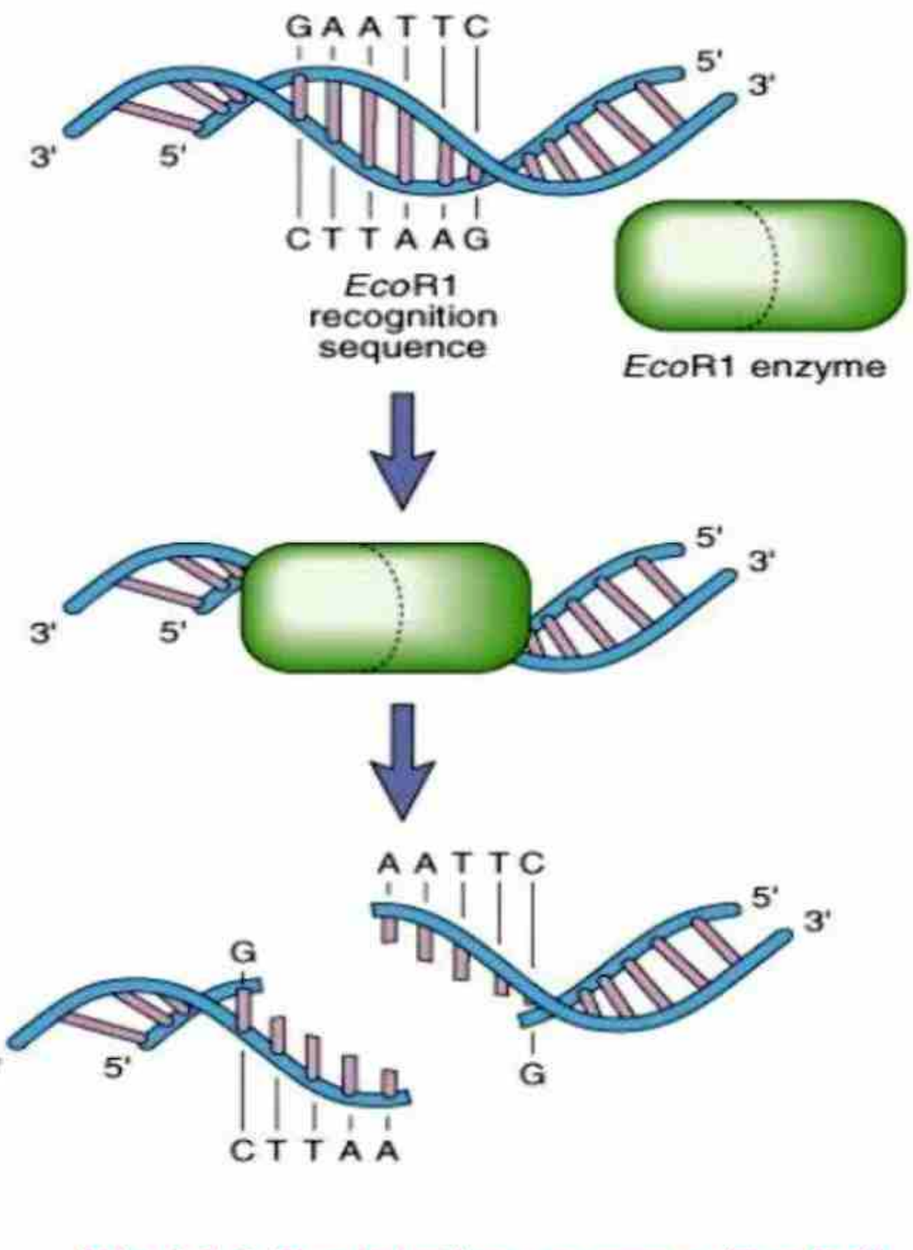


Fig.26.2 Restriction enzyme (EcoR1)

(b) DNA Ligase and its role (Molecular Glue):

Another enzyme use in developing recombinant DNA is DNA Ligase, which catalyze the formation of phosphodiester bond between adjacent nucleotides of DNA. These enzymes join the nucleotides of gene of interest with nucleotides of vector at sticky ends to form rDNA,

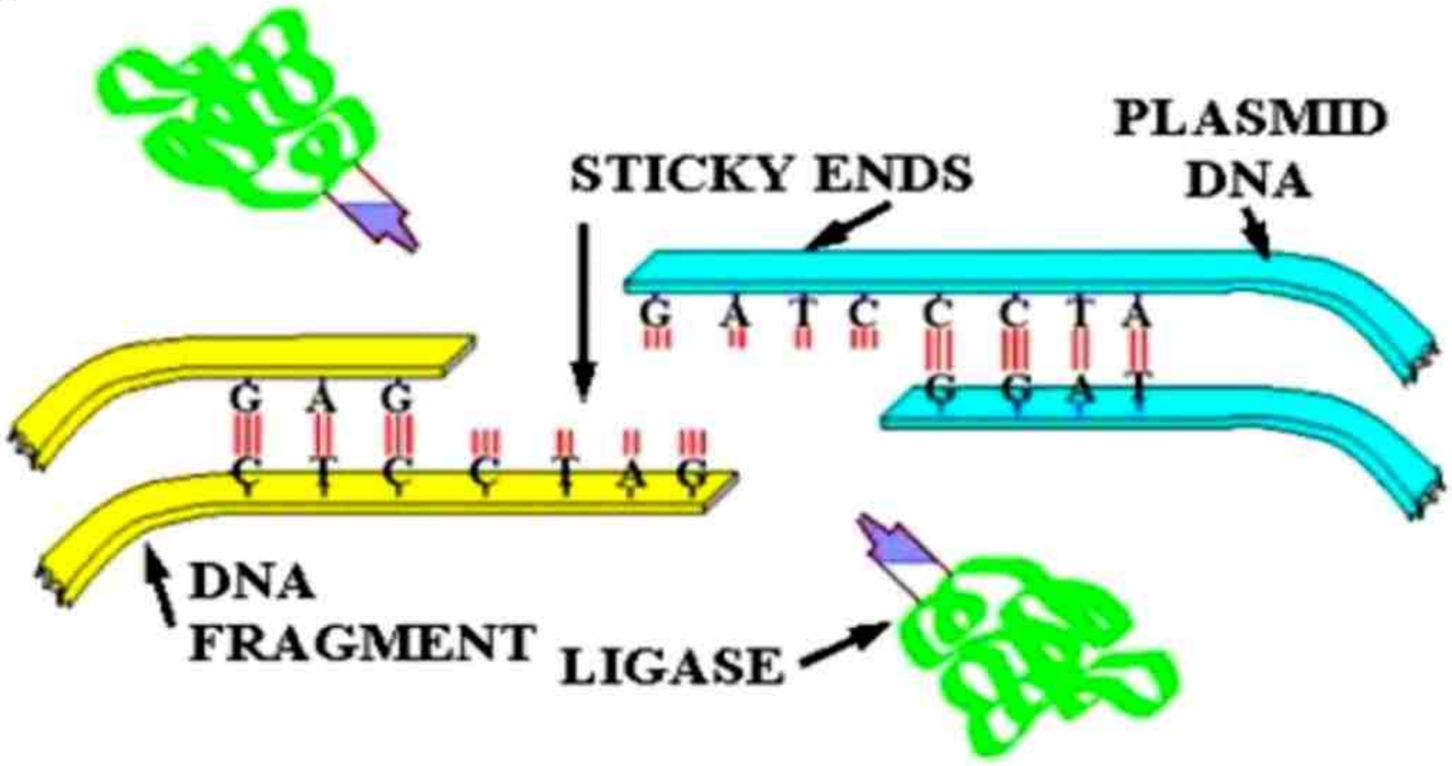


Fig.26.3 DNA ligase

26.1.3. Selection and Isolation of Gene of Interest

There are different methods used to select gene of interest. Usually, a gene library or DNA library is constructed where a comprehensive collection of cloned DNA fragments taken from cell, tissues or organism are present. The genes of interest are also identified by DNA probes. DNA probes are complementary fragments of know unique sequences comprising the gene of interest. The probes are radioactively labeled. Once the probes are added the Hybridize or attach only to the gene of interest and this help in identification of the desired fragment of DNA.

After identification the fragment of DNA is cut by restriction enzyme. These fragments are isolated by gel electrophoresis techniques or they are clone of by PCR method. The isolated gene can be cloned into vector and need for various applications.

26.1.4. Role of Vector in Recombinant DNA Technology

Vectors are DNA molecules used to transport the gene of interest into host cells. In host cell gene interest can be replicated

and expressed. Usually small extra chromosomal DNA of bacteria i.e. plasmid used as Vectors. Vector must possess following characters:

i) It should a DNA molecule has origin of replication site.
ii) It have antibiotic resistant gene.
iii) It has restriction sites of different enzymes

Some of examples of vectors are, Plasmid, Lambda (λ) phage DNA, yeast artificial Chromosome, Cosmid (It is a combination of Plasmid and Phage DNA) etc.

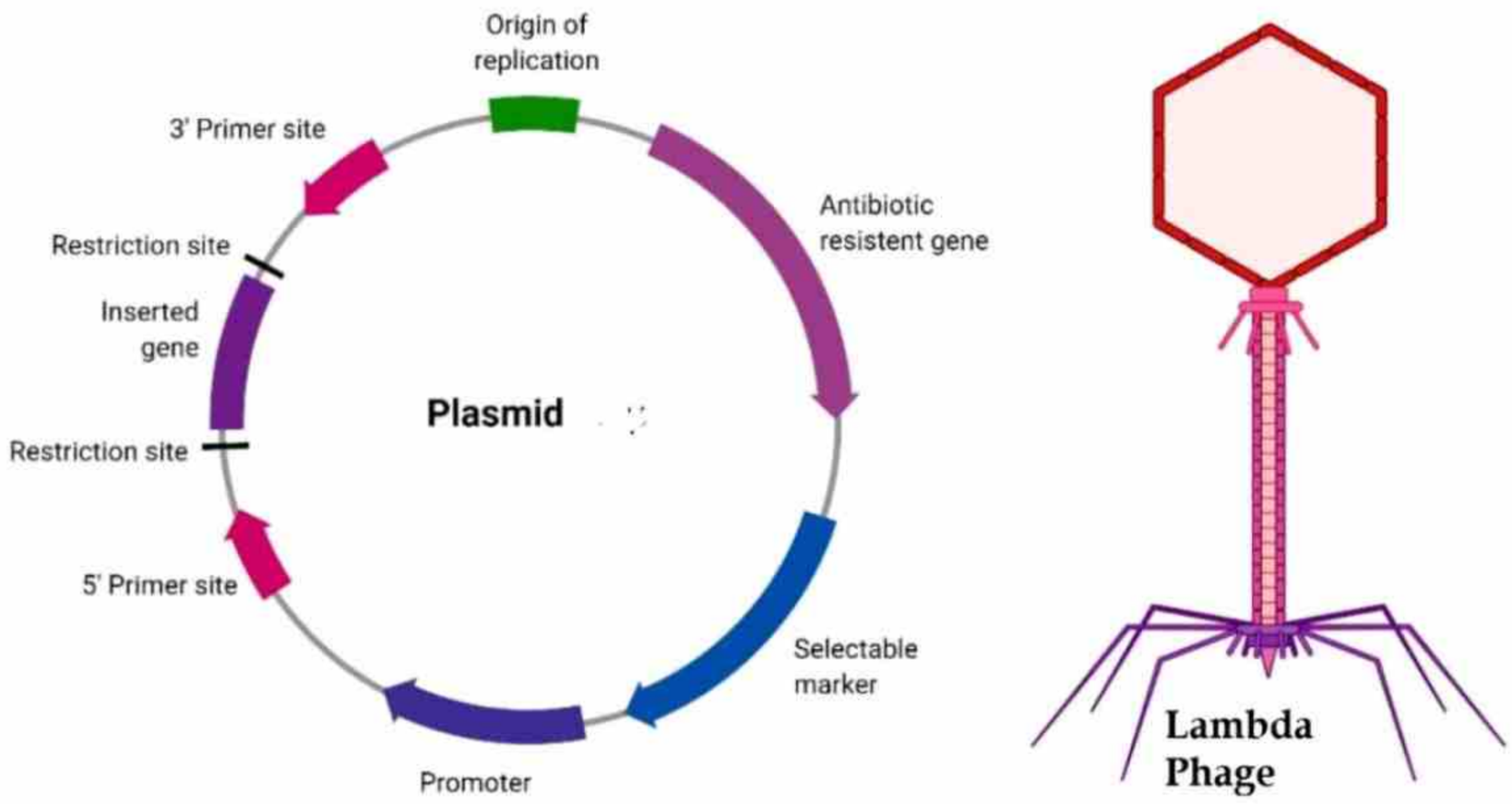


Fig.26.4 Plasmid and Lambda phage DNA

26.1.5 Steps for integration of DNA (gene of interest) insert into vector:

The integration of gene of interest into vector involves several following steps:

1st step:

The vector and gene of interest are digested by same restriction enzymes to create sticky ends.

2nd step:

The digested fragments are purified to isolate the desired size fragments.

3rd step:

The purified vector and DNA insert are ligated together through ligase.

4th step:

The ligated DNA is introduced into host cells through transformation using methods like electrophoresis, chemical transformation or heat shock method. The selected clones can be scaled up and used for various applications, including protein expression therapy or genetic modification.

The techniques applied for the selection of vector

The techniques which applied for selection of vector are based on the presence of suitable **markers**. The markers a may be genetic elements like **antibiotic resistance gene** or gene which produce different colours in host or **fluorescent protein genes** identify and select only those host cells that have successfully up the vector with gene of interest.

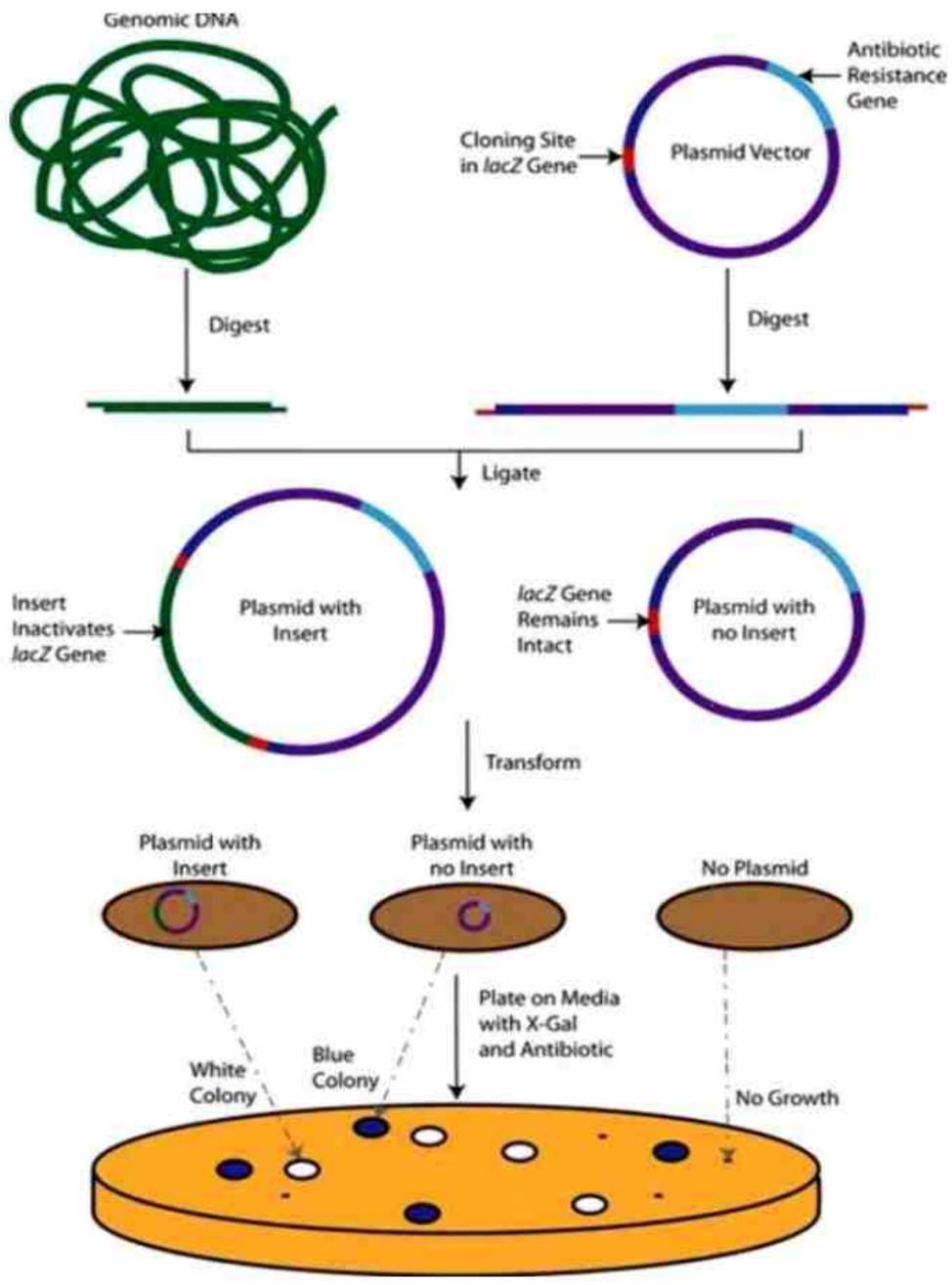


Fig.26.5 Selection of clones

(a) Antibiotic resistance: Amp^R gene is the gene if present in plasmid the host can grow on a medium containing Ampicillin.

(b) Colour producing gene: Lac^Z gene contain vector if present in plasmid the host bacteria can hydrolyze X-Gal (a modified sugar) and produce blue colour in bacteria which shows the presence of vector. When gene is inserted, the bacteria will not produce blue colour.

(c) Fluorescent protein: Another approach is use of Gene florescent protein (GFP). The vector contains FPG with gene of interest, when

vector with gene of interest is taken up by host cell the FPG also express and produce fluorescence which can be observed under fluorescence microscope.

By incorporating selectable markers into vectors biotechnologists can identify and propagate the host successfully.

26.1.7 Gene Amplification through Polymerase Chain Reaction (PCR):

As we have discussed earlier that there are two methods of gene cloning. One this method is **Polymerase Chain Reaction** (PCR). It is a technique used for amplifying (cloning) a specific DNA fragment or gene into millions of copies. It takes place in vitro in specific conditions and in the presence of enzymes. Following are the steps in gene replication through PCR:

Fig.26.5 PCR Machine

Denaturation: The first step in PCR is denaturing where the, double stranded DNA template is heated to high temperature. i.e. 94-98^{0}C to separate the two strands.

Primer Annealing: The temperature is then lowered abruptly up to 50-65 ^{0}C. The primer, a short DNA which is complementary to the ends of the target sequence are added. The primer anneals to the template DNA. It provides a starting point for DNA synthesis.

Extension or polymerization: A heat stable DNA polymerase enzyme e.g., Taq polymerase, is added, along with a supply of nucleotides. The temperature is raised up to 72^{0}C be which is the optimal temperature for DNA polymerase to extend the primer and synthesize a new complementary strand of DNA.

Repeat Cycle: The above steps are repeated for multiple time i.e., 25-40 cycles each time the amount of DNA become double. The exact

number of cycles" depends in the length of the target sequence, and the amount of starting template DNA.

PCR has revolutionized field of biology and medicine, allowing the amplification and analysis of DNA sequences from variety of sources e.g., Clinical samples, fossils and environmental samples.

Table. 26.1 Applications of polymerase chain reaction (PCR)

Application	Description
Medical Diagnosis	PCR is used for the diagnosis of genetic diseases, including cancer, HIV, and genetic disorders. It amplifies specific sequences of DNA, allowing the detection of disease-causing mutations even at very low concentrations.
Forensic Analysis	It is used in forensic analysis to amplify small amounts of DNA from crime scenes or evidence samples. Amplified DNA can then be analyzed to identify suspects, match DNA profiles, and establish the presence or absence of specific genetic markers.
Environmental Monitoring	It is used to detect and quantify microorganisms in environmental samples. It is used to monitor water quality, identify pathogens in food, and detect the presence of harmful bacteria and viruses.
Genetic Research	In genetic research, PCR amplifies DNA sequences for further analysis. It generates DNA fragments that can be cloned, sequenced, and used for a wide range of molecular biology techniques.
Paternity Testing	It compares DNA samples from a child and a potential father to establish paternity with high accuracy. Its high sensitivity, specificity, and versatility make it a powerful tool for DNA analysis and diagnostics

26.1.8 Genome Library

A genome library is a collection of DNA fragment representing an organism's entire genome. These DNA fragments of an organism are cloned in different bacteria or bacteriophage, so we can also say that the genome library is a collection of bacteria or bacteriophage

clone, which contain DNA of a genome of an organism. The Fragments of genome of an organism are inserted into vectors.

These all bacteria are collected and labelled and stored in a freezer below -30^{0}C. The whole sequences of these DNA fragments and their products are also known. Following are the steps for creating genome library.

i) Extract and purify chromosomal DNA of an organism.

ii) Digest the genome with restriction enzyme to create DNA fragments.

iii) Insert DNA fragment into specific vectors, which creates a large port of recombinant molecules.

iv) These rDNAs are taken by host bacteria which transform them, it creates a DNA library.

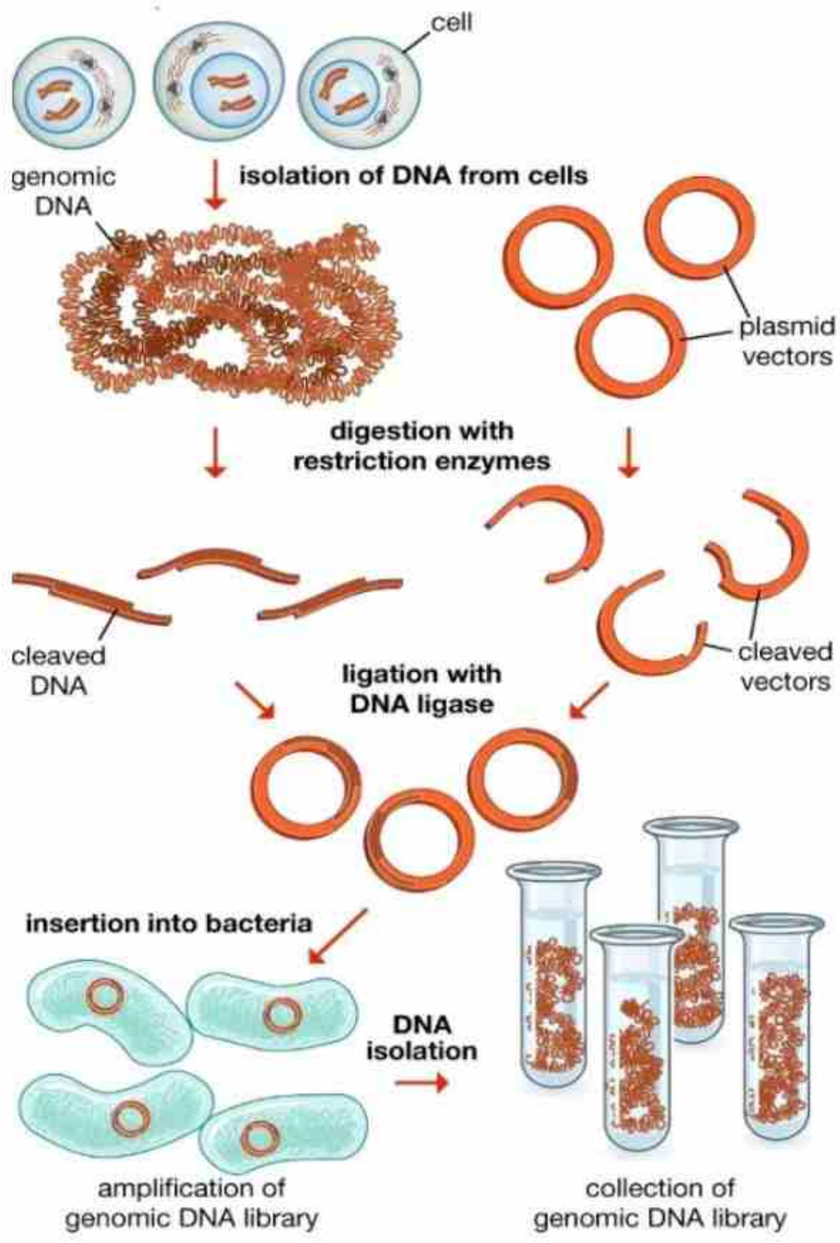


Fig.26.6 Genomic Library

26.2 DNA SEQUENCING

As we know that DNA is made up of 4 types of deoxyribonucleotides. Each fragment by DNA (gene) has specific sequences of their four nucleotides. To determine the exact sequences of these nucleotides called DNA sequencing.

The DNA sequencing process involves break down of a large DNA molecule into small fragments and then reading of its nitrogenous base arrangement by different method, which gives sequences of letters A, G, C, T. These sequences can be analyzed and compared to other DNA sequences, to understand different genetic makeup of an organism, disorders and develop treatments.

There are several methods of DNA sequencing, each have its own advantages, disadvantage and limitations. Some common

methods include Sanger sequencing method, next generation sequencing automated sequencing method, Maxam - Gilbert procedure.

26.2.1. (a) Maxam-Gilbert method

It is a DNA Sequencing method develops in early 1970s by Allan Maxam and Walter Gilbert. It is also known as the chemical cleavage method. In this method Chemicals are used to cleave the DNA at specific nucleotide. It involves following four major steps:

i) DNA fragmentation: The Genome DNA is fragmented into specific size using chemicals and enzymes.

ii) End Labeling: These fragments are now labelled at one end with a radioactive or fluorescent marker to aid in detection.

iii) Chemical cleavage: The labelled fragments are then subjected to specific chemical treatments that cleave the DNA at specific nucleotide residue, producing fragments of varying length.

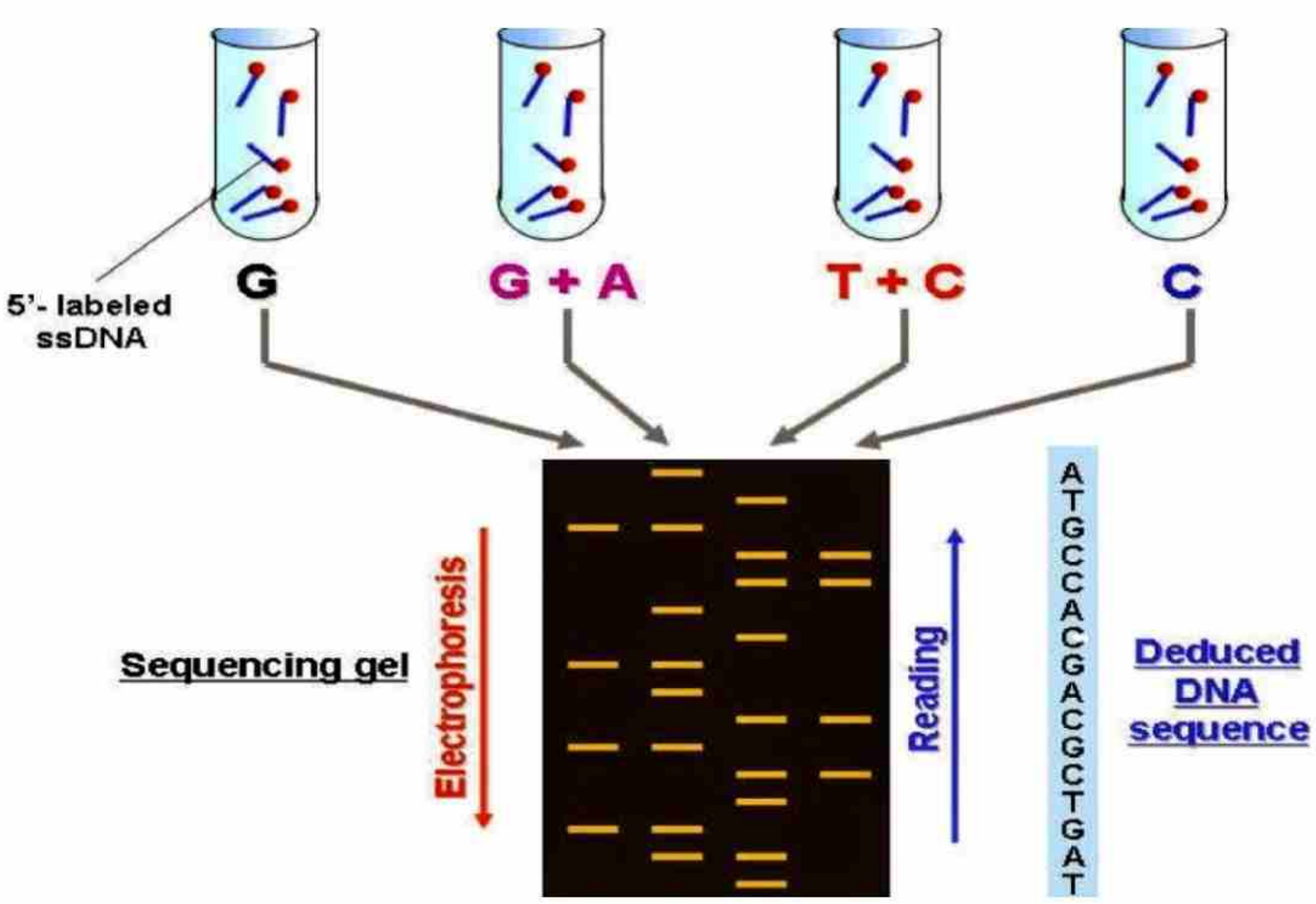


Fig.26.7 Maxam-Gilbert Method

iv) Electrophoresis: Finally, the fragments separated by size, using gel electrophoresis and the sequence can be read, based on the position of cleavage site.

This method has the advantage of able to sequence DNA fragments up to about **500 bases in length**. The disadvantage of this method in that it requires toxic chemicals, time to consume and labour intensive.

26.2.1(b) Singer-Coulson Method

Another early developed method of gene sequencing is called Singer Coulson method or dideoxy Chain-termination method. It is more reliable, efficient and widely used method of gene sequencing in late 1970s and early 1980s. In this method a modified nucleotide, are called dideoxy nucleotides (dd NTPs). These modified nucleotides do not contain 3'-hydoxyl group, which is required for DNA elongation. Then dd NTP's are incorporated into growing DNA chains by DNA polymerase, which result chain termination. In this way, a series of DNA fragments of different length are generated. These fragments are separated by Gel-electrophoresis and the sequence can be determined by reading the band pattern from the gel. By this method longer fragments up to several thousand bases in length can be sequenced.

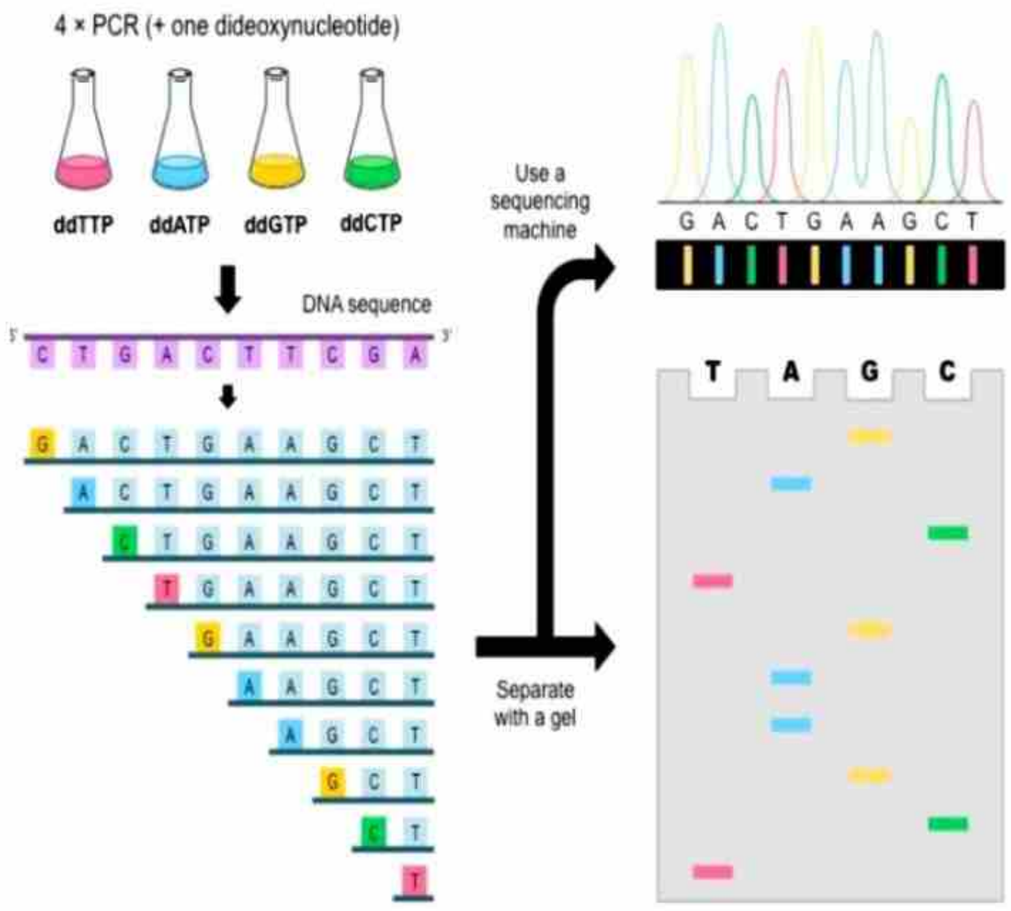


Fig.26.8 Singer-Coulson Method

26.2.2 Gel Electrophoresis and its Principle:

As we have discussed in XI-Biology that the **electrophoresis** is a technique to separate different sized charged fragments of polymers (Protein, DNA and RNA) under the influence of electric current in an **electric cell**. In gel Electrophoresis these molecules move from the tiny pores of semi-solid gel medium of agarose and polyacrylamide. The polymers of different sized are loaded into the well of developed in gel material this gel is placed in an electric cell which is filled with an electrolytic solution. When electric current applied, the different sized DNA fragment begins to move to opposite electrode. (In the case of DNA, they move toward +ve pole) through, pores of gel. After sometimes the different sized molecules are separated in the shape of bands in the gel.

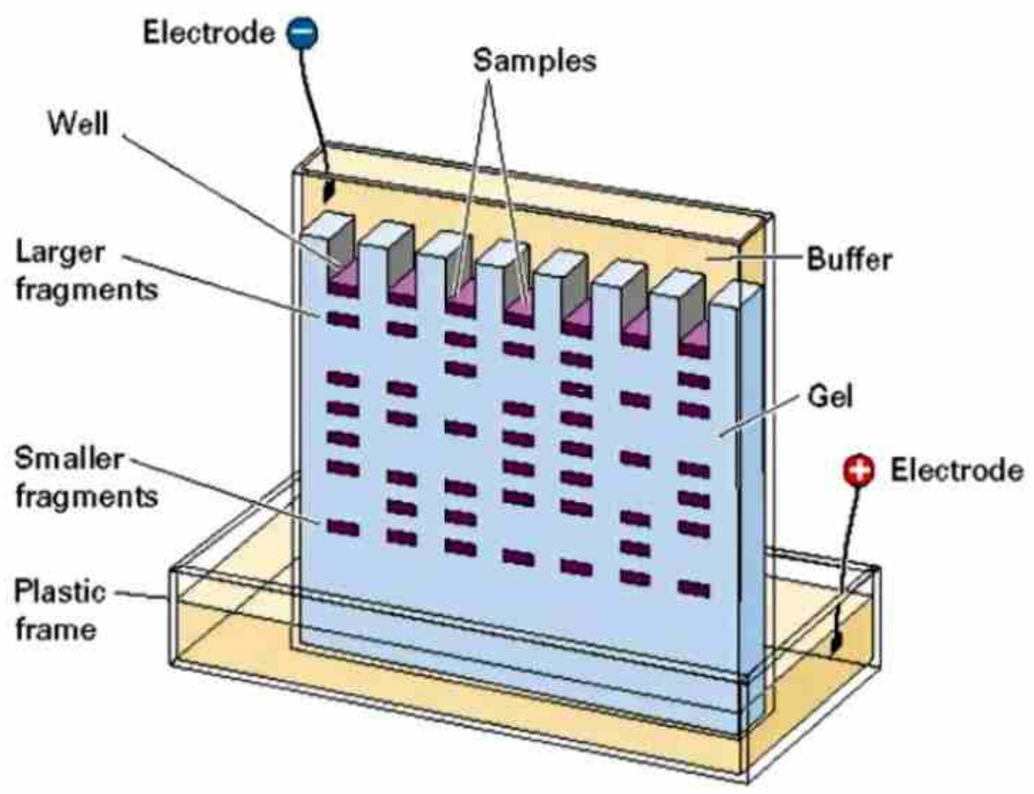


Fig.26.9 Electrophoresis

Principle of Gel electrophoresis

The separation of DNA fragment by gel electrophoresis in based on the size, charges and distance traveled by fragment of DNA molecules. It is proportional to its length, so the smaller fragment moves faster through gel matrix than larger fragments. The movement also depends upon charges, number of strands, shapes of molecules and concentration of gel per size.

Visualization of fragments: After completion of electrophoresis, the DNA fragments are visualized by staining the gel with fluorescent dye, such as **ethidium bromide** or **SYBR Green**. The DNA fragments appear as bands or Smears under UV light, with the smallest fragments closest to the bottom of the gel.

26.2.3 The automated DNA sequencing based on the Sanger-Coulson

Automated DNA sequencing highly efficient method of DNA sequencing based on the Sanger-Coulson method. The key features of automated DNA sequencing are:

i) Fluorescently labelled dideoxy nucleotide (ddNTP):

The fluorescent labelled ddTNPs are used instead of radioactive ddTNPs. Each of the four ddTNP's are labelled with a distinct colour fluorophore, allowing for the simultaneous sequencing of all four nucleotides.

ii) Capillary electrophoresis:

In automated method capillary electrophoresis is used instead of Gel electrophoresis. The DNA fragments are separated in at thin capillary filled with a polymer matrix. The capillary is placed in an instrument that applies an electric current for DNA fragment separation and migration. As the fragment pass through a laser beam, the florescent labels are excited, producing a signal which is detected by a detector.

The data generated is analyzed by computer software by converting signals into a sequence of nucleotides. **Bioinformatics** tools are software applications as computational method used to store analyze and interpret biological automated DNA sequencing has several advantages over traditional methods. It is faster, performing sequencing of thousands of bases per day. It also requires accurate than manual method. It also requires less starting material and suitable for application.

6.3 DNA ANALYSIS

A set of techniques used to study DNA structure, function and properties. It is essential in genetics, forensics, medicine and biotechnology. Techniques, like DNA sequencing, PCR and gel electrophoresis enable the detection of genetic mutation, identification of disorders analysis of gene expression and exploration of evolutionary history. It is also used to diagnosis of diseases, developing drugs, enhancing agriculture yield and solving crimes.

6.3.1 Purpose and mechanism of DNA analysis

On DNA Analysis It is found that each individual has a specific percentage of DNA which does not code for protein but repeated frequently on the genome of that individual. These repetitive units vary in length from organism to organism of the same species each of such repetitive units are 20-40 base pair lung. These variable and unique lengths of non-functional DNA are passed on to the offering along with the compliment of gene in a Mendelian fashion. The differences in DNA electrophoresis pattern among individuals are called, **Restriction fragment length Polymorphisms** (RFLPs pronounced as Riff Lips). It is also called **DNA finger print**.

It is used to settle down the disputes over parentage relationship identification of individual during accidents. It is also used to identify criminals from blood, semen, saliva and hair follicle etc. left at the scene of crime. It has also spectacular potential for medicine, for instance in the parental diagnosis of individual disorders.

Mechanism of DNA analysis:

Numbers of techniques are used for analysis. Restriction Fragment Length polymorphism (RFLP) is one of the first method used in DNA analysis. Following are the steps to make a DNA finger prints by using this method:

i) Collection of DNA sample: A small fraction of DNA sample is collection from blood saliva, semen or hair follicle. It can amplify to get clones by PCR.

ii) Digestion and separation of RFLP: The collected DNA sample is digested by specific restriction enzymes it produces different sized DNA fragments. This mixture of DNA is separated by electrophoresis.

iii) Denaturation of fragments: The electrophoresed gel is placed into an alkaline solution (NaOH) to denature the dsDNA. The denaturation improves binding of the negatively charged DNA to positively charged membrane and separating it into ssDNA for later hybridization to the probe.

iv) Blotting: In this step transfer of DNA at nitrocellulose membrane perform. A sheet of nitrocellulose membrane placed on the top of alkaline gel. The ssDNA bind with membrane by ion exchange interaction because the DNA is negatively charge which the membrane is +vely changed. The membrane is then baked in a vacuum or regular oven at 80^0C for 2 hours for permanent attachment of ssDNA with membrane.

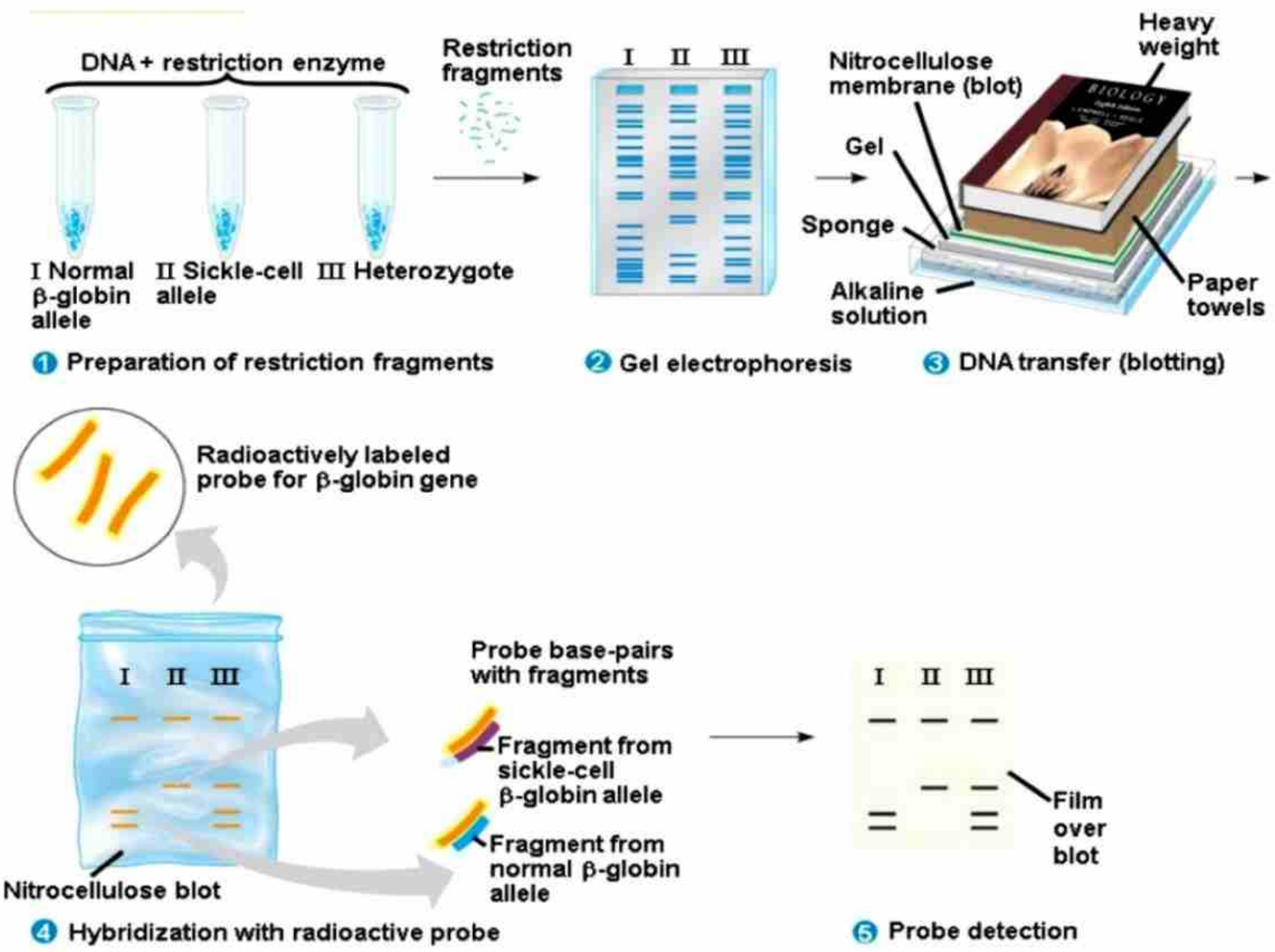


Fig. 26.10 DNA analysis

Labelling of RFLPs: The membrane is then expose to radioactive probe to hybridize the denatured ssDNA fragments in all bands. The radioactive DNA can be observed by autoradiography.

Autoradiography: After hybridization membrane is washed to remove excess amount of probe, the pattern of hybridization in observed by exposing the membrane on x-ray film. It is called **autoradiography**.

26.4. Genome Map:

Total DNA present on the chromosomes of Eukaryotic call called **Genome**. Each Chromosome carry specific genes at specific position of chromosome the position of gene at chromosome of gene at chromosome called **gene loci**. In diploid cell these genes are present in two sets which in haploid cells these are found in one set. It requires to know that a specific chromosome have genes of what of type of characters and what are their position at that Chromosome to find out the nature and position of genes at particular chromosome called **Genome Mapping**.

26.4.1 Genome Analysis

To make the Genome map the biologist perform analysis of the DNA of each chromosome by these techniques discussed earlier. The branch of biotechnology which deals with genome analysis is called **genomics**. This branch covers the analysis of complete DNA sequence of organism's genome.

Genome Map

Genome map is just like the road map and street map of a city which guide us to reach at specific location. It is used to search a specific gene at specific chromosome. There are two types of maps. (a) Genetic Maps (b) Physical maps. Genetic map shows the sequence of gene chromosomes while physical map shows the sequence of nucleotides in the DNA.

Genetic Markers: DNA Sequences or Variations used to identify or distinguish individual population or traits called Genetic markers like RFLPs. These markers are used in genome analysis to map genes, identify disease causing mutations biodiversity and evolution.

26.4.2 The history of the human genome project.

The Human Genome Project (HGP) was an international scientific research project that aimed to sequence and maps the entire human genome. The project was initiated in 1990 by the US National Institutes of Health (NIH) and the Department of Energy (DOE), with the participation of many international collaborators. James Watson, a prominent molecular biologist and one of the co-

discoverers of the structure of DNA, was appointed as the first director of the HGP in 1990. Watson was known for his pioneering work in molecular biology, and his leadership and vision were instrumental in the project's success. The project was completed in 2003, ahead of schedule and under budget, and its results were published in several landmark papers in the journals Nature and Science.

26.4.3 Goals of the human genome project.

The Human Genome Project (HGP) was a scientific research initiative aimed at mapping and sequencing the entire human genome, which is the complete set of genetic instructions that determines the traits and functions of an individual.

The primary goal of the HGP was to determine the complete sequence of the human genome, including all the genes, non-coding regions, and repetitive sequences. The HGP aimed to identify and annotate the function and location of all the genes and other functional elements in the human genome, including regulatory regions, splice sites, and other features. It aimed to identify new genes and genetic variations associated with human diseases, traits, and drug responses, using approaches like linkage analysis, association studies, and functional genomics.

Ethical, legal, and social implications: The HGP recognized the need to address the ethical, legal, and social implications of the genomic information and technologies generated by the project, and established programs to study and address these issues. However, the completion of the HGP laid the foundation for new discoveries and applications in personalized medicine, gene therapy, and other areas of health and biotechnology.

26.4.4 Benefits of the human genome project:

It revealed that humans have 23 pairs of chromosomes and showed us where genes and other important parts of the genome are located. The HGP also found differences in the structure of the genome, like deletions and duplications that can affect our health. By identifying all the estimated 20,000-25,000 genes in the human genome, researchers can study how these genes work and their role

in diseases. They have also discovered genetic variations linked to diseases like cancer, diabetes, and heart disease, which helps develop better ways to diagnose and treat these conditions.

26.5 TISSUE CULTURE

Tissue culture involves the isolation of cells or tissues from a living organism, providing them with the necessary nutrients, growth factors, and conditions to support their growth and proliferation.

26.5.1 Basic Terminology

Term	Definition
Explants	Small pieces of plant tissue (leaves, stems, roots and flowers) taken from a parent plant used to initiate a culture of cells or tissues in vitro.
Callus	Mass of unorganized and undifferentiated cells that arise from the explant culture in vitro. It can be used as a source of cells for further tissue culture experiments or for inducing somatic embryogenesis.
Micropropagation	Tissue culture technique involving rapid multiplication of plants by producing multiple shoots or plantlets from a single explant. Widely used for high-quality planting materials and multiplication of rare and endangered plant species.
Plantlets	Small, fully developed plants produced in vitro through micropropagation or somatic embryogenesis. They can be transferred to soil and grown into mature plants.
Somatic embryogenesis	Tissue culture technique involving the induction of embryo formation from somatic cells in vitro. It can produce many genetically identical plant embryos and regenerate whole plants.
Soma clonal variation	Genetic variation that arises from the culture of plant cells or tissues in vitro. It can result from mutations, chromosomal aberrations, epigenetic changes, or other factors affecting the genetic stability of cultured cells. It can have positive or negative effects on plant phenotype and can be utilized in developing new plant varieties.

26.5.2 Tissue culture, organ culture and cell culture:

Tissue culture is a technique used to grow and maintain cells, tissues, or organs in vitro, outside the organism. It involves the aseptic culture of plant or animal cells, tissues, or organs in nutrient media under controlled conditions of temperature, light, and humidity.

Table. 26.2 Comparison between Organ Culture and Cell Culture

Feature	Organ Culture	Cell Culture
Definition	In vitro culture of whole organs or tissues	In vitro culture of isolated cells
Types	Slice, explant, suspension culture	Monolayer, suspension, spheroid culture
Complexity	More complex, includes multiple cell types	Less complex, single cell type
Maintenance	Requires specialized maintenance	Easy to maintain
Nutrient supply	May require more complex nutrient supply	Nutrient supply can be controlled precisely
Experimental use	Mimics physiological conditions	Allows for more precise experimentation
Applications	Tissue engineering, drug development, toxicology testing	Vaccine development, cancer research, gene expression studies

26.5.3 The callus culture and suspension culture techniques:

Both techniques have different applications in research and commercial production of plant-based products. Callus culture and suspension culture are two common techniques used in plant tissue culture. The main differences between the two techniques are as follows.

Table. 26.3 Comparison between Callus culture and Suspension Culture

	Callus culture	Suspension culture
Cell organization	Callus culture involves the growth of undifferentiated mass of cells, which are disorganized and heterogeneous	Suspension culture involves the growth of individual cells suspended in liquid media.
Culture conditions	It requires a solid medium, such as agar, for the cells to grow and proliferate	It requires a liquid medium that allows for the free movement of the cells.
Cell growth:	produces a compact mass of cells that can be induced to differentiate into specialized tissues or organs	Produces single cells that can be used for recombinant proteins, monoclonal antibodies, or other biologically active molecules.
Maintenance:	easy to maintain, as the cells can be sub-cultured by simply transferring a small piece of the callus to a new culture medium.	It requires more attention, as the cells need to be regularly sub-cultured to prevent clumping and to maintain optimal growth conditions.

26.5.4 The anther culture, ovary culture, meristem culture and embryo culture techniques:

Anther culture, ovary culture, meristem culture, and embryo culture are all techniques used in plant tissue culture to produce new plants with desirable traits.

Anther culture: Anther culture is a plant tissue culture technique that involves the culture of anthers (male reproductive organs) in a nutrient medium to induce their development into haploid plants. The technique is widely used in plant breeding programs to produce haploid plants, which can be used to develop homozygous lines through chromosome doubling. The process involves the removal of

anthers from the flowers of a donor plant, followed by their placement on a nutrient medium containing plant growth regulators such as auxins and cytokinins. The anthers are then allowed to grow and develop into haploid plants, which can be further propagated and used for breeding purposes. The anther culture technique is particularly useful for the rapid production of homozygous lines, which can be used to develop new crop varieties with desired traits such as disease resistance, improved yield, and quality

Ovary culture: Ovary culture involves the culture of immature ovules on a nutrient medium such as cytokinins and auxins. The cells in the ovary can be induced to divide and differentiate into embryos, which can be used to produce new plants. Ovary culture is used to produce haploid and diploid plants, depending on the method used.

Meristem culture: Meristem culture is a plant tissue culture technique that involves the isolation and culture of shoot apical meristems, which are regions of actively dividing cells located at the tips of plant shoots. The technique is used to produce disease-free plants from infected or diseased plant material, as the shoot apical meristem is often free of viruses, bacteria, and other pathogens.

Embryo culture: Embryo culture involves the culture of embryos, which can be obtained from seeds or by inducing the formation of embryos in tissue culture. Embryo culture is used to produce genetically identical plants, as embryos can be divided to produce multiple plantlets with the same genetic makeup.

Each technique has its own advantages and limitations and can be used for different applications, such as the production of haploid plants, disease-free plants, and genetically identical plants.

26.5.5 Techniques, Applications, and limitations of animal tissue culture:

Animal tissue culture involves the growth of animal cells in vitro under controlled conditions. This technique has a wide range of applications in basic and applied research, drug discovery,

biotechnology, and regenerative medicine. Here are some of the commonly used techniques:

Primary cell culture:

Primary cell culture involves the isolation of cells directly from animal tissues and their growth in vitro. This technique is used to study the behavior of cells in their native environment and to test the toxicity and efficacy of drugs. The limitations of primary cell culture include the limited lifespan of cells and the potential for contamination with microorganisms.

Cell line culture:

Cell line culture involves the establishment of immortalized cell lines from primary cells. These cell lines can be used to study cell behavior and function under different conditions, to screen for new drugs, and to produce recombinant proteins. The limitations of cell line culture include the potential for genetic drift, the lack of physiological relevance, and the potential for contamination with other cell lines or microorganisms.

Transfection and gene expression analysis:

Transfection involves the introduction of foreign DNA into animal cells, which can be used to study gene function and regulation. This technique can be used to express recombinant proteins, to knock down or overexpress specific genes, and to study the effect of genetic mutations on cellular processes. The limitations of transfection include the potential for toxicity, the low efficiency of gene transfer, and the potential for off-target effects.

3D culture:

3D culture involves the growth of animal cells in three-dimensional structures, which can mimic the architecture and function of native tissues. This technique is used to study tissue development, regeneration, and disease, and to test the toxicity and efficacy of drugs. The limitations of 3D culture include the complex and variable nature of the structures, the potential for contamination, and the high cost and technical expertise required.

Applications of Animal tissue culture:

Animal tissue culture is a widely used technique in modern biological research with many applications in various fields. Some of the most common applications of animal tissue culture include:

Cell-based assays: Animal tissue culture is used to create a standardized platform for cell-based assays that allow researchers to test the effects of various drugs, chemicals, or other substances on cells in a controlled environment.

Vaccine development: Tissue culture is used to grow viruses or bacteria for use in vaccine production, which helps to reduce the risk of contamination and increase the purity of the vaccine.

Cancer research: Tissue culture is used to grow cancer cells in vitro, which can help researchers to study the mechanisms of cancer development, test new treatments, and screen potential drugs.

Toxicity testing: Tissue culture is used in toxicology studies to determine the potential harmful effects of chemicals, drugs, or other substances on cells or tissues.

Regenerative medicine: Tissue culture is used to grow cells or tissues for transplantation, tissue engineering, and other regenerative medicine applications

26.6 TRANSGENIC BACTERIA, PLANTS AND ANIMALS:

Transgenic living thing are those having foreign gene is inserted in it.

26.6.1 Main Objectives behind Transgenic Bacteria, Plants and Animals

The objectives of producing transgenic bacteria, plants, and animals include:

Transgenic bacteria:

Transgenic bacteria are genetically modified by the introduction of foreign genes or DNA. Making transgenic bacteria

involves inserting a desired gene into the bacterial DNA through recombinant DNA technology. The gene of interest is first isolated and then inserted into a **plasmid**.

The plasmid is then introduced into a bacterial strain such as **Escherichia coli** (E. coli) through transformation. The use of transgenic bacteria for insulin production has allowed for large-scale production of insulin at a lower cost, making it more accessible to patients with diabetes. Once the transgenic bacteria are produced, they can be used for various applications such as the production of recombinant proteins, bioremediation, and gene therapy.

Transgenic plants: The production of transgenic plants aims to introduce new genes or modify existing ones to improve plant traits such as yield, disease resistance, and nutrient uptake, and to produce useful products such as pharmaceuticals, vaccines, and **biofuels**.

Biofuels are a type of fuel derived from renewable biological sources, such as plants. **Cellulose** can be broken down into simple sugars that can be fermented and distilled to produce biofuels such as ethanol. One example of a transgenic plant used in biofuel production is **switchgrass**, which has been engineered to produce higher levels of cellulose and to be more resistant to pests and diseases. Other transgenic plants used in biofuel production include corn, soybeans, and canola.

Transgenic animals: transgenic animals are genetically modified organisms that have had one or more genes from a different species introduced into their genome. The goal of producing animals that have desired traits, such as improved disease resistance, enhanced growth rate, or the ability to produce pharmaceuticals.

One modern application of transgenic animals is in the field of medicine. For example, transgenic animals can produce human proteins used to treat various diseases. One such example is **antithrombin**, a protein used to treat blood clotting disorders, in transgenic goat milk. This can be especially useful in areas where food is scarce, as it can increase the amount of food that is available.

26.6.2 Introduction of DNA into plant and animal cells/embryos

Method	Description
Electroporation	High voltage electrical pulse creates temporary pores in the cell membrane, allowing DNA to enter.
Microinjection	DNA is directly injected into the nucleus of the cell/embryo using a fine needle.
Biolistics or gene gun	DNA-coated tiny particles are propelled at high speed into cells/embryos using a gene gun.
Agrobacterium-mediated transformation	Agrobacterium tumefaciens bacterium is used to introduce DNA into plant cells. The bacterium transfers a portion of its own DNA (T-DNA) into the plant cell, which can be replaced with desired DNA.
Liposome-mediated transfection	Liposomes (tiny spheres made of lipids) encapsulate DNA, which is then introduced into cells/embryos.
Viral vectors	Modified viruses deliver DNA sequences to specific cells, commonly used for gene therapy in animals.

26.6.3 Role of biotechnology in the production of insect, virus, and herbicide resistant plants:

Biotechnology has played a significant role in insect, virus, and herbicide-resistant plants. By introducing specific genes into the plants, scientists have been able to enhance the plants' resistance to certain pests and environmental stressors, thus improving their productivity and yield.

Insect-resistant plants: Scientists have developed genetically modified (GM) plants that produce a toxin called **Bacillus thuringiensis** (Bt), which is toxic to certain pests, such as the European corn borer and cotton bollworm. The Bt toxin is produced by a gene transferred into the plant's genome, usually via Agrobacterium-mediated transformation. The toxin is highly specific

to the target pest, reducing the need for chemical pesticides, which can be harmful to the environment and non-target species.

Virus-resistant plants: Virus-resistant plants have been developed by introducing genes encoding viral coat proteins, which prevent viral replication and infection in the plant. The coat protein gene is either delivered through Agrobacterium-mediated transformation or viral vectors. Several virus-resistant crops have been developed through biotechnology to combat the threat of viral diseases to crops. These include genetically modified papaya that is resistant to the ringspot virus, tomato that is resistant to the Tomato yellow leaf curl virus, potato that is resistant to the Potato virus Y, and maize varieties, such as the Maize dwarf mosaic virus-resistant maize.

Herbicide-resistant plants: Herbicide-resistant plants are developed by introducing a gene encoding an enzyme that can detoxify the herbicide, making the plant resistant to the herbicide's effect. This allows farmers to use specific herbicides to control weeds without harming the crop. The most used herbicide-resistant crops are glyphosate-resistant, developed by Monsanto and known commercially as roundup Ready.

26.6.4 Human gene transfers in different animal species

There have been several notable human gene transfers into different animal species, with potential applications and prospects.

Mice: Mice are the most used animal models in biomedical research, and human gene transfers have been used extensively to create mouse models of human diseases. For example, scientists have introduced human genes into mice to study diseases such as cystic fibrosis, Alzheimer's disease, and cancer.

Sheep: Sheep have been genetically modified to produce human proteins in their milk, which can then be used to produce biotech products such as insulin, blood clotting factors, and growth hormones.

Pigs: Pigs have been genetically modified to produce organs that are compatible with human recipients. This technique is called xenotransplantation, and it could help to address the shortage of human organs for transplantation.

Fish: Fish have been genetically modified to produce human proteins, such as insulin and growth hormone, which can be used to treat human diseases. This technique is called aquaculture biotechnology, and it can produce biotech products at a lower cost than traditional manufacturing methods.

Primates: Non-human primates, such as monkeys, have been genetically modified to create animal models of human diseases, such as Parkinson's disease and HIV.

26.6.5 Role of transgenic bacteria in making biotechnology products:

Transgenic bacteria are important tools in biotechnology to produce various products. These bacteria are genetically engineered to express specific genes that enable them to produce a wide range of useful substances, such as enzymes, hormones, vaccines, and antibodies. One of the most common uses of transgenic bacteria is producing recombinant proteins, such as insulin and growth hormones. These proteins can be produced in massive quantities by inserting the gene for the protein of interest into the bacterial genome. The bacteria can then be grown in large-scale cultures and the protein harvested and purified. Transgenic bacteria are also used to produce vaccines. For example, the hepatitis B vaccine is produced using transgenic yeast or bacteria that express the hepatitis B virus surface antigen. The antigen can then be purified and used to produce the vaccine. It can be engineered to produce enzymes that break down cellulose to produce biofuels.

26.6.6 Some ecological concerns surrounding transgenic bacteria:

Transgenic bacteria can escape into the environment and transfer their modified genes to other bacteria, potentially creating new and unknown organisms that could have negative ecological

impacts. It is called Genetic Pollution. Transgenic bacteria can affect natural ecosystems by competing with native bacteria for resources, potentially leading to the displacement of native species. Bacteria may have unintended effects on non-target organisms, including beneficial insects and microorganisms. The use of antibiotic resistance genes in transgenic bacteria can potentially contribute to the spread of antibiotic resistance in the environment. The introduction of transgenic bacteria can potentially alter microbial ecology, including the composition and function of microbial communities in soil, water, and other environments.

26.6.7 Genetic engineering and farm animals:

Genetic engineering can benefit farm animals and agriculture in many ways. For example, it can introduce disease-resistant genes into farm animals, leading to better health and protection from common illnesses and infections. Additionally, genetic engineering can improve the growth rates of farm animals, leading to larger and more productive animals. It can also enhance nutrient utilization in animals, leading to better growth and overall health. Technology can even improve the quality of animal products, such as meat, milk, and eggs, by altering their composition. Moreover, genetic engineering can reduce the environmental impact of farming by improving feed utilization efficiency and decreasing waste produced by animals. However, proper regulation and monitoring of genetic engineering technologies are crucial to ensure their responsible and ethical use.

26.7 BIOTECHNOLOGY AND HEALTH CARE:

26.7.1 Biotechnologists produce vaccines to combat health problems Vaccine:

A vaccine is a biological preparation that provides immunity to a particular disease. It contains antigens that stimulate the body's immune system to produce antibodies to fight off specific pathogens, such as viruses or bacteria that cause the disease. Vaccines are usually administered through injection or oral route and can prevent or reduce the severity of the disease.

Table. 26.4 Some important vaccines developed by biotechnologists

Vaccine	Description
Hepatitis B vaccine	Made using recombinant DNA technology. The gene for hepatitis B surface antigen is inserted into yeast cells, which produce large quantities of the antigen. The antigen is purified to make the vaccine.
Human papillomavirus (HPV)	Made using genetic engineering. The gene for HPV surface protein is inserted into insect cells, which produce large quantities of the protein. The protein is purified to make the vaccine.
Influenza vaccine	Made using a combination of biotechnological techniques. Each year, the WHO identifies prevalent influenza strains, and a vaccine is produced containing appropriate influenza antigens.
COVID-19 vaccine	Developed by Pfizer-BioNTech, Moderna, and Johnson & Johnson, these vaccines use mRNA technology to instruct cells to produce a spike protein found on the surface of the coronavirus for immune response.
Malaria vaccine	Still in development, potential candidates use biotechnology. Sanaria's vaccine, for example, uses a weakened form of the malaria parasite to stimulate an immune response

26.7.2 Biotechnology and disease diagnosis (DNA/RNA probes, monoclonal antibodies):

Biotechnology plays a significant role in disease diagnosis through the development and use of various techniques, including DNA/RNA probes and monoclonal antibodies.

DNA/RNA probes: These probes are small molecules designed to bind to specific DNA or RNA sequences. In disease diagnosis, these

probes are used to detect the presence of specific pathogens or genetic mutations associated with certain diseases. This technique is particularly useful for detecting viral infections such as HIV, hepatitis B and C, and human papillomavirus (HPV). These probes are labeled with a fluorescent or radioactive marker, making it possible to detect their binding to the target DNA or RNA sequences. This allows for quick and accurate detection of pathogens or genetic mutation in clinical samples, such as blood, urine, or tissue.

Monoclonal antibodies:

Monoclonal antibodies are laboratory-made antibodies designed to bind to specific antigens, such as proteins on the surface of pathogens or cancer cells. In disease diagnosis, monoclonal antibodies are used to detect these antigens in clinical samples. This technique is useful for diagnosing infectious diseases such as tuberculosis, syphilis, and Lyme disease. It is also used in the diagnosis of cancer, where monoclonal antibodies are used to detect specific tumor markers in blood or tissue samples. They are also used in imaging techniques, such as positron emission tomography (PET), to detect cancer cells in the body.

26.7.3 Products biotechnologists obtain for use in disease treatment:

Application	Description
Recombinant Proteins	Production of proteins using recombinant DNA technology for treating diseases like diabetes, growth hormone deficiency, and anemia.
Monoclonal Antibodies	Laboratory-made antibodies designed to target specific antigens, used for treating diseases such as cancer, rheumatoid arthritis, and multiple sclerosis.
Vaccines	Production of vaccines using recombinant DNA technology to stimulate the immune system and provide protection against diseases like influenza, hepatitis B, and human papillomavirus (HPV).

Application	Description
Gene Therapy Products	Development of gene therapy products to treat genetic disorders by replacing or repairing defective genes, targeting diseases like cystic fibrosis, muscular dystrophy, and sickle cell anemia.
Stem Cell Therapies	Utilization of stem cells to develop therapies for diseases such as Parkinson's disease, spinal cord injuries, and diabetes, enabling targeted and effective treatments for a wide range of conditions, improving patient outcomes and quality of life.

26.7.4 Current methods employed for gene therapy (in-vitro and in-vivo methods):

Gene therapy is a technique that involves the insertion, removal, or modification of genetic material within a patient's cells to treat or prevent disease. There are two main methods of gene therapy: in-vitro and in-vivo.

Therapy Name	Description
In-vitro Gene Therapy	Manipulation of cells outside the patient's body, followed by transplantation back into the patient
	a) Isolate patient's cells: Bone marrow or blood cells are isolated.
	b) Genetically modify cells: Cells are genetically modified using a viral vector or other delivery system.
	c) Expand modified cells: Modified cells are expanded to produce many cells with therapeutic genes.
	d) Transplant modified cells: Modified cells are transplanted back into the patient's body for treatment.

Therapy Name	Description
In-vivo Gene Therapy	Direct delivery of the therapeutic gene to the patient's cells or tissues within their body
	a) Deliver therapeutic gene: Gene is delivered directly using a viral vector or other system.
	b) Express therapeutic gene: Gene is expressed within patient's cells for protein production.
	c) Treat disease: Protein production leads to the treatment of the disease

26.7.5 Gene therapies in the detection and treatment of some genetic diseases:

Gene therapy has shown great promise in the detection and treatment of various genetic diseases. Here are some examples:

Hemophilia: Hemophilia is a genetic disorder that affects the blood's ability to clot properly. In-vivo gene therapy for hemophilia involves the delivery of a functional copy of the clotting factor gene to the liver cells using a viral vector. The goal of this therapy is to replace the defective gene with a functional one, leading to the production of normal clotting factors and the prevention of bleeding episodes.

Adrenoleukodystrophy (ALD): ALD is a genetic disorder that affects the nervous system and leads to the progressive destruction of the myelin sheath that covers nerve cells. In-vivo gene therapy for ALD involves the delivery of a functional copy of the ABCD1 gene to the brain cells using a viral vector. The goal of this therapy is to replace the defective gene with a functional one, leading to the production of normal ABCD1 protein and the prevention of nerve cell destruction.

26.7.6 Gene therapy for cystic fibrosis:

Cystic Fibrosis (CF): It is a genetic disease caused by a mutation in the CFTR gene that leads to the production of thick mucus in the lungs, pancreas, and other organs. In-vivo gene therapy for CF

involves the delivery of a functional copy of the CFTR gene to the lungs using a viral vector. The goal of this therapy is to replace the defective gene with a functional one, leading to the production of normal CFTR protein and improvement of lung function.

Gene therapy for CF involves the delivery of a functional copy of the CFTR gene to the lung cells of patients with the disease. The *CFTR* gene provides instructions for making a protein called the CF **transmembrane conductance regulator** (CFTR). This protein functions as a channel across the membrane of cells that produce mucus, sweat, saliva, tears, and digestive enzymes. The channel transports negatively charged particles called chloride ions into and out of cells. The transport of chloride ions helps control the movement of water in tissues, which is necessary to produce thin, freely flowing mucus. Mucus is a slippery substance that lubricates and protects the lining of the airways, digestive system, reproductive system, and other organs and tissues. The CFTR protein also regulates the function of other channels, such as those that transport positively charged particles called sodium ions across cell membranes. These channels are necessary for the normal function of organs such as the lungs and pancreas.

Genetic counseling:

Genetic counseling is a crucial process that helps individuals and families understand and manage genetic risks. It involves assessing family history and performing genetic testing to identify potential genetic disorders or mutations. Genetic counseling provides education, support, and helps individuals make informed decisions about family planning and medical management options. It also addresses ethical concerns related to genetic testing. Ultimately, genetic counseling empowers individuals and families to make informed decisions about their genetic health and care.

Genetic screening:

It is a vital medical procedure that involves analyzing an individual's DNA to detect genetic disorders and mutations. It serves various purposes such as early detection of diseases, carrier screening, prenatal screening, cancer screening, and pharmacogenomics. Early detection enables timely intervention and

better disease management, carrier screening helps with family planning, prenatal screening aids in informed decision-making, cancer screening identifies high-risk individuals for early detection, and pharmacogenomics enables personalized medicine for better treatment outcomes. In brief, genetic screening plays a crucial role in identifying risks, aiding family planning, and facilitating personalized medical care for improved disease management.

26.8 SCOPE AND IMPORTANCE OF BIOTECHNOLOGY

Biotechnology is of great importance due to its potential in addressing global challenges such as disease, hunger, and environmental degradation. It enables the development of new treatments, improved crop yields, and sustainable energy sources. Additionally, biotechnology has the power to transform industries, create economic opportunities, and drive technological advancements. With its positive impact on human health, food security, and sustainable development, biotechnology will continue to shape the future of science, technology, and society.

26.8.1 Social/ ethical implications of using gene technology in human:

The use of gene technology in humans carries significant social and ethical implications. There are health risks associated with gene therapy, including immune reactions, off-target effects on genes, and the potential for cancer or genetic diseases. The unequal access to genetic therapies raises concerns about social inequality, as lower-income individuals and those in developing countries may struggle to afford these treatments, leading to healthcare disparities. Ethical concerns arise regarding genetic enhancement and the creation of "perfect" humans, which could result in discrimination against those without desired traits. Genetic discrimination is another worry, with potential misuse of genetic information by insurers, employers, and others leading to privacy violations and increased social inequality. Additionally, unintended consequences such as genetic changes in future generations or the emergence of new genetic diseases must be carefully considered and addressed before widespread implementation of gene technology in humans.

SUMMARY

- Process of creating identical copies of DNA fragments or whole organisms.
- Allows for large amounts of specific DNA sequences.
- Used in genetic engineering, gene therapy, and agriculture.
- Technique used to determine the exact order of nucleotides in a DNA molecule.
- Crucial tool for studying genetic mutations and diseases.
- Has revolutionized fields such as genomics, personalized medicine, and forensics.
- Involves the identification, isolation, and manipulation of DNA molecules.
- Widely used in forensic science and paternity testing.
- Techniques include polymerase chain reaction (PCR) and gel electrophoresis.
- Detailed maps of the arrangement and location of genes on a chromosome.
- Used to identify genes associated with diseases and genetic disorders.
- Can aid in the development of new treatments and therapies.
- The growth of cells or tissues in a controlled environment outside of an organism.
- Used to study cellular processes, develop new medical treatments, and produce vaccines.
- It can be used to produce clones of plants and animals.
- Organisms that have had foreign genes introduced into their DNA.
- Used to improve crop yields, develop new treatments for diseases, and produce biopharmaceuticals.
- Can raise ethical concerns related to genetic engineering and genetically modified organisms (GMOs).

EXERCISE

1. Encircle the correct choice.

i) Cloning of genes creates an identical copy of a DNA sequence. The process of cloning is significant for what reason?
(a) To create a transgenic organism
(b) To diagnose genetic disorders
(c) To study gene function
(d) All the above

ii) DNA sequencing is a technique used to determine the sequence of nucleotides in a DNA molecule. What is the significance of DNA sequencing?
(a) To identify genetic variations
(b) To create a transgenic organism
(c) To study gene expression
(d) All the above

iii) DNA analysis is used to identify genetic disorders. What is the purpose of DNA analysis?
(a) Sequence of nucleotides in a DNA
(b) To study gene expression
(c) To identify genetic variations
(d) All the above

iv) Biotechnology has many applications in healthcare, including gene therapy, drug production, and diagnosis of diseases. What is the significance of biotechnology in healthcare?
(a) To study gene function
(b) To improve animal welfare
(c) To develop new materials
(d) All the above

v) Polymerase chain reaction (PCR) is a technique used to amplify DNA. What is the significance of PCR?
(a) To sequence DNA
(b) To identify genetic disorders
(c) To study gene expression
(d) All the above

vi) Gel electrophoresis is a technique used to separate DNA fragments based on size. What is the significance of gel electrophoresis?
(a) To study gene expression
(b) To sequence DNA
(c) To identify genetic variations
(d) All the above

vii) Sanger sequencing is a technique used to read the sequence of DNA. What is the significance of Sanger sequencing?
(a) To identify genetic disorders
(b) To sequence DNA
(c) To study gene expression
(d) All the above

viii) Southern blotting is a technique used to transfer DNA fragments from a gel to a membrane. What is the significance of Southern blotting?
(a) To identify genetic disorders
(b) To sequence DNA
(c) To study gene expression
(d) All the above

ix) Genomic maps are useful for:
(a) Identifying genes associated with specific diseases
(b) Creating genetically modified organisms
(c) Analyzing DNA methylation patterns
(d) Detecting protein-protein interactions

x) What is the significance of monoclonal antibodies in biotechnology?
(a) To study gene expression
(b) Used to diagnose diseases
(c) Genetically modified organisms
(d) They can be used to create new drugs

2. Write short answer of the following:

i) Why Amp^R and Lac^Z are used in construction of rDNA?
ii) What do you mean by RFLPs?
iii) How is biotechnology used in healthcare, and what are some of the potential benefits and challenges associated with its use?
iv) Why restriction enzymes are called molecular scissors?

v) What do you mean by palindrome?
vi) Enlist enzymes use in rDNA technology?

3. Give detailed answers to following questions:

i) What is DNA sequencing, and how has it been used to study genetic mutations and diseases?
ii) What is the role of DNA analysis in forensic science and paternity testing, and what are some of the methods used in this field?
iii) Describe the process of creating genomic maps and explain how this technology has been used to study genes and diseases.

BIOLOGY AND HUMAN WELFARE

Chapter 27

Major Concept

In this Unit you will learn:

- Vaccination and Integrated Disease Management
- Animal Husbandry
- Latest Techniques Applied to Enhance Crop and Fruit Yield
- Home Gardening
- Role of Microbes in Human Welfare

Biology tries to create and develop new fields with considerable changes for human welfare. It is derived and originated from human society. It could be proved by the improvements of plants and animals, production of medicine, food processing, agricultural developments, diagnosis of diseases, and information of social, habitual and cultural changes in the society. Therefore, it is very important to know the basics of biology and human welfare to investigate further prospects. It can be studied in three groups:

1. Human health and diseases
2. Role of Microbes in human welfare
3. Polices or the improvement of food

27.1 VACCINATION AND INTEGRATED DISEASE MANAGEMENT

Vaccination is the administration of a vaccine to develop artificial immunity against the infectious diseases. The effective and proper control of different, serious, vulnerable or common diseases of population by using various appropriate measures is called **integrated disease management** (IDM).

27.1.1 Integrated Diseases Management

There are some basic values of disease management including control, protection, resistance and prevention of vectors. Disease can be managed by controlling the pathogen and changing the environmental conditions which control the dispersal of pathogen.

Disease management refers to proactive measures taken to prevent and control diseases, while disease control involves reactive measures in response to existing diseases. These approaches are based on **primary prevention** (preventing diseases from occurring), **secondary prevention** (early detection and treatment), and **tertiary prevention** (minimizing impact and recurrence). Collectively, these preventive measures aim to prevent disease onset, reduce disease rates, and decrease the likelihood of diseases occurring.

Effective disease management can be achieved by implementing healthy habits and practices. Proper hand washing is essential to prevent the spread of diseases ensuring hands are washed thoroughly with soap and water. When cooking or handling food, maintaining hygiene is crucial by following safe food handling practices. Using tissue papers while coughing and sneezing helps

prevent the transmission of respiratory infections, it is important to avoid direct contact with wild animals to minimize the risk of zoonotic diseases. Furthermore, avoiding the sharing of personal items reduces the chances of disease transmission.

Major mechanisms of Diseases Management

1. Host resistance against the causative agents.
2. Biological control
3. Culture control
4. Chemical control

Host Resistance against the causative agents: The resistance property is found in animals and plants which restrain appearance of diseases or the ability of host to limit the pathogen activity. Such as defense through physical barriers and rapid immune system.

Biological Control: This is the control of disease through other living organisms (predators) that reduces the severity of diseases.

Culture Control: Culture control is usually engaging the environmental changes either having pets or diseases as well.

Cultural control based on intercropping, crop rotation, field sanitation and manipulation of spread dates etc. some of these techniques provide only small benefits when integrated with other techniques, they significantly improve disease management.

Chemical Control: Chemical control is very useful for plant and animal diseases, it is necessary to spray in that area where vector borne diseases are found. It uses pesticides, bactericides, insecticides and fungicides etc. to control pests and diseases. Chemical control produces some problems such as poisoning of humans and destroying of beneficial insects and crops as well as remainders.

Aims and objectives of integrated Disease Management

The integrated disease management approach aims to effectively halt disease prevalence, conduct protective trials to assess the effectiveness of preventive measures in reducing the risk or impact of diseases, and eliminate biological causative agents. Active

community participation and awareness through print and electronic media play a vital role, while educational institutions can organize workshops and seminars to disseminate information. Proactive measures encompass preventive actions taken to mitigate the occurrence or severity of diseases before they occur. Various preventive measures, including drug treatments, therapies, and vaccinations, are available, underscoring the importance of avoiding self-medication and seeking professional medical assistance.

27.1.2 Vaccination and Its Importance

Vaccine is a suspension that contains weakened or killed microorganisms that help to stimulate the immune system of organism against diseases. It is usually used through injections, but sometimes can be used through the mouth or sprayed into the nose. There are several types of vaccines including inactivated and live attenuated vaccines.

Vaccines are distinct from other substances as they possess the ability to evoke a response from the body's immune system, thereby enhancing its adaptive immunity and serving as a preventive measure against infectious diseases. These vaccines typically consist of fragmented or inactivated microorganisms, viruses, proteins, toxins, antibodies, lymphocytes, or messenger RNA (mRNA).

Fig. 27.1 Vaccination

The initial vaccine was developed by Edward Jenner, a British physician, in 1796. Jenner employed the cowpox virus as a vaccine to safeguard against smallpox, a related virus affecting humans. In 1881, Louis Pasteur, a French microbiologist, established immunization against anthrax by administering attenuated forms of the bacillus responsible for causing the disease.

The process of introducing vaccines into the body elicits protection against specific diseases and is known as **vaccination**. This procedure enables the immune system to effectively combat and counter germ infections. Vaccination serves as the paramount method for safeguarding communities and preventing the spread of preventable diseases. Individuals who have been vaccinated are incapable of transmitting infections to those around them. Certain vaccine-preventable diseases can lead to severe complications and even fatalities, underscoring the importance of vaccination in keeping individuals safe from these ailments. By significantly reducing the occurrence of illnesses, vaccination stands as the most crucial approach for safeguarding both adults and children. It is estimated to prevent approximately 3 million deaths worldwide

When individuals choose to forgo vaccination, they expose themselves to various diseases, including pneumococcal, influenza, HPV, hepatitis B, COVID, and more. Notably, adults are often the primary source of whooping cough infections, which can be particularly fatal for younger individuals. Therefore, it becomes imperative for adults to protect themselves, their families, and their community by receiving the appropriate vaccinations.

Chicken pox caused by the varicella-zoster virus, manifests as itchy rashes accompanied by blisters, headache, and fever. The Varicella vaccine is specifically designed to prevent this viral infection. **Tetanus**, a bacterial disease, presents symptoms such as painful spasms and muscle stiffness. The Tdap and Td vaccines are available to provide protection against tetanus and are recommended for individuals based on their age and vaccination history.

It is important to note that all vaccines undergo rigorous testing and evaluation before they are approved for use. This ensures their safety and effectiveness in preventing the targeted diseases. While some individuals may experience mild side effects after vaccination, such as temporary fever, body aches, swelling, itching, and tenderness at the injection site, these symptoms typically subside within a few days. The overall benefits of vaccination far outweigh these temporary discomforts

27.1.3 LIST OF SOME VIRAL DISEASES

Table 27.1 List of some viral diseases

Virus	Disease	Symptoms	Vaccine
Corona virus	Common cold	Fever, headache, fatigue and pain in chest shortness of breath	Sino-pharm, Sinovac, Pfizer, Moderna and AstraZeneca
Pox viruses	Cow & Small pox	Fever, sores, rashes	Varicella
Polio virus	Poliomyelitis (polio).	Fever, lack of appetite, nausea, sore throat, malaise, constipation and abdominal pain	Inactivated polio virus (IPV) Weakened poliovirus (OPV)
Hepatitis viruses	Hepatitis	Fever, Muscle aches, loss of appetite, nausea, vomiting and fatigue	Hepatitis-B vaccine
Measles, mumps, rubella viruses	Measles, mumps, rubella	A high fever, Tiredness. A barky cough. Red or bloodshot eyes. A runny nose. A red rash, which starts at the head and then spreads downward.	Measles, mumps, rubella (MMR) vaccine
Diphtheria, Tetanus viruses	Diphtheria, Tetanus	Painful stiffening of the muscles. "Whooping cough," can cause uncontrollable, violent coughing that makes it hard to breathe, eat, or drink.	Diphtheria toxoid(DT) vaccine, Tetanus toxoid(TT) vaccine

27.1.4 The Role of Vaccines in Preventing Polio, Measles, Hepatitis and Tetanus

Vaccines play a vital role in preventing the spread and occurrence of several infectious diseases, including polio, measles, hepatitis, and tetanus. These diseases have significant health risks and can lead to severe complications, disabilities, or even death. Vaccines have been developed to provide effective protection against these illnesses by stimulating the body's immune system to recognize and combat the specific pathogens responsible for causing them. Through widespread vaccination efforts, these diseases have been significantly controlled and, in some cases, even eliminated in certain regions. The use of vaccines has proven to be a critical tool in safeguarding individuals, communities, and public health by preventing the transmission and impact of these dangerous diseases

i) Vaccination against the polio

Polio or Poliomyelitis is infectious disease that is caused by **polio virus**. The virus infects the throat and intestinal tract.

Fig. 27.2 Poliomyelitis

Transmission:

Person-to-person transmission is the primary mode of spreading the polio virus. The virus can be transmitted through contact with infected fecal material and saliva. Contaminated water and food sources can also contribute to the transmission of the polio virus.

Symptoms:

Polio symptoms may include fever, reduced appetite, nausea, vomiting, sore throat, constipation, and abdominal pain.

Vaccination:

There are two types of vaccine used for prevention. **IPV** inactivated polio vaccine is administrated through the injection and **OPV** oral polio vaccine is given orally especially to the children under the age of five.

Fig. 27.3 Polio vaccine

ii) Vaccination against the Measles

Measles is caused by a virus in the **paramyxovirus** family, an infectious disease that is highly transmissible from one person to another.

Transmission:

Measles is transmitted through the air, making it an airborne disease. The virus is primarily spread through respiratory droplets and aerosol particles when an infected person coughs or sneezes.

Symptoms:

High fever, cough, red eyes, runny nose, sore throat, and a characteristic rash that begins on the head and spreads throughout the entire body

Vaccination:

The **MMR** vaccine offers protection against Measles, Mumps, and Rubella. It is a combination vaccine that contains live attenuated measles virus and is highly effective in preventing measles. The MMR vaccine has been proven to be safe, with no significant side effects reported.

iii) Vaccination against the Hepatitis

Hepatitis is an inflammation of the liver, primarily caused by hepatitis viruses, which are categorized into five main strains: types A, B, C, D, and E.

Hepatitis A can lasts from few weeks to various months, it is acute and short-term disease.

Hepatitis B lasts from few weeks to chronic conditions.

Hepatitis C develops from mild to chronic infection; it is blood born viral infection for long term.

Hepatitis D is not common infection. Spread through direct contact with the bodily fluids of an infected person.

Hepatitis E is water born disease; it is acute but dangerous for pregnant women.

Transmission:

Different types of hepatitis have distinct modes of transmission. Hepatitis A spreads through contaminated food and water, while hepatitis B and C are transmitted through body fluids such as blood and vaginal secretions. Hepatitis D specifically transmits through blood contact. Lastly, hepatitis E is primarily transmitted through contaminated food and water sources.

Symptoms:

These are some common symptoms of Hepatitis; Flu like symptoms, loss of appetite, abdominal pain, fatigue and jaundice like symptoms such as yellow eyes, skin, urine and stool.

Vaccination:

Vaccination against hepatitis is essential in preventing the diseases. The hepatitis A vaccine is formulated using an inactivated form of the virus, while the hepatitis B vaccine is produced using recombinant DNA technology. These vaccines are readily accessible and effective in providing protection against their respective hepatitis strains. It's important to note that currently, there is no available vaccine for hepatitis C

iv) Vaccination against the Tetanus

Tetanus, commonly known as "lockjaw," is indeed a bacterial infection caused by the bacterium *Clostridium tetani*. However, the toxin produced by the bacterium affects the nervous system, leading to muscle stiffness and spasms rather than direct muscle contraction. The incubation period for tetanus is usually between 3 and 21 days, with an average of 10 days.

Transmission:

C. tetani is found in the soil and dust, and it enters into the body through the injured skin.

Symptoms:

Tetanus is characterized by several symptoms, including muscle stiffness and contractions, which can lead to lockjaw, causing difficulty in fully opening the mouth. Prolonged muscle contractions called tetany result in sustained muscle spasms and rigidity. Additional symptoms may include breathing difficulties, feeding problems, and gastrointestinal issues like constipation.

Vaccination:

Different types of vaccines are used to protect from diphtheria and tetanus. The vaccine is called **DT vaccine**. (Diphtheria & tetanus). TDP vaccine is used for Tetanus, diphtheria and Pertussis (whopping cough).

27.1.5 Schedule of the Vaccination of Polio, Measles, Hepatitis and Tetanus

Table 27.2 Schedule of the Vaccination

Disease	Vaccine	Age group
Polio	OPV vaccine, IPV vaccine	Birth to 5 years
Measles	MMR vaccine (Measles, Mumps and rubella)	Up to one year
Hepatitis-A Hepatitis-B	Hepatitis A vaccine is inactivated Hepatitis B vaccine is recombinant DNA	At any age
Tetanus & Diphtheria	DT vaccine (Tetanus & Diphtheria) TDP vaccine (Tetanus, diphtheria and Pertussis or whopping cough).	Childhood

27.2 ANIMAL HUSBANDARY

Animal husbandry, is a branch of agriculture, encompasses the management and care of livestock such as buffaloes, cows, cattle, sheep, goats, horses, and poultry for various purposes including milk, eggs, meat, fiber, and other food products. This involves providing proper care for the animals, including their living space, cleanliness, timely and appropriate feeding, access to water, breeding, reproductive processes such as calving i.e., giving birth to a calf in cattle, provision of shelter during inclement weather, shade for protection from sunlight, and attentive care during the birthing process and subsequent nourishment of the offspring. Additionally, ensuring the availability of veterinary medicine and professionals for

the health and well-being of the animals is crucial, along with fulfilling all necessary requirements and necessities.

Animals play a vital role in providing a diverse range of highly nutritious food products, emphasizing the need for proper care and attention. Meat and dairy products from animals like cows, buffaloes, and goats are commercially significant, as they are rich sources of protein and in high demand. Additionally, animals such as hens and ducks contribute to the protein supply through the production of eggs. Animal husbandry encompasses various sectors including poultry, dairy farming, apiculture (beekeeping), and aquaculture. Adequate preparation and maintenance of healthy and visually appealing animals are crucial for successful sales and marketing in this field

Major types of Animal husbandry

These are some major types of animal husbandry

Dairy farming:

Dairy farming focuses on the production of milk, which serves as a significant source for various dairy products like cheese, yogurt, cream, and butter. The successful management of dairy animals, including cows, buffaloes, sheep, and goats, is crucial for ensuring their physical and mental well-being, as it directly impacts human welfare. To maintain commercial value, these dairy animals require constant attention and regular inspections.

Poultry Farming:

Poultry farming involves the breeding and rising of birds for commercial purposes. Birds such as hens, ducks, and turkeys are raised both for meat and egg production, serving both commercial and household needs. Ensuring the well-being and health of these birds is of utmost importance, requiring careful care and regular inspections to maintain a disease-free and healthy environment.

Apiculture (Bee farming):

Apiculture, also known as bee farming, involves the management of bee colonies within manmade hives. Honey bees are domesticated for their commercial value in providing honey, wax, and playing a crucial role in pollination. The designated location for keeping bees is referred to as an apiary.

27.2.1 Role of live stocks in National Economy

Livestock plays a crucial role in Pakistan's economy, contributing approximately 11.9 percent to the GDP and employing about 37.4 percent of the labor force according to economic survey 2021-22. It provides essential products like milk, meat, eggs, wool, and various by-products, which ensure food security, nutrition, and income for numerous rural and urban households. Livestock also serves as a valuable source of draught power for agriculture and transportation, as well as organic fertilizer for crop production. Despite facing challenges such as low productivity and inadequate infrastructure, the livestock sector has exhibited impressive growth, driven by factors like high yields, favorable prices, government support, and improved access to resources. Pakistan has emerged as a leading global producer of milk and meat. However, there is a need to address issues like low productivity, feed quality, healthcare services, marketing infrastructure, and environmental degradation. Embracing modern technologies, enhancing animal welfare standards, promoting value addition and processing capabilities, and facilitating exports are vital for enhancing the sector's competitiveness and sustainability.

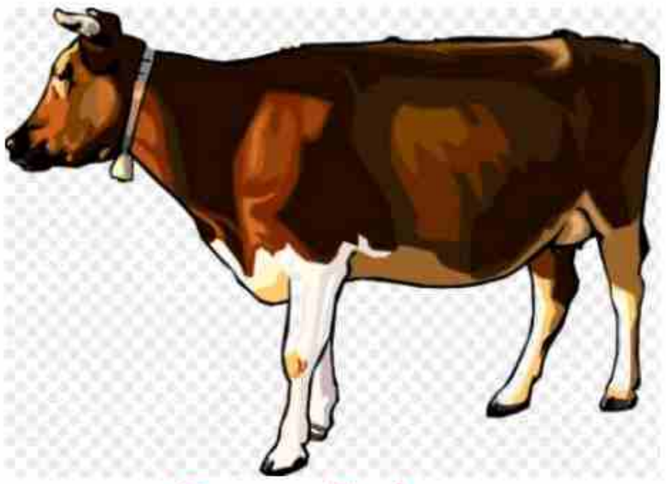
27.2.2 List of Outstanding Milk Producer Breed of Cows in Pakistan

Cow is the second leader of outstanding milk producer breeds in Pakistan; there are five main Cows such as Brown Swiss, Simmental, Normande, Jersey and Holstein. Whereas **Brown Swiss** and **Simmental** are the best milk producing breeds.

Table: 27.3 Outstanding milk producing breeds of Cow per lactation cycle

	Cow	Per lactation cycle
1.	Brown Swiss	10,000- 12,000 L
2.	Simmental	About 9,000 L
3.	Normande	6,000 - 7,000 L
4.	Jersey	5,000-6000 L
5.	Holstein	4,000- 5000L

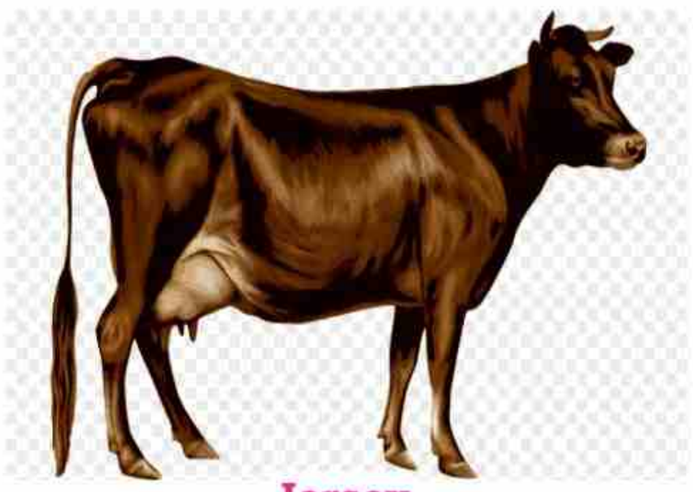
Note: (The lactation cycle is the period between one calving and the next one. It consists of three phases the early, mid and late lactation and dry period)



Brown Swiss

Simmental

Normande



Jersey

Holstein

Fig. 27.2 Types of Cows

27.2.3 Outstanding Milk Producing Breeds of Buffalo

Buffalo is the chief milk producing breeds in Pakistan. There are different varieties of buffalo such as Nili-Ravi, Kundi, Jaffrabadi, Godavari and Bhadawari. **Nili-Ravi** is the top milk producing animal of this group, Pakistan has two best breeds of buffaloes such as Nili-Ravi and Kundi.

Table: 27.4 Outstanding milk producing breeds of Buffalo per lactation cycle

	Buffalo	Per lactation cycle
1.	**Nili- Ravi**	**1500-2500 L**
2.	**Kundi**	**1700-2000 L**
3.	**Jaffrabadi**	**1000-1200 L**
4.	**Godavari**	**1200-1500 L**
5.	**Bhadawari**	**800-1000 L**

Note: (The lactation cycle is the period between one calving and the next one. It consists of three phases the early, mid and late lactation)

Fig. 27.3 Types of Buffalos

27.3.1 Latest Techniques Applied to Enhance Crop and Fruit Yield

Plant breeding is to change the characters of plants qualities into wanted or advancement in characters. **Mendel is known to be the father of Plant breeding**. Plant breeding also enhances the biodiversity which shows genetically and ecologically variations.

Methods adopted for plant improvements

There are different methods which are adopted for plant improvement such as Acclimatization, selection, hybridization and back crossing.

Acclimatization:

Acclimatization is a natural process through which plants adjust to changes in their environment, including variations in temperature, humidity, salinity, behavior, and physiology. It involves the plant's ability to adapt and regulate its biological functions to thrive under different conditions.

Plant introduction, on the other hand, refers to the intentional transfer of plants from their original habitat to a new location. The purpose of plant introduction is to establish new crop varieties or species in that particular area. This process plays a crucial role in agricultural development by expanding crop diversity and enhancing productivity.

As examples of successful plant introductions, Kinohimitsu or kino originated from Singapore, papaya from South Mexico and Central America, potatoes from Peru and northwestern Bolivia, and sweet potatoes from Central or South America have all been introduced and cultivated in the subcontinent

Selection:

Selection is a fundamental process in plant breeding and serves as the basis for crop improvement. It involves choosing or segregating the best quality plants from a population of crop plants. The purpose of selection is to identify and propagate plants that exhibit desirable traits under specific conditions.

Hybridization:

Hybridization is a key technique in plant breeding that involves the crossing or fusion of two genetically dissimilar parents through artificial pollination. This process results in the production of offspring or hybrids that are characterized by heterozygosity. Hybrids display characteristics such as vigor, size, growth rate, and yield. The outcome of hybridization is the development of hybrid varieties in crops such as onions, tomatoes, oilseeds, pulses, and fruits. Heterosis or hybrid vigor refers to the superiority of hybrids over their parents in one or more traits. This superiority is reflected in higher yield rates and increased resistance to diseases and pests.

Backcrossing:

Backcrossing is a technique used to introduce specific traits from a hybrid back into its parent or a genetically similar individual. It is commonly applied in horticulture, animal breeding, and the development of knockout or unconscious individuals. Backcrossed hybrids are often denoted by the acronym "**BC**." For instance, when an F1 hybrid is crossed with one of its parents or a genetically similar individual, it is referred to as " $\mathbf{BC_1}$." Subsequent crossings lead to the production of " $\mathbf{BC_2}$**'** " generation and so on.

27.4.1 Home Gardening

Home gardening is a multifaceted system that combines farming and gardening practices within and around the home. It involves the cultivation of various plants, including flowers, attractive plants, vegetables, and fruits. Home gardening serves several purposes, such as meeting food requirements, beautifying the house, and providing a space for children to play and for hosting social gatherings. It offers numerous benefits on economic, social, physical, and environmental levels.

Fig. 27.6 Home gardening

One of the key aspects of home gardening is the promotion of organic plantation. This method has gained significant importance nowadays as it avoids the use of pesticides and artificial fertilizers, focusing instead on natural and sustainable practices.

Importance of Home Gardening:

Enhancement of Nutritional Value: Home gardens contribute to the improvement of the nutritional value of food by providing fresh and organic fruits, vegetables, and other produce.

Mental and Physical Health Benefits: Engaging in gardening activities boosts mood and reduces stress. Tasks such as preparing the garden area, digging, plant selection, and watering contribute to keeping the body active and provide aerobic exercise. Simply spending time in the garden, particularly walking, has positive effects on physical well-being.

Positive Environmental Effects: Home gardening creates a natural environment around houses, balconies, and galleries, often utilizing containers and pots for plant growth. The plants absorb carbon dioxide (CO_2) and release oxygen, contributing to a vigorous and fresh environment.

Erosion Reduction: The presence of plants in the soil helps in reducing erosion.

Source of Fresh and Organic Food: Home gardening ensures the availability of fresh, clean, and organic food. The produce grown in such gardens is rich in vitamins, as it grows in soil free from pesticides but enriched with natural fertilizers.

Control of Family Budget: Growing fruits and vegetables at home reduces expenses and allows families to have better control over their budgets. These homegrown products are of high quality, delicious, and available year-round, requiring families to only purchase items such as cooking oil from the market.

Year-round Food Availability: Home gardening enables a continuous supply of food throughout the year, avoiding the need for consuming produce from cold storage, which may not be as healthy.

Entertainment and Activities: The garden space around the house provides opportunities for exercise, yoga, parties, and play. Children benefit from the garden as a playground, and the presence of green plants has positive effects on health and eyesight. Beautiful decorative plants add to the overall aesthetic appeal of the home.

27.4.2 Some Seasonal Vegetable and Fruit Plants Suitable for Home Gardening

Table No. 27.5 List of summer vegetables and fruits

Vegetables of Summer	Fruits of Summer
Green beans	Mango
French beans	Apricots
Squash	Plums
Carrot	Leeches
Cauliflower	Grapes
Garlic & Onion	Guava
Okra	Papaya
Brinjal	Peaches
Cabbage	Water melon
Green & red chilies	Grewia

Table No. 27.6 List of winter vegetables and fruits

Vegetables of Winter	Fruits of Winter
Asparagus	Oranges
Peas	Banana
Garlic	Grape fruit
Spinach	Date
Potato	Pummel
Tomato	Kiwifruit
Winter lettuce	Passion fruit
Broad beans	Pear
Onion	Tangeries
Spring cabbage	Pomegranate

27.5 ROLE OF MICROBES IN HUMAN WELFARE

Microbes, including bacteria, viruses, and parasites, are microscopic organisms that cannot be seen with the naked eye. They are found in various environments such as water, soil, and air. Microbes have both beneficial and harmful effects on human welfare. While some microbes can cause diseases, they also play crucial roles in the production of antibiotics, vaccines, enzymes, vitamins, and the fermentation of dairy products such as cheese and curd.

27.5.1. List of some Beneficial Viruses

Cowpox virus: Provides immunity against smallpox.
Oncolytic viruses: Kills cancer cells and aids immunity.
Bacteriophages (phages): Specifically infect and kill bacteria.
Endogenous retroviruses: Contributed to placenta evolution
Gamma herpes virus (MHV-68): Shows resistance to infection

27.5.2 Role of microbes in household food processing:

Microbes play a vital role in everyday food processing in households, including the production of yogurt, bread, and cheese.

Bread: Bread dough contains yeast, specifically ***Saccharomyces cerevisiae***, which undergoes fermentation. During fermentation, yeast produces carbon dioxide (CO_2) and ethyl alcohol. The CO_2 gas creates air pockets in the dough, giving it a puffy and soft texture once baked.

Yogurt: The conversion of milk into yogurt involves the use of specific microbes, such as ***Lactobacillus*** species. These microbes ferment the lactose present in milk, converting it into lactic acid. This fermentation process gives yogurt its tangy flavor and thick texture.

Cheese: Various types of cheese available in the market are produced using specific microbes. For example, Swiss cheese utilizes the bacteria ***Propionibacterium shermanii***, while Roquefort cheese is ripened using the fungi ***Penicillium roqueforti***. These microbes contribute to the unique flavors, textures, and ripening processes involved in cheese production.

Role of microbes in industrial production:

Microbes also play a significant role in industrial production, particularly in the food industry. They are utilized in the production of various products, including chemicals, hormones, antibodies, beverages, fruit juices, and enzymes.

Fermented beverages: ***Saccharomyces cerevisiae***, the same yeast used in bread production, is commonly employed in the production of fermented beverages. These microbes convert sugars into alcohol during the fermentation process, resulting in the production of alcoholic beverages like beer and wine.

Role of microbes in sewage treatment:

Sewage treatment involves the removal of pollutants from wastewater. Microbes, particularly Bacillus species, play a significant role not only in sewage treatment but also in the breakdown of proteins and oils. The treatment of wastewater is crucial to mitigate its negative impact on the environment. The process typically consists of three steps: primary, secondary, and tertiary treatments.

Primary Treatment: Primary treatment focuses on the removal of floating solids and organic materials from the sewage. It involves allowing the sewage to pass slowly through a basin, where heavy solid materials settle down. This stage is often carried out in a primary sedimentation tank.

Secondary Treatment: In the secondary treatment phase, solid materials are further removed by employing microbes to digest and break down residual organic matter. The microorganisms naturally present in the sewage feed on the solid organic materials, facilitating their growth and multiplication. This step reduces the organic content of the sewage through aerobic or anaerobic processes.

Sludge Digestion: Sludge digestion is a biological process in which organic solids present in the wastewater are decomposed into stable substances. This process helps in reducing the volume of sludge and converting it into more manageable and environmentally friendly forms.

Tertiary Treatment: Tertiary treatment serves as the final stage of sewage treatment, aimed at improving the quality of the treated water before it is reused or discharged. This stage involves various advanced processes such as filtration, disinfection, and nutrient removal to further enhance the water quality.

Effluent: Effluent refers to the treated wastewater that is released or reused after undergoing the necessary treatment processes.
Microbes play a crucial role in the breakdown and removal of organic materials during sewage treatment, contributing to the effective and environmentally responsible management of wastewater.

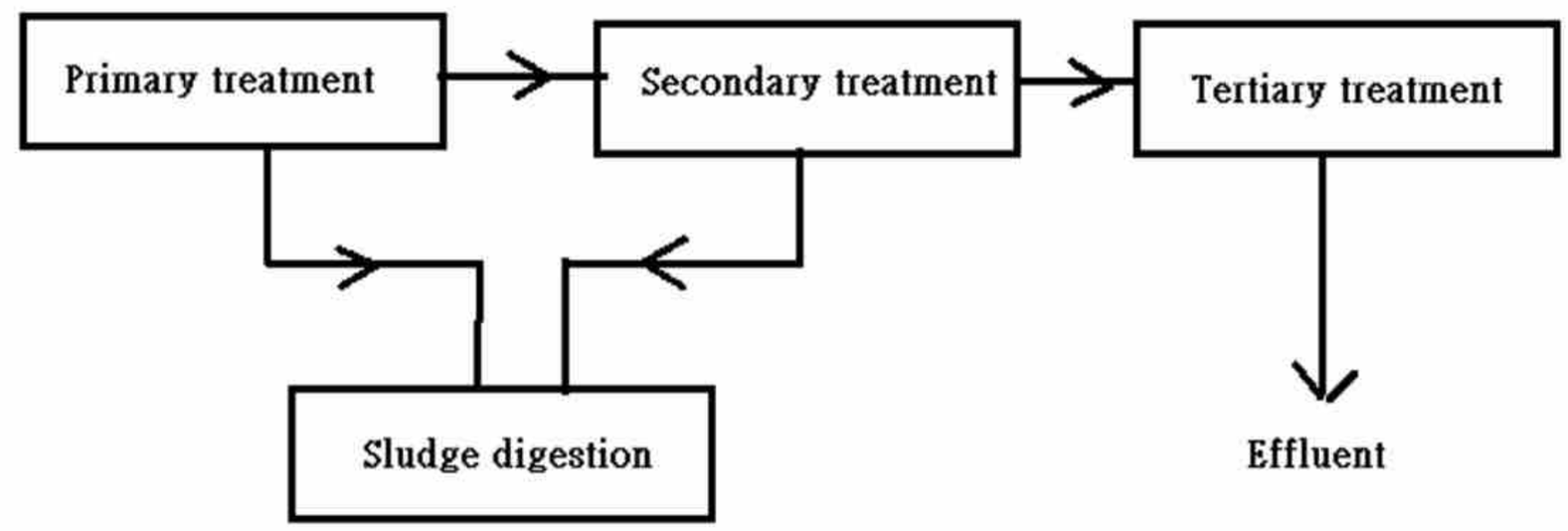


Fig. 27.7 Sewage treatment plant

Role of microbes in energy generation:

Microbes play a crucial role not only in sewage treatment but also in energy generation. They have the ability to generate various forms of fuel, such as hydrogen, methane, lipids, and ethanol, which can be utilized as sources of energy. When these fuels are burned, they produce energy.

Microorganisms also contribute to energy generation through their role in the decomposition of organic or inorganic matter in ecosystems. During this process, they produce electrons that can be harnessed for energy production.

Specific bacteria, such as *Escherichia coli* and *Bacillus subtilis*, have the capability to thrive on carbon resources present in the environment through processes like photosynthesis and enzymatic hydrolysis. These bacteria have been utilized to produce strains of ethanol or liquid biofuels, which can serve as renewable energy sources.

The ability of microbes to generate energy-rich compounds and participate in the breakdown of organic matter contributes to the development of sustainable energy solutions. By harnessing the energy-generating capabilities of microorganisms, we can explore and utilize alternative sources of fuel that have a reduced environmental impact compared to traditional fossil fuels

SUMMARY

- The effective and proper control of different, serious, vulnerable or common diseases of population by using various appropriate measures is called integrated disease management.
- Effective disease management can be achieved by implementing healthy habits and practices.
- The control of disease through other living organisms (predators) that reduces the severity of diseases.
- The initial vaccine was developed by Edward Jenner, a British physician, in 1796. Jenner employed the cowpox virus as a vaccine to safeguard against smallpox, a related virus affecting humans.
- The process of introducing vaccines into the body elicits protection against specific diseases and is known as vaccination.
- The Varicella vaccine is specifically designed to prevent this viral infection.
- Polio symptoms may include fever, reduced appetite, nausea, vomiting, sore throat, constipation, and abdominal pain.
- Animals play a vital role in providing a diverse range of highly nutritious food products, emphasizing the need for proper care and attention.

EXERCISE

1. Encircle the correct answer:

i) DT vaccine is used for
(a) Hepatitis (b) Measles
(c) Common cold (d) Diphtheria toxoid

ii) *Clostridium tetani* which caused tetanus is a
(a)Virus (b) Bacteria
(c) Parasite (d) Fungi

iii) MMR vaccine is effective for
(a) Measles (b) Polio
(c) Measles, Mumps & rubella (d) Hepatitis

iv) The top milk producing animal of Pakistan is
(a) Bhadawari (b) Jaffrabadi
(c) Nili- Ravi (d) Godavari

v) The yeast that gives puff appearance to dough is called
(a) *Saccharomyces* (b) *Lactobacillus*
(c) *Penicillium* (d) *Escherichia coli*

vi) The removal of floating solids and organic materials from the sewage is
(a) Primary treatment (b) Secondary treatment
(c) Tertiary treatment (d) none of these

vii) The process of hybrid crossing with its parents is called
(a) Selection (b) Hybridization
(c) Back cross (d) Acclimatiz ation

viii) French beans and Cauliflowers are vegetables of
(a) Winter (b) Summer
(c) Spring (d) all seasons

ix) The Science that deals with the modification of DNA and enhances the characteristic of an organism is called
(a) Genetic Engineering (b) Biotechnology
(c) Biology (d) None of these

x) Sludge digestion is a biological process in which organic solids are decomposed into stable substances
(a) Stable substances (b) non stable substances
(c) Effluent (d) None of these

2. Write short answer of the following

i) Why vaccination is important for infectious disease?
ii) List the outstanding milk producing breeds of cow.
iii) What do you mean by integrated diseases and its management?
iv) What is the role of livestock?
v) Differentiate between following
(a) Selection and Backcross
(b) Vegetables of summer and vegetables of winter
(c) Selection and Hybridization

3. Give detail answer of the following questions

i) Explain in detail different steps of sewage treatment.
ii) Explain vaccination and its importance.
iii) Describes the role of microbes in food processing and sewage treatments.

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تو نِشان عزمِ عالی شان ارضِ پاکستان
مرکزِ یقین شاد باد

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