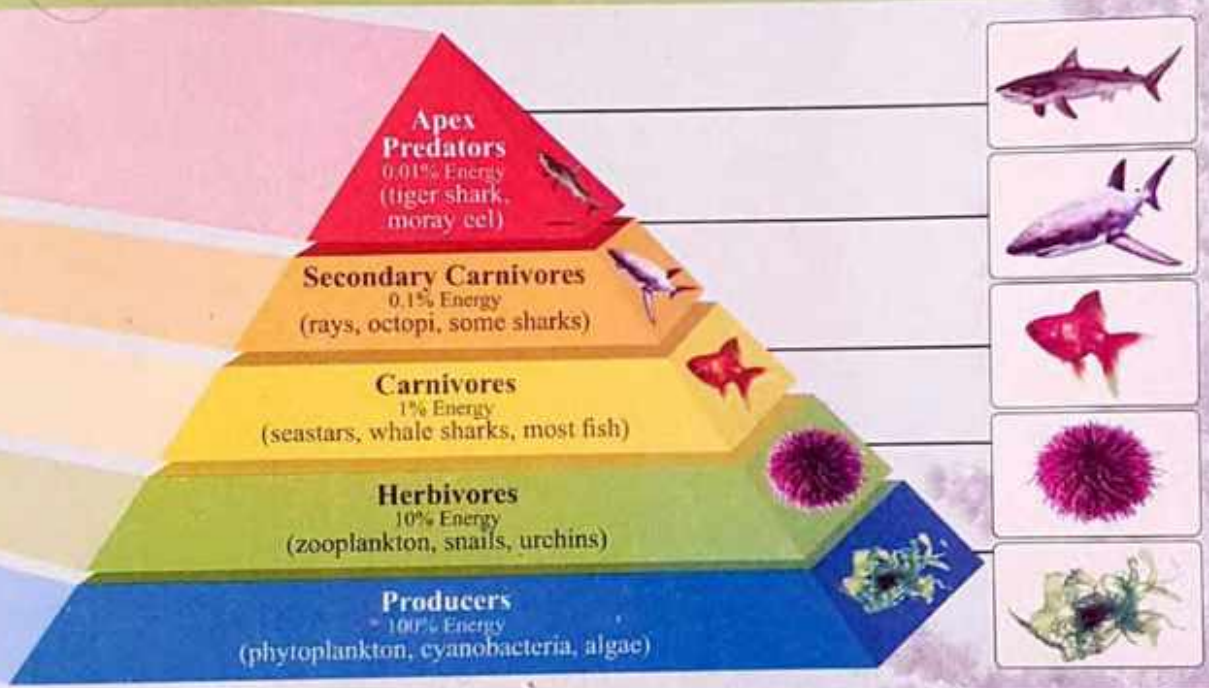
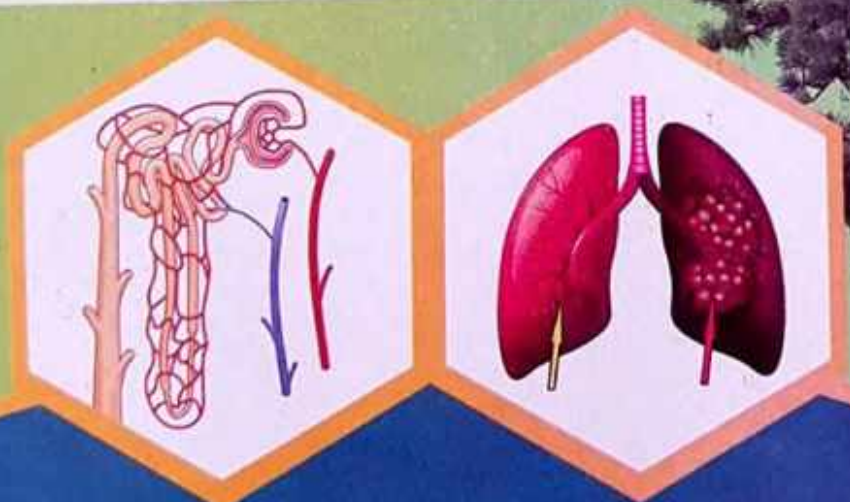
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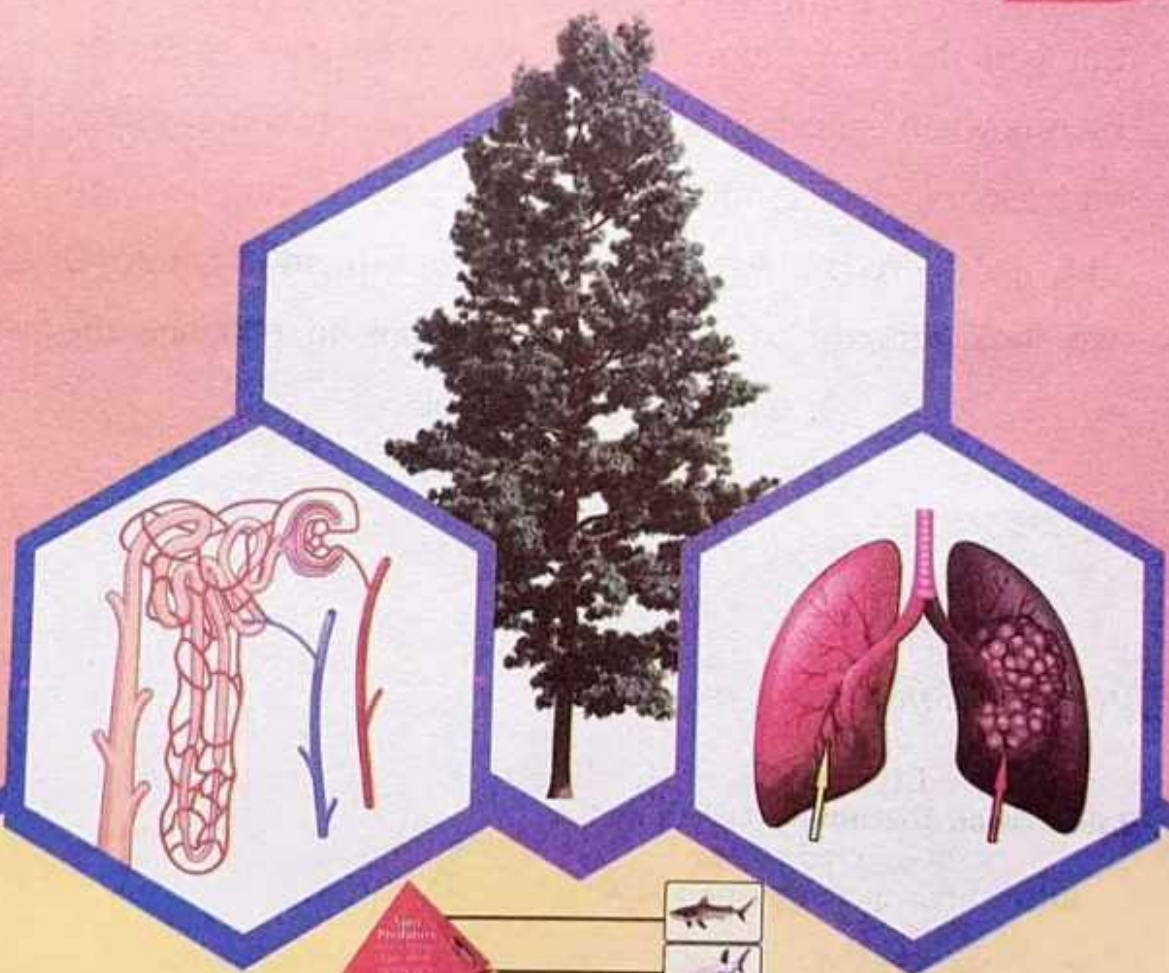
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Authors

Preface

Biological Research is in the midst of a revolutionary change due to the integration of powerful technologies alongwith new concepts and methods derived from inclusion of Physical Sciences, Mathematics, Computational Science and Engineering.

We are living in the 21st century where the role of science and technology cannot be denied. Biology as subject is playing a pivotal role to explain the complex nature of life. Now, there is a need for every individual to know the worth of scientific saturations, and in this regard it's Biology which is going to help every individual of a society in today's world.

It is essential that we learn the Morphology and Physiology of all living things. How to live in harmony with the other residents of earth. Thus study and teaching of Biological Science at each and every level of education has become inevitable.

The text for class XII has been developed in accordance with the demand of national curriculum 2006, which is based on attainment of standard benchmarks and learning outcomes.

The special features of this book are:

- Each chapter begins with the brief introduction of topic.
- The headings and sub-headings of each topic is written in different colours which help the students to differentiate between topics and sub topics.
- For the first time new informative pattern is introduced e.g., extra and interesting information, tables or boxes, STS connection etc.
- The exercise of each chapter is written according to the pattern of paper as prescribed by educational board that is section 1 is comprising of objective questions which include MCQs and completion of blank spaces. Section 2 includes short questions and section 3 includes long questions.
- SLOs of each chapter are given in the beginning of the chapter while summary is given at the end of each chapter in order to assist students recall their knowledge about said chapter.
- Biological names of organisms are written in italics letter.

At the end of this book:

- Glossary has been provided to understand the biological terms.
- Index is also given for the convenience of students to locate different topics.

Your kind guidance will be appreciated:

- Despite our earnest efforts there can be certain errors and omissions in this book as human limitations, suggestions and positive criticism, therefore, from our colleagues, teachers and students will definitely inculcate a new spirit in us for further improvement of the textbook.

Authors

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UNIT 14

RESPIRATION

Major Concept

14.1 Respiratory System of Man
14.2 Mechanism of Transport of Respiratory Gases
14.3 Respiratory Disorders

Learning Outcomes

Students will be able to:

- Define the respiratory surface and list its properties
- Describe the main structural features and functions of the components of human respiratory system
- Describe the ventilation mechanism in humans
- State lung volumes and capacities
- Explain how breathing is controlled
- Describe the transport of oxygen and carbon dioxide through blood
- Describe the role of respiratory pigments
- State the causes, symptoms and treatment of upper Respiratory Tract Infections (sinusitis, otitis media) and lower Respiratory Tract Infections (pneumonia, pulmonary tuberculosis)
- Describe the disorders of lungs (emphysema and lung cancer)
- List the effects of smoking on respiratory system

Introduction

For normal functioning of organisms chemical substances are needed, which must be transported into and around the body, while waste substances must be transported from where they are produced to outside.

Respiration is the one of most important processes in this respect. There are two levels of respiration *i.e.* external respiration and internal respiration.

External Respiration is also known as breathing which is the process of taking fresh air (containing more oxygen) into the respiratory organs (lungs) then to cells and removal of stale air (containing more CO_2) from respiratory surfaces or organs.

Internal Respiration is also known as cellular respiration. It is a catabolic process, releases energy from organic food molecules. The energy is released in the form of Adenosine Triphosphate (ATP) that is used for development, growth various bodily activities, repair damage parts and reproduction.

14.1 Respiratory System of Man

Respiratory system is responsible for the gaseous exchange between cells, body fluids (blood), respiratory surfaces and outer environment.

14.1.1 Properties of Respiratory Surfaces in Animals and Human

Respiratory surface are the areas where gaseous exchange between animals and environment occur. These surfaces in various animals are skin, tracheas, gills and lungs. The respiratory surfaces show following characteristics for readily exchange of gases through diffusion.

1. It should be large, moist and highly permeable for easy exchange of gases.
2. It should be thin epithelium (1mm or less) and also possess network of blood capillaries, which facilitate rapid transport and diffusion of gases between respiratory surface and blood.
3. A good ventilation mechanism should be present to maintain a steep diffusion gradient.

14.1.2 Components of Respiratory System of Man

This system can be divided into two main parts, the respiratory tract or air passage way and respiratory organs. The **respiratory tract** consists of external nostrils, nasal sacs or cavities, internal nares, pharynx, larynx, trachea, bronchi, bronchioles and alveolar ducts that terminate into the alveoli while respiratory organs are a pair of lungs.

14.1.3 Nose or Nasal Cavities

The human **nose** is the only externally visible parts of respiratory tract which is made of bones, cartilages and fatty muscle tissues. The external opening of nose is called

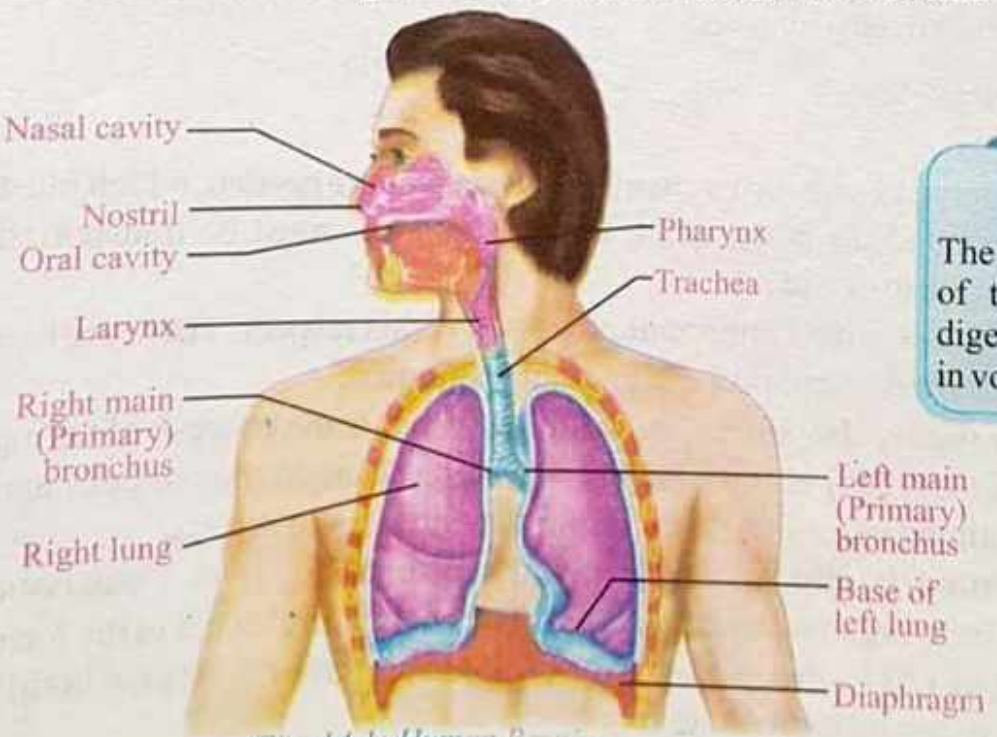


Fig. 14.1: Human

Extra Information

The throat or pharynx is part of the both respiratory and digestive system. It also helps in vocalization.

external nostrils. There is a nasal septum which separates two **nasal cavities** or **vestibules** from each other. These cavities contain a network of hair, lined by mucous membranes (secrete mucus) along with cilia, which serves as a defense mechanism against pathogens, trap dust and solid particulate substances present in the air. These substances are pushed to pharynx by cilia for removal.

The mucus also moists the air and brings the temperature of inhaled air close to body temperature about 30°C depending upon external temperature. (Fig.14.1)

14.1.4 Pharynx

The internal nostrils at the back of nose, opens the nose into the pharynx, which is muscular mucus secreting passage, cone shaped, conne-cts oral cavity and nasal cavities to the oesophagus and larynx. It consists of three sections, the **nasopharynx**, **oropharynx** and **laryngoph-arynx**. The inter connection of oral and pharyngeal cavity is medically beneficial to us, which allows to breath both by mouth and nose. (Fig.14.2)

14.1.5 Larynx

Larynx is also called **voice** or **sound box**. It is composed of cartilages and muscles, one of the cartilages that acts as a lid called **epiglottis**. During swallowing the epiglottis automatically covers the opening and cavity of larynx known as glottis. Two **vocal cords**, made of elastic fibres, placed horizontally in the lower side of glottis. The vibration of these cords produces voice. In adult male these cords are larger thus usually produce low pitched voices. (Fig. 14.3)

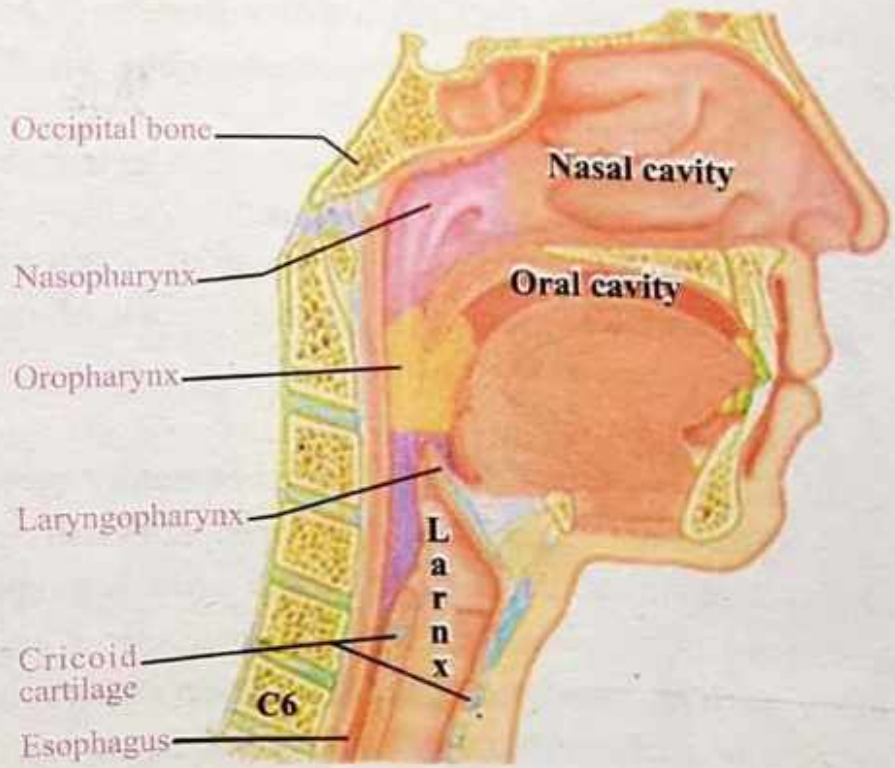


Fig. 14.2: Nasal Passage

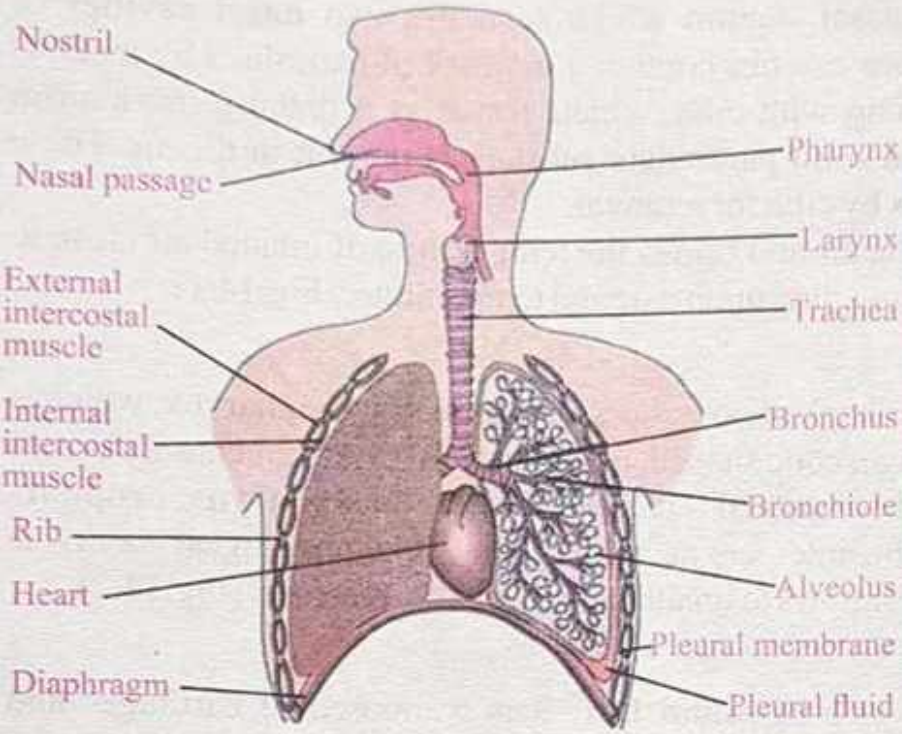


Fig. 14.3: Larynx, Trachea and Bronchi

Extra Information

Larynx also acts as an air canal to the lungs and organ of phonation. **Adam's** apple is a feature of the human (mostly male) neck and is the protrusion formed by the angle of thyroid cartilage surrounding the larynx.
In female, larynx does not grow as much as male therefore, most female do not posses Adam's apple.

14.1.6 Trachea and Bronchi

Trachea is a ciliated membranous wind pipe, runs ventral to oesophagus and extends to thoracic cavity up to 5th thoracic vertebrae (about 10 -12 cm long). It contains **15-22 C-shaped cartilaginous rings.** Each ring is with a diameter of 2 cm. These rings prevent the trachea from collapsing and keep an open air passage way. The trachea first divides into two primary bronchi.

Each **bronchus** enters into its side lung where it redivides in many bronchi. It is also made of cartilages but these instead of C-shaped become plate like cartilages.

The bronchi finally give rise to smaller membranous tubes that are less than 1cm in diameter known as **bronchioles**, which lack cartilages, made of ciliated **cuboidal epithelium** and a layer of circular smooth muscles.

14.1.7 Alveolar ducts and Alveoli

The bronchioles divide and subdivide to form respiratory bronchioles which eventually terminate into **alveolar ducts.** These ducts open into small collections of air sacs known as **alveoli**. The air sacs are made of simple **squamous epithelium**, only 0.1cm thick and have rich network of capillaries, thus these are sites of gaseous exchange between air and blood. Each lung possesses about **350 million alveoli**, so these increase the surface area for gaseous exchange. Alveoli also contain collagen and elastin proteins which allow them to expand and recoil easily during breathing. (Fig. 14.4)

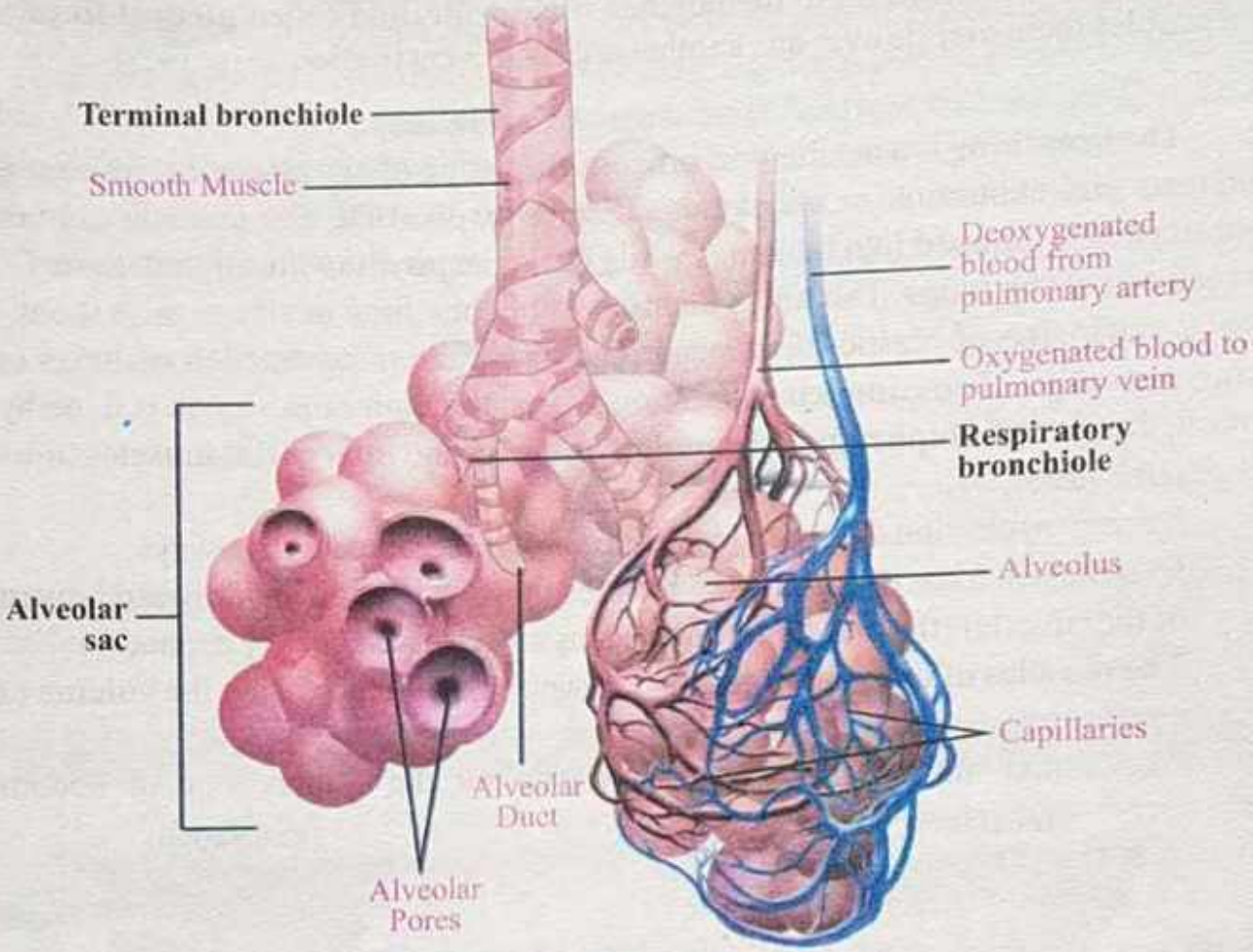


Fig. 14.4: Alveolar Ducts and Alveoli

14.1.8 Respiratory Organs (Lungs)

In human, respiratory organs are a pair of spongy **lungs**, located in the thoracic cavity, bonded dorsally and ventrally by twelve pairs of ribs. The floor of thoracic cavity is called diaphragm. The lungs are conical in shape, left lung possesses two lobes while right lung has three lobes. Both lungs are separated from each other by a membrane known as **mediastinum.** Each lung is covered by double pleural membrane.

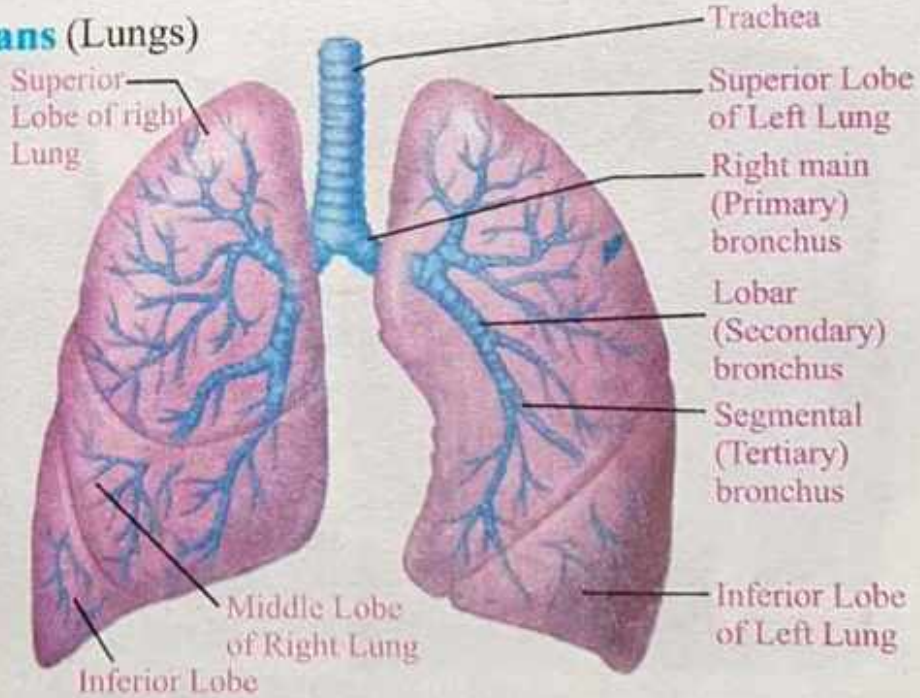


Fig 14.5: Human Lungs

There is a space between these membranes filled with fluid called **pleural fluid**. This fluid enables them to slide over one another and to prevent friction. (Fig. 14.5)

14.1.9 The Mechanism of Breathing (Ventilation)

The **breathing** is a mechanical process consisting of two phases *i.e.* inspiration or inhalation and expiration or exhalation. During **inspiration**, the fresh air containing more oxygen is pumped into the lungs while during **expiration** the air with more CO_2 is pumped out of the lungs. The lungs themselves neither draw in air nor push it out. The passive expansion of elastic lungs occur and also passive contraction of lungs occur during expiration. The complete expiration and contraction of the lungs is done by the combined action of **diaphragm, abdominal muscles** and **intercostal muscles** (muscles between the ribs).

During inspiration the space inside the chest is increased by two ways.

i) External rib muscles contract, which result in the upward and forward movement of the ribs, thus the pressure from the lungs is released and they expand.

ii) The muscles of diaphragm contract, lowering it and increasing the volume of the chest cavity.

Abdominal muscles relax to compensate for the compression of abdominal

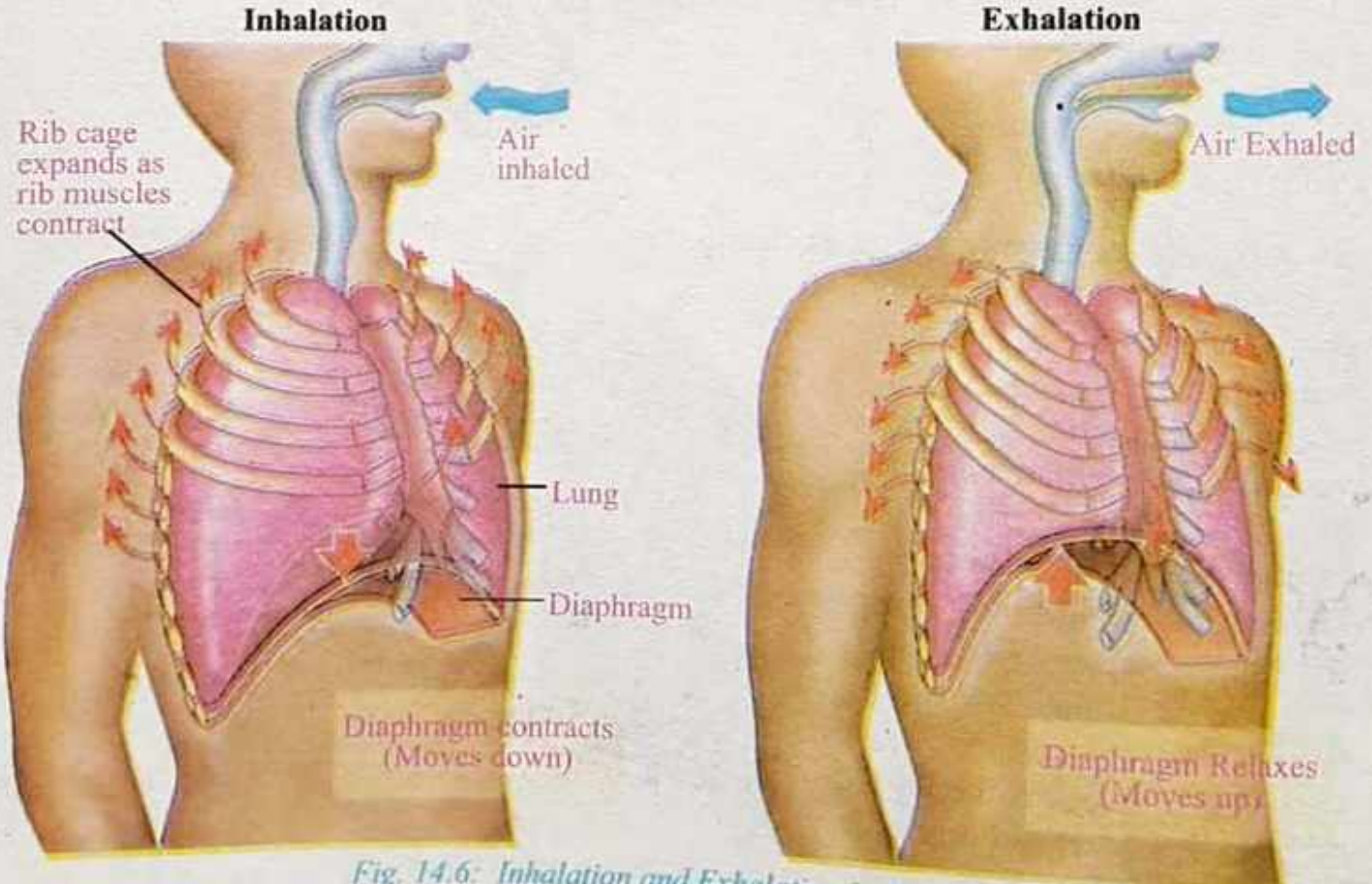


Fig. 14.6: Inhalation and Exhalation in Human

organs. The release of pressure from lungs by upward movement of ribs and increase in the chest cavity by downward movement of diaphragm causes the pressure in the chest cavity to drop below the atmospheric pressure and thus air rushes through the respiratory passage into the lungs to equalize the pressure inside and outside.

During expiration the volume of chest cavity is decreased. Muscles of the ribs are relaxed and the ribs move downward and inward, in this way from the side of the chest cavity the space becomes less.

At the same time the muscles of diaphragm also relax, the diaphragm projects into the thoracic cavity and become dome-shaped, therefore, the chest cavity is also reduced from the floor as well.

The abdominal muscles contract to push the abdominal organs against the diaphragm. The elastic lungs also contract and force the air to expel out. The reduction of space of the chest cavity exert pressure on the lungs thus the air inside the lungs move out of the lungs and this is known as expiration. (Fig. 14.6)

Table: 14.1 Differences between internal and external respiration

S.No.	External Respiration	Internal Respiration
i)	It is the exchange of respiratory gases (O_2 and CO_2) between the organism and its environment.	It is a biochemical process occurs within the cell to oxidize food molecules.
ii)	It is exchange of gases between circulatory fluid and external environment.	It is exchange of gases between the cell and circulatory fluid.
iii)	No ATP, H_2O are formed.	ATP, CO_2 and H_2O are produced.
iv)	It is aerobic respiration.	It may be aerobic or anaerobic respiration.

14.1.10 Lungs Respiratory Volumes and Capacities

The **respiratory volume** is also known as **pulmonary volume**, which is the amount of air inspired, expired and stored within lungs at any given time. It is the amount of air during breathing.

Tidal volume is the amount of air moved in and out with each quiet breath which is normally 500 ml during deep breath. We can increase the inspiration by as much as 3000 to 4000 ml of air during forced inspiration. This is known as **inspiratory reserve** volume. About 1200 – 1500 ml air always remains in the lungs (even during deep breath), this is called **residual volume**. (Fig. 14.7)

Extra Information

Spirometer is a device which helps to measure the respiratory volume and the process.

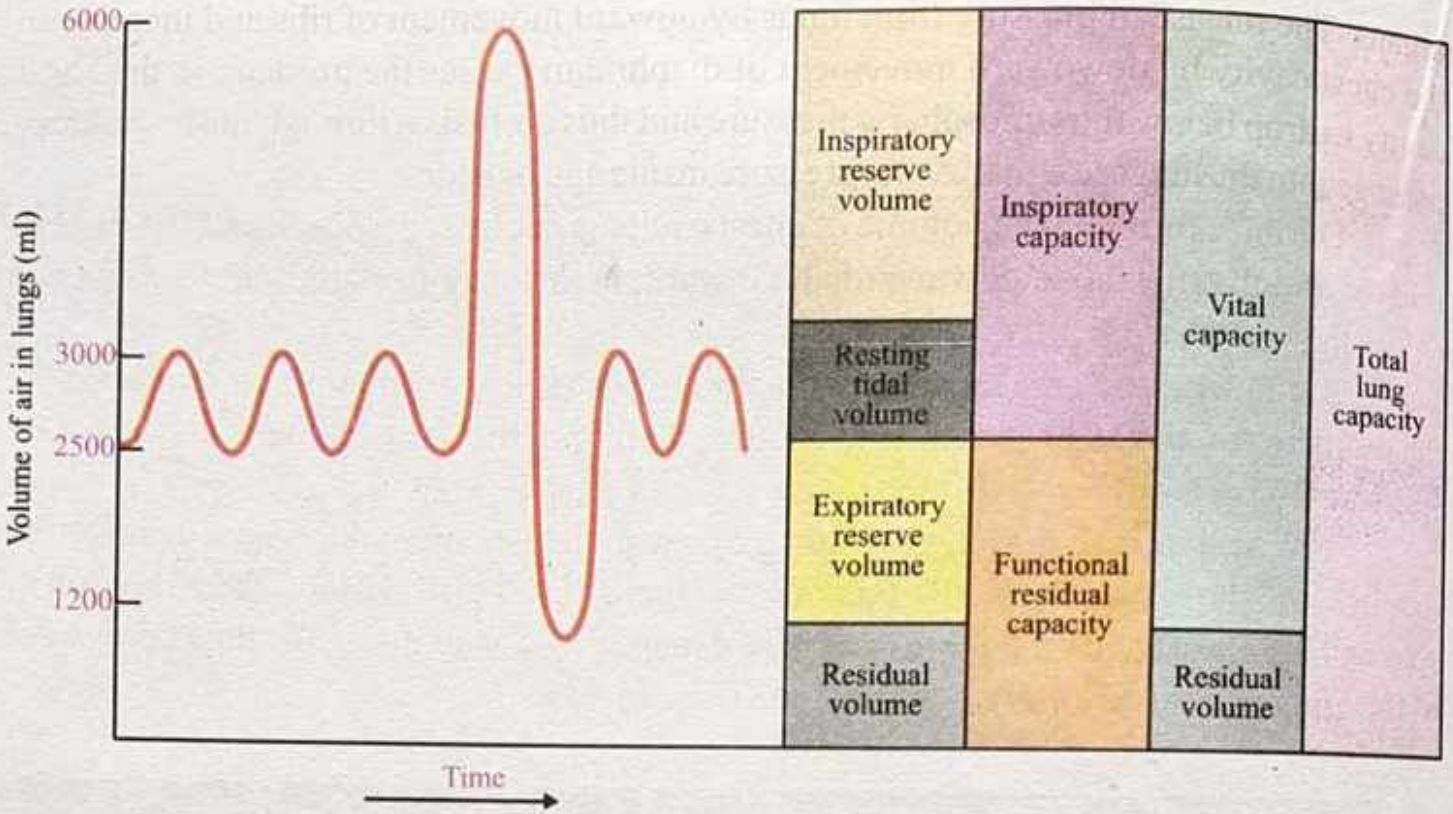


Fig. 14.7: Respiratory Volume

14.1.11 Controlling Centres of Breathing

Breathing is controlled both involuntarily and voluntarily. The **medulla** of our brain is controlling centre for involuntary breathing. The normal breathing rate is 15–20 times per minute. The voluntary or consciously control centre is **cerebral cortex of cerebrum** while **limbic system** of the brain also acts as respiratory centre during emotional acts.

Extra Information

The lower portion of medulla acts as inspiratory centre while upper and lateral portions acts as expiratory centres.

14.2 Mechanism of Transport of Respiratory Gases

Respiratory gases **(CO_2 and O_2)** are transported to various body regions by means of blood.

14.2.1 Respiratory Pigments and their Role

i) **Haemoglobin** is the most important respiratory pigment present in many animals including man. It is a complex protein consisting of four polypeptide chains *i.e.* 2 alpha chains and 2-beta chains having 574 amino acids. Each chain is associated with an haeme group. Haeme group is an iron containing group, which consists of **porphin** with a central atom of ferrous (iron) between four pyrrole rings. (Fig. 14.8)

Function of Haemoglobin

Haemoglobin is an iron containing protein in the red blood cells of vertebrates. It

transport oxygen to the tissues. Haemoglobin increases the oxygen carrying capacity of the blood in human to about 75 times. Iron in haemoglobin combines loosely with oxygen in the red blood cells (RBC) of pulmonary capillaries to form oxyhaemoglobin. This bright red blood containing oxyhaemoglobin is then circulates and reaches tissue and cells of the body where oxyhaemoglobin releases oxygen. This happens because haemoglobin has a property to release its oxygen where there is low concentration of oxygen and color of blood become purple red. After releasing oxygen, the haemoglobin returns back to the lungs with deoxygenated blood, to become again oxyhaemoglobin.

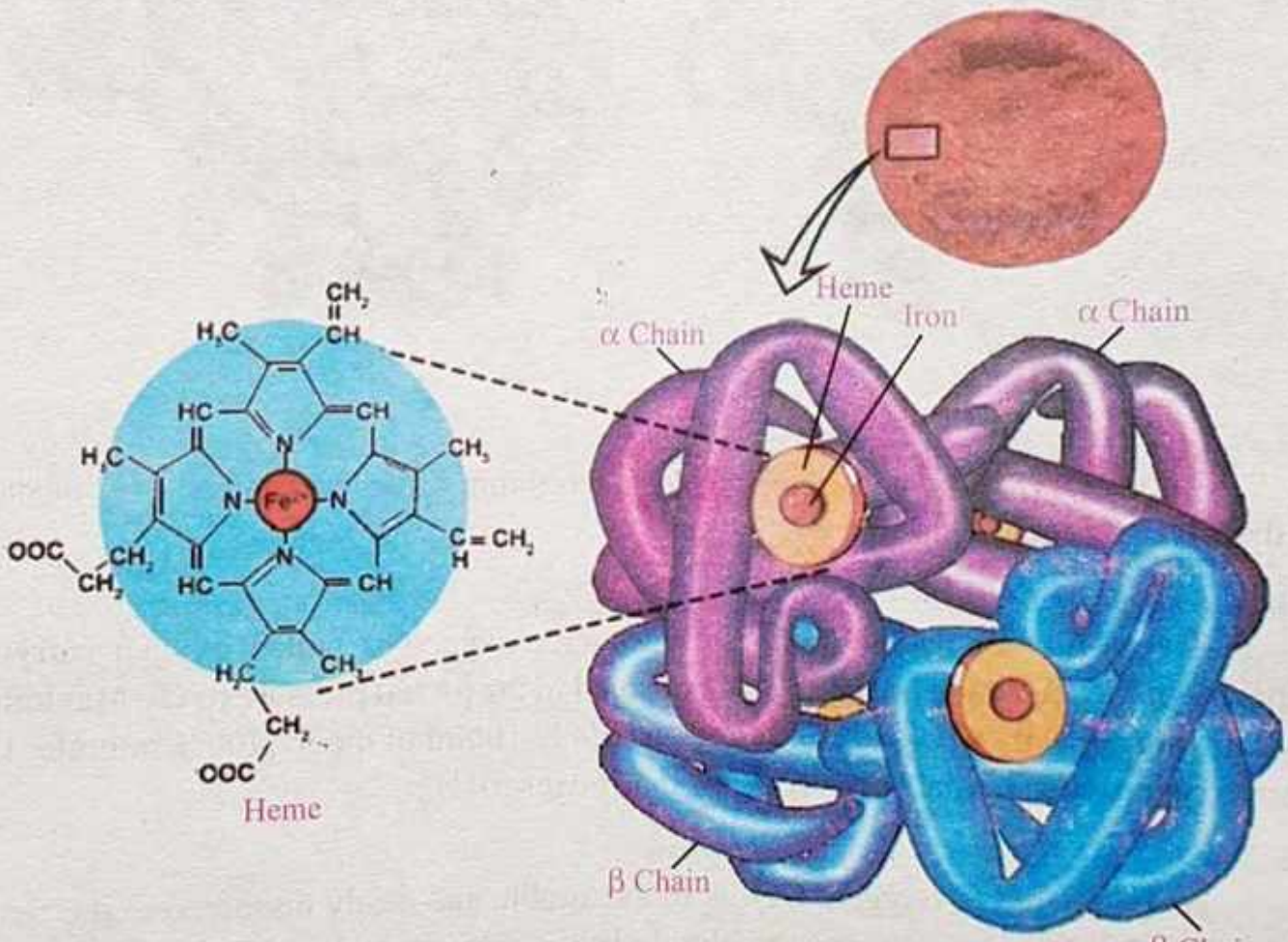


Fig. 14.8: Haemoglobin

ii) **Myoglobin** is another respiratory pigment in man, which is present in the muscle of human and other mammals. Therefore, meat is red. It is made of one iron containing polypeptide chain (contain 154 amino acids and bind only one molecule of oxygen).

Function of Myoglobin:- It stores oxygen in the muscle and gives oxygen when partial pressure of oxygen is below 20 mm of Hg. It has more affinity to combine with oxygen than haemoglobin. (Fig. 14.9)

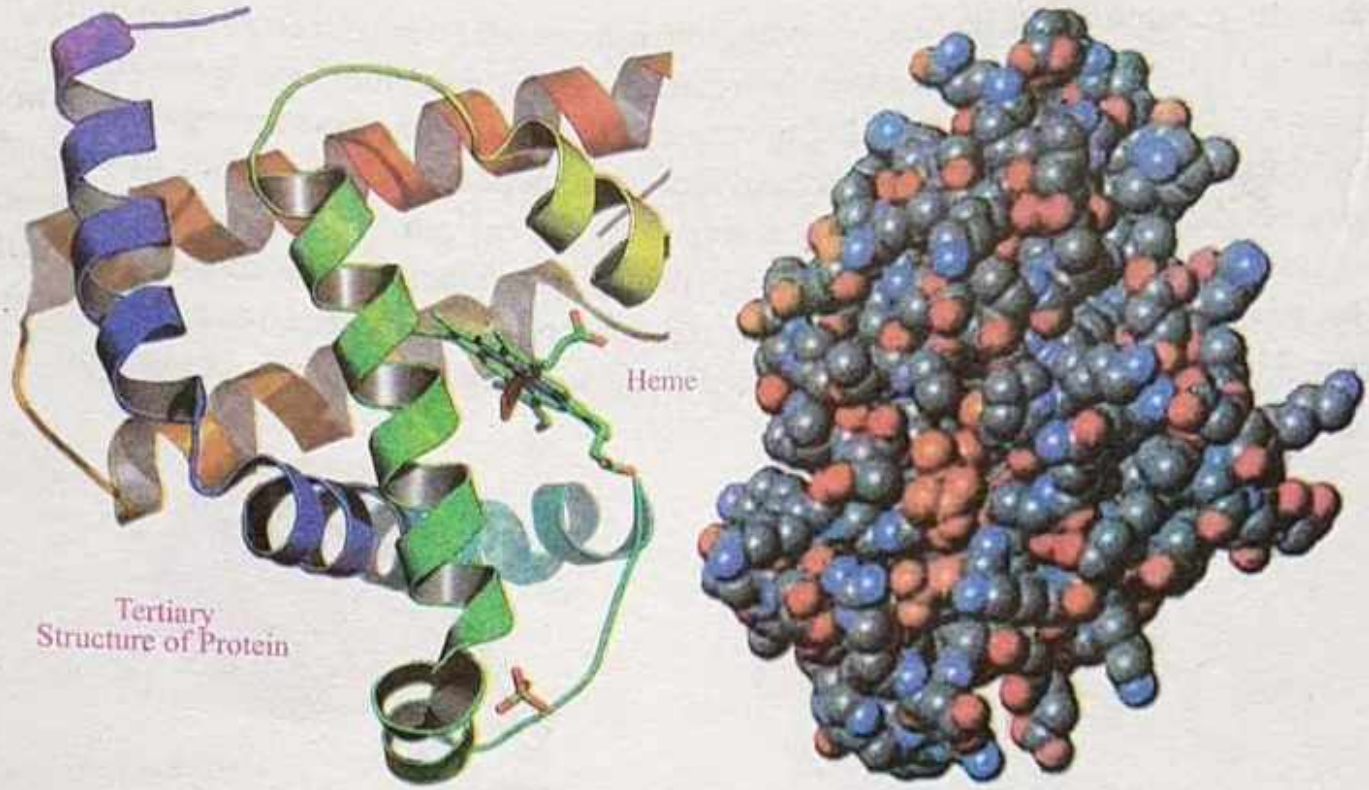


Fig. 14.9: Myoglobin

14.2.2 Transport of Oxygen in Blood

About 97-98% oxygen is carried by haemoglobin while remaining 2-3% transport as dissolved oxygen in plasma.

$$Hb\ (Haemoglobin) + 4O_2 \xrightleftharpoons{Carbonicanhydrase} 4O_2Hb\ (oxyhaemoglobin)$$

The ability of haemoglobin to bind with oxygen is called oxygen carrying capacity of blood, which is directly proportional to the partial pressure of O_2. Maximum O_2 carrying capacity of blood at sea level is 20ml / 100ml of blood (100% saturated). It loses oxygen when partial pressure is less than 60 mm of Hg.

14.2.3 Transport of Carbon Dioxide

As compared to oxygen, CO_2 is more soluble and easily dissolved in the tissue fluid. The CO_2 from tissue passes to blood plasma, present within the blood capillaries where its transport occurs by three ways.

i) As bicarbonate ions (about 70%)
ii) As carboxyhaemoglobin (about 23%)
iii) As dissolved CO_2 in plasma (about 7%)

i) As bicarbonate ions (HCO_3)

First of all, the CO_2 is released as a result of oxidation reduction reaction and enters the plasma of the blood in tissue fluid. In blood, CO_2 combines in the presence of

an enzyme named as carbonic anhydrase with water inside RBCs and form carbonic acid.

$$CO_2 + H_2O \xrightarrow{\text{Carbonic Anhydrase}} H_2CO_3 \text{ (Carbonic Acid)}$$

The carbonic acid splits quickly and ionizes to form hydrogen ions (H^+) and bicarbonate ions (HCO_3).

$$H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$$

All these reactions are reversible. When the blood leaves the capillaries and comes into blood vessel all the CO_2 is now in the form of bicarbonates. Bicarbonates diffuse out of the red blood cells and carried by the plasma and H^+ is absorbed by the globin protein of haemoglobin.

When the blood reaches the alveoli of lungs capillaries, the bicarbonate ions again combine with H^+ ions to form carbonic acid again.

$$HCO_3^- + H^+ \rightleftharpoons H_2CO_3$$

The carbonic acid again splits into H_2O and CO_2

$$H_2CO_3 \xrightarrow{\text{Carbonic Anhydrase}} H_2O + CO_2$$

This CO_2 diffuses out of the capillaries into alveoli of lungs from where it is expelled out by the process of expiration. (Fig. 14.10)

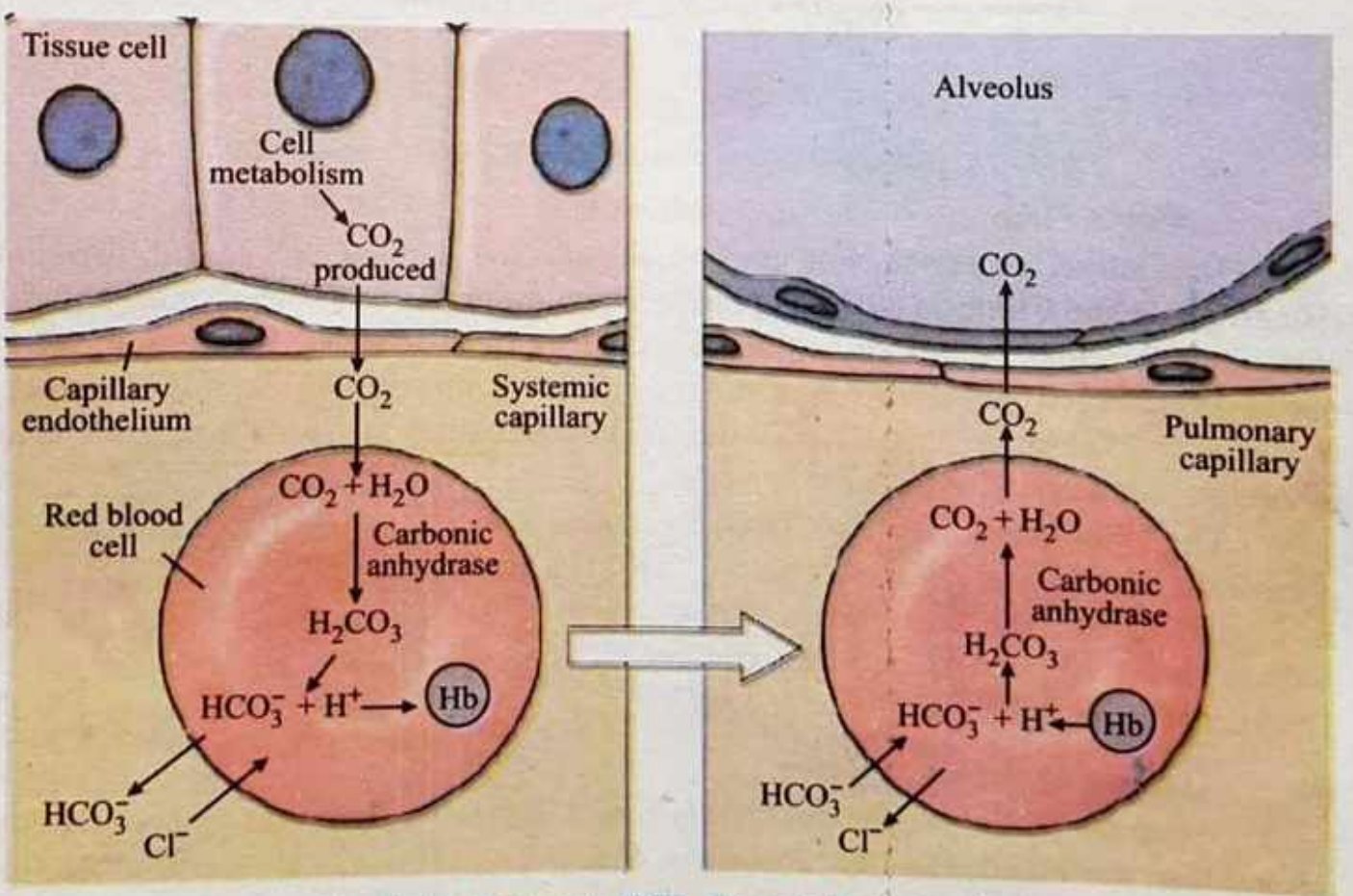


Fig. 14.10: Transport of CO_2 (From Cells to Alveolus)

Role of Hydrogen Ions

The pH of blood may decreases due to H^+ ions in the blood, but it does not occur since haemoglobin acts as buffer for Hydrogen ions. The oxyhaemoglobin readily combines with hydrogen ions to become reduced into **haemoglobin acid (HHb)** and oxygen is released to the tissues. (Fig.14.11)

$$4O_2\ Hb + H^+ \square\square\square \quad HHb + 4O_2$$

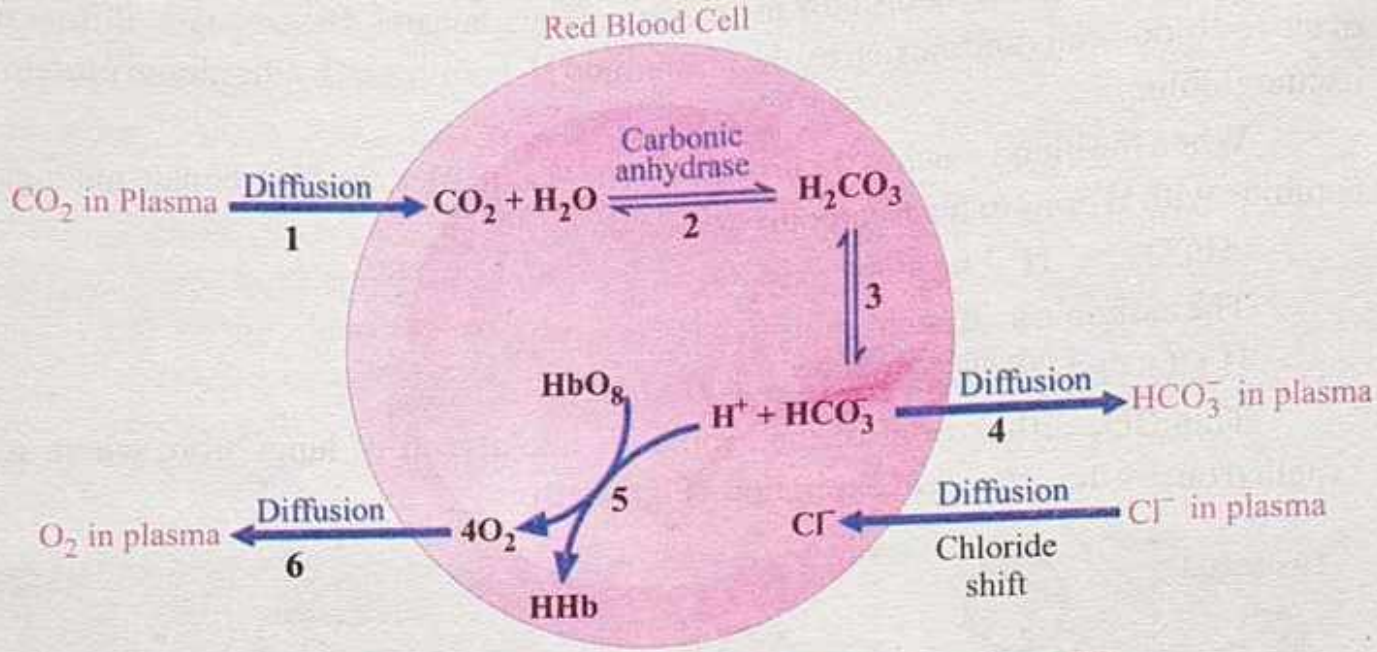


Fig. 14.11: Release of O_2 and Absorption in Blood Plasma and RBC

Hamburger`s Phenomenon or chloride shift

Hamburger`s phenomenon explain the maintenance of balance of two ions (Bicarbonate and Chloride Ions) in opposite directions, by special bicarbonate chloride carrier protein that is located in the plasma membrane of RBC. When from RBCs negatively charged bicarbonate ion (HCO_3^-) diffuse out into the plasma, this is balanced by diffusion of chloride ions in RBCs in opposite direction thus maintaining the balance of ions on either side of plasma membrane.

The chloride ion in the RBC combines with potassium (K^+) to form potassium chloride (KCl) where as in the plasma, the bicarbonate ions combine with sodium (Na^+) to form sodium bicarbonate ($NaHCO_3$). Thus the pH of blood is maintained at 7.4.

ii) As Carboxyhaemoglobin

When the partial pressure of CO_2 is higher in the tissues than the blood, the CO_2 combines with amino group of haemoglobin to form carboxyhaemoglobin. In

Extra Information

The CO_2 concentration. in arterial blood is 50ml / 100 ml of blood while venous blood contains 54 ml /100 ml blood, thus only 4 ml of CO_2 as it passes through the tissue-es and gives off 4 ml of CO_2 /100 ml of blood as it passes through the lungs.

the lungs the partial pressure of CO_2 is less than blood, it again breaks and releases CO_2.

iii) As Plasma Protein

Some CO_2 (about 7%) transported from tissue fluids to the lungs with the help of plasma proteins, which is rather inefficient way to carry CO_2.

14.3 Respiratory Disorders

Many problems in respiratory system can take place if inner lining of respiratory organs exposed continuously to unhealthy air, containing poisonous gases. (Such as smoke and other pollutants). Some common respiratory disorders are as under.

14.3.1 Upper Respiratory Tract Infections

i) Sinusitis

The **sinuses** are holes in the skull between the facial bones and inflammation in these holes is called sinusitis. So the **sinusitis** may be **acute** (if symptoms last 2-8 weeks) or **chronic** (slowly progress and symptoms last much longer).

Interesting Information

There are four large sinuses, two maxillary lie inside the cheek bones and two frontal sinuses, lies above the eyes.

The sinuses are lined with mucus secreting membrane, which secretes antibody rich mucus, helps to trap and prevent entry of irritants.

Causes: It is generally caused by atmospheric pollution, dust, smoke, cold and wet climate, excessive dryness and bacterial or viral infections, etc.

Treatment: Antibiotics or sulfa drugs are recommended for bacterial infection. Antiallergic and decongestants are also prescribed by doctors. Steam inhalation called **nebulization** is also useful to treat sinusitis.

ii) Otitis Media

It is an inflammation of the middle ear in which **Eustachian tube** (tube between middle ear and pharynx) filled with fluid and become close. If this fluid is not clear up after three months or more, then it becomes **chronic otitis media**.

Causes: The main causes of otitis media are infection, allergy, recurrent attacks of common cold, blockage of Eustachian tube, nutritional deficiency and sinusitis, measles, etc.

Symptoms: The common symptoms of this disease are sudden and severe ear ache, deafness, fever, headache, sense of fulfilness of ear, **tinnitus** (ringing or buzzing in the ear), fluid leaking from ear, difficulty in speaking and hearing, etc. Sometime even eardrum can burst, which causes a discharge of pus and relief of pain.

Treatment: Mostly (around 80% patients) treated by clearing up the fluid within three to four days, **ear drum** has self-repairing ability. However, for complicated cases antibiotic therapy is prescribed. Pain killers may be given to relieve pain and fever.

14.3.2 Lower Respiratory Tract Infections

i) Pneumonia

It is serious disorder of lower respiratory tract. Pneumonia is characterized by inflammation of alveolar wall and accumulation of fluid and pus in alveolar sacs of one or both lungs. (Fig.14.12)

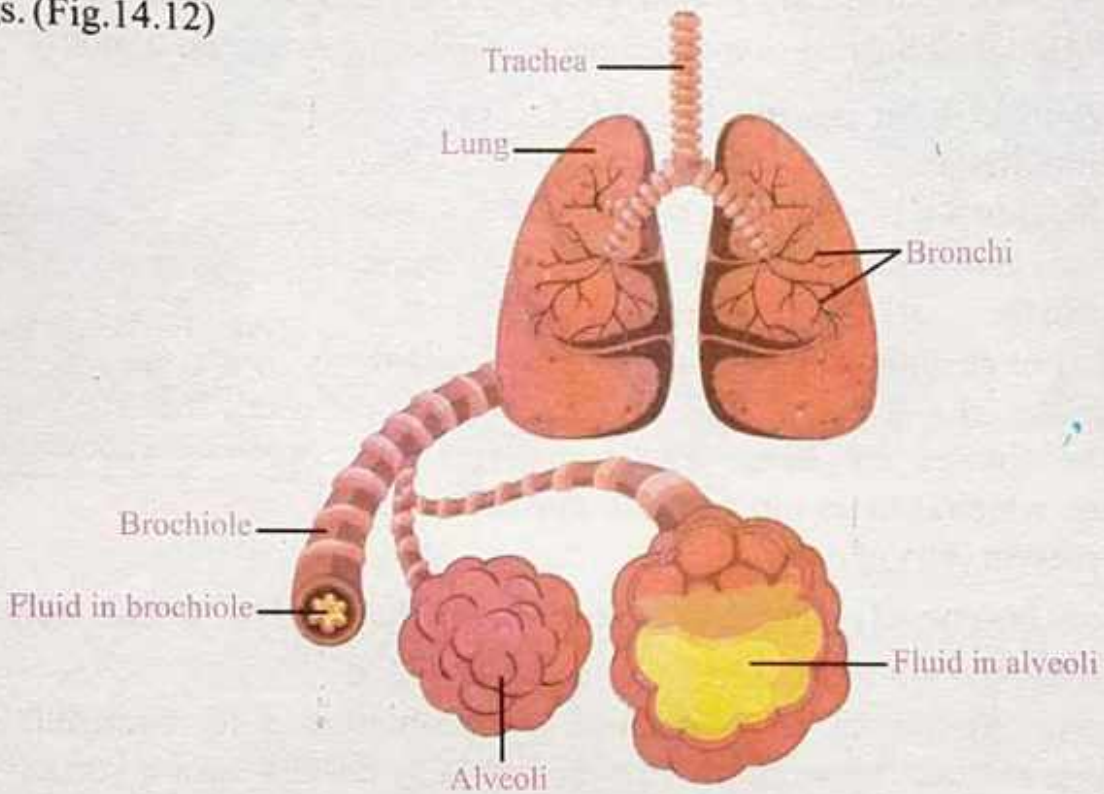


Fig. 14.12: Pneumonia of the Lungs

Causes: Mostly caused by bacterial genera such as ***Streptococcus pneumoniae***, ***Staphylococcus aurexs***, ***Haemophilus influenza and Mycoplasma,*** etc. Sometime it also occurs due to viral, fungal or protozoan infection.

Symptoms: The person with bacterial pneumonia may experience with chill, chattering teeth, shaking, chest pain, sweating due to high fever, increase pulse rate and breathing, violent coughing (due to *Mycoplasma*). In viral and other form dry cough, headache, fever and muscle pain, bluish color of lips, and red brown rusty color sputum are also symptoms of pneumonia.

Treatment: Mostly antibiotic treatment is prescribed.

ii) Lung Cancer

Cancer is **malignant tumor** which may develop due to uncontrolled cell division.

It is one of the most common cancer in the world.

Causes: Smoking and inhalation of unhealthy air. The chances of lung cancer are ten times more in those persons who smoke or live in crowded smoky areas. It is estimated that 90% of lung cancer is caused by smoking. (Fig.14.13)

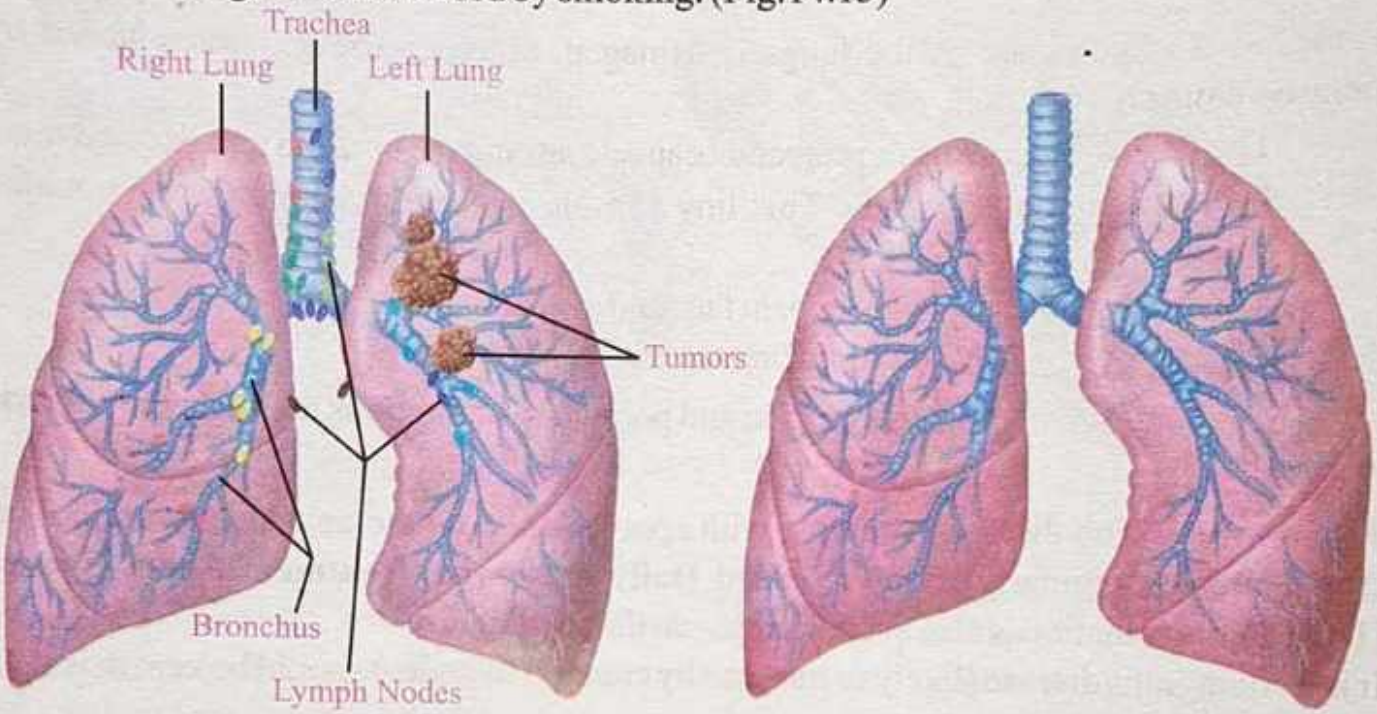


Fig.14.13: Lung Cancer (Cancerous and Healthy Lungs)

Symptoms: In initial stages the thickening and **callusing** (hardening) of cells occur, which are present in the lining of bronchi. The cilia in nasal passage (to prevent dust and dirt from seating in the lungs) are destroyed. The tumor consisting of disordered cells, spread and penetrates to other tissues known as **metastases**. These tumors grow until the bronchus is blocked and cutting off the supply of air to lung. The secretions are trapped in the spaces of lungs and become infected known as pneumonia or a lung abscess (swelling area containing pus) or only lung abscess result.

Extra Information

Pneumonectomy: Surgical removal of lung or part of lung.

Chemotheraphy: The use of chemical agents to treat or control diseases.

Radiotherapy: A therapy (Treatment) using ionizing radiation, generaly as a part of cancer treatment to control or kill malignant cell.

Treatment: To remove the tumor or the lung completely before the secondary growth has to occur. This operation is called **pneumonectomy**. **Chemotherapy** and **radiotherapy** may treat cancer.

iii) **Pulmonary Tuberculosis** (TB)

It is infectious bacterial disease of lower respiratory system. It is more common in

poor people due to poor living conditions and malnutrition.

Causes: Pulmonary tuberculosis is caused by a *Bacillus* bacterium known as ***Mycobacterium tubercle.*** Although about 15% develop TB of lymph nodes, joints and gastro intestinal tract.

Symptoms: The inside of the lungs is damaged, alveoli burst and are replaced by inelastic connective tissue.

- The cells of lungs form a protective capsule around the bacteria and isolated them from the rest of the body. This tiny capsule is called tubercle (small rounded swelling).
- The patient has cough, fever, pale face and sweating at night.
- In severe form, chest pain and breathlessness may occur.

Facilitating Condition: Malnutrition and poor living conditions facilitate the bacteria to grow.

Treatment: The disease is curable with appropriate drug therapy such as antibodies (for 9 months regularly). This is called **Daily Observed Treatment Short Course (DOTS)**. Vaccination is also available against the bacteria.
It is a contagious disease (likely to transmit by contact) so patient should be kept in isolate environment to prevent infection.

iv) Emphysema

It is a lung disorder in which the air sacs (alveoli) degenerate and the elastic fibers present in them are destroyed. As a result, alveolar wall degenerate and small alveoli combine to form larger alveoli. This results in less alveoli with an increased volume and decrease surface area for complete gaseous exchange.

Symptoms: Increasing breathlessness, patient faces difficulty in walking. Lung loses elasticity, so it becomes more difficult to exhale air and lot of air remains in the lung during expiration. Inflammation and narrowing of bronchioles occur. The patient feel fatigue, coughing and **cyanosis** (blue skin). (Fig. 14.14)

Causes: The root cause of emphysema is the long term irritation of the lungs by cigarette smoke, polluted air or industrial dust and exposure of lungs to certain drugs, coal, etc. The substances present in the smoke of tobacco weakens the walls of alveoli.

Treatment: There is no cure of emphysema but some care may be helpful.

- Avoid smoking.
- All kinds of respiratory infections should be treated immediately.
- Oxygen equipment and respiratory devices are helpful.

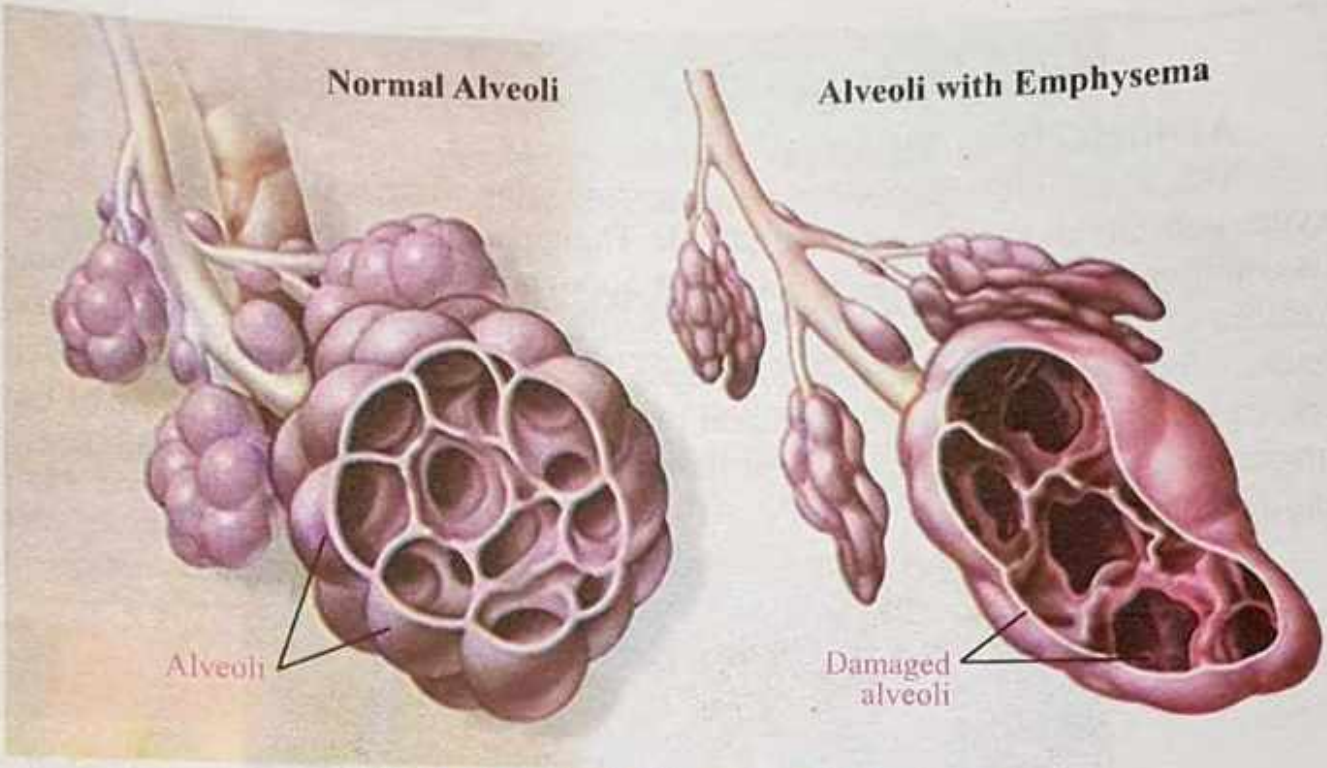


Fig. 14.14: Alveoli (Normal and Emphysema)

14.3.3 Effects of Smoking on Human Health

There are many effects of smoking on our respiratory system such as 87% of cigarette smokers also develop lung cancer. The smoking causes cancer of mouth, larynx and oesophagus. Smoking also causes many other diseases such as chronic bronchitis and emphysema.

The smoke of cigarette contains chemicals which irritate the respiratory tract and lung which results in early morning coughing and wheezing. It is indirect cause of pneumonia because cigarette smoke damages or destroys cilia. Thus microbes cannot be trapped and are easily settled in respiratory system. (Fig.14.15)



Fig.14.15: Effects of Smoking

- **Artificial Breathing Apparatus**

This apparatus is used when we swim under the water and the areas with low oxygen concentration such as at high altitude. The apparatus is also used by fire fighter. It is commonly called **aqua-lung** or **SCUBA apparatus** (Self Contained Under Water Breathing Apparatus). It contains compressed air that is a mixture called **nitrox**, contains about 35% oxygen and 65% Nitrogen. The pressure of compressed air is much less than ambient pressure (The **ambient pressure** on an object is the pressure of the surrounding medium, such as a gas or liquid, in contact with the object), thus divers could breathe readily at any depth of water or areas with low oxygen.



- **Respiratory system in birds is the most efficient and elaborate. Why?**

Respiratory system in birds is the most efficient than other animals due the following features. There is one way of the air through the lungs and air is renewed after inspiration and also no foul air is left in the lungs.

The direction of the blood flow in the lungs is opposite to the air flow, the parabronchi. This counter current exchange increases the amount of oxygen which enters the blood.

Also birds have air sacs which reach into all parts of the body and even penetrates some bones. These air sacs store air and act as balloons and blow air into parabronchi for exchange of gases. This system provides a large amount of oxygen for the high metabolic rate, and birds can breathe and fly on high altitude of about 6000 meter or more.

- **Relate the transportation of gases to hiccups, sneezing and snoring.**

The hiccups, sneezing and snoring are the conditions which are related to breathing.

Hiccups:- It is sharp respiratory sound produced by the spasmodic contraction of the diaphragm while the glottis is closed. It is reflexive and serve no known functions but person feels difficulty in breathing.

Sneezing:- Deep inspiration followed by a closure of the glottis. The forceful expiration that results abruptly opens the glottis, sending a blast air through the nasal cavity. The eyelids close

reflexively during sneeze. Sneezing is a reflexive response to irritating stimulus of the nasal muscosa. Sneezing clears the upper respiratory passages.

Snoring:- It is rough, raspy noise that can occur when a sleeping person inhales through the mouth and nose. The noise usually is made by vibration of the soft plate which may occur as a result of vocal cord vibration.

- **Describe the carbon monoxide poisoning (caused by gas heaters left on overnight in closed environments).**

Gases that have undergone incomplete combustion produce CO and toxic fumes (hydrogen cyanide). In carbon monoxide poisoning caused by gas heaters, left on overnight in closed environments, CO binds to haemoglobin preventing the uptake of oxygen by haemoglobin. The symptoms of CO poisoning are nausea, vomiting, headache, mental status changes and ability of haemoglobin to release oxygen to tissue.

SUMMARY

- Breathing or ventilation or external respiration is the phenomenon of taking in of fresh air (with more O_2) into the lungs and removal of the air (with more CO_2) out of the lungs.
- An extensive network of capillaries around alveoli help in rapid exchange of gases.
- Upper respiratory tract includes nostrils, nasal cavities and pharynx.
- Lower respiratory tract includes larynx, trachea, bronchi and bronchioles.
- Respiratory organs in human and all terrestrial vertebrates are a pair of lungs.
- Hair, cilia and mucus in the nostrils trap large dust particles and microbes.
- Air sac is the functional unit of lungs.
- Each alveolar sac is made of simple squamous epithelium.
- Each lung is surrounded by a double fluid filled membrane called pleura.
- Inter costal muscles located between ribs contract and relax and cause the rib cage to move downward and backward.
- Respiratory volume is the amount of air inhaled, exhaled and stored within the lungs at a given time.
- Myoglobin is an iron containing respiratory proteinaceous pigment, present in muscle fibres to store oxygen.
- Sinusitis is an inflammation of the nasal sinuses.
- Cancer is malignant tumor which may develop due to uncontrolled cell division.
- *Pulmonary tuberculosis* is caused by *mycobacterium tubercle*.
- Pneumonectomy is the surgery of lung.
- Cigarette smoking is the major cause of lung cancer and chronic obstructive disease (bronchitis and emphysema).
- *Streptococcus pneumoniae* cause pneumonia.
- Otitis media is an inflammation of the middle ear.

EXERCISE

SECTION-I: OBJECTIVE QUESTIONS

Multiple Choice Questions (MCQs)

A. Select the correct answer.

1. Pleura is a double layered thin membrane that covers:
   (a) Heart (b) Liver
   (c) Kidney (d) Lungs
2. Hemoglobin in man increases the oxygen carrying capacity of the blood to about:
   (a) 75 times (b) 50 times
   (c) 60 times (d) 100 times
3. Plasma proteins are involved in the release of CO_2.
   (a) 70% (b) 7%
   (c) 30% (d) 20%
4. Structure, which closes the passage to lungs when food is coming, is called:
   (a) Glottis (b) Epiglottis
   (c) Uvula (d) Pharynx
5. Myoglobin loses oxygen at:
   (a) 60 mm Hg (b) 19.6 mm Hg
   (c) 90 mm Hg (d) 20 mm Hg
6. Breathing is an example of:
   (a) Diffusion (b) Osmosis
   (c) Ventilation (d) Cellular Respiration
7. The structure which prevents entry of food to wind pipe is called:
   (a) Glottis (b) Epiglottis
   (c) Tongue (d) Soft palate
8. Which one of the following lacks cartilage?
   (a) Trachea (b) Bronchioles
   (c) Bronchi (d) Larynx
9. The pleural fluid surround the:
   (a) Liver (b) Kidneys
   (c) Heart (d) Lungs
10. The percentage of CO_2 carried in the form of bicarbonate is:
    (a) 85% (b) 60%
    (c) 70% (d) 65%

11. Each molecule of myoglobin combines with one molecule of:
    (a) Oxygen (b) Carbon dioxide
    (c) Nitrogen (d) Sulphur
12. In human, respiratory pigment is:
    (a) Haemocyanin (b) Haemoerythrin
    (c) Chlorocrurin (d) Haemoglobin
13. The residual volume of air in human lung is
    (a) 2.5 liter (b) 5.0 liter
    (c) 1.5 liter (d) 3.0 liter
14. Chemotherapy and radiotherapy may help in the treatment of:
    (a) Flu (b) Emphysema
    (c) Lung cancer (d) Asthma
15. *Mycobacterium tubercle* causes:
    (a) Emphysema (b) Sinusitis
    (c) Pneumonia (d) Pulmonary tuberculosis

B. Fill in the blanks.

1. Respiratory surface must be permeable, so that ..... can pass through it.
2. The pharynx is part of both the respiratory and ..... system.
3. The trachea divides into two primary .....
4. Each lung contains about 35 millions .....
5. About 97- 98 % of O_2 is carried by the RBC as .....
6. The chloride shift is also called ..... phenomenon.
7. Sinusitis is an inflammation of nasal .....
8. Haemoglobin can carry ..... oxygen.
9. ..... media is an inflammation of middle ear.
10. Mycoplasma cause lower respiratory infection named .....

SECTION-II: SHORT QUESTIONS

C. Give the short answers of the following questions.

1. Differentiate between internal respiration and external respiration.
2. Write three properties of respiratory surfaces.
3. Describe briefly about the functions of nasal cavities.
4. Define Bronchi, bronchioles and alveolar ducts.
5. Write any three differences between inspiration and expiration.
6. Difference between tidal volume and inspiratory reserve volume.

7. Write short note on myoglobin.
8. Describe transport of CO_2 as carboxyhaemoglobin.
9. Write causes and symptoms of sinusitis.
10. Describe the treatment of lung cancer.

SECTION-III: EXTENSIVE QUESTIONS

D. Give detailed answers of the following questions.

1. Explain breathing mechanism in humans.
2. Describe respiratory tract up to bronchi.
3. Explain causes, symptoms and treatment of tuberculosis.
4. Write a detail note on transport of CO_2 in human.
5. Write a detail note on transport of Oxygen in human.
6. Explain causes, symptoms and treatment of emphysema.
7. Illustrate the effects of smoking on human health.
8. Write note on otitis media.
9. Explain alveolar duct and alveoli.
10. Write a note on lung cancer.

UNIT 15

HOMEOSTASIS

Major Concept

15.1 Homeostasis
15.2 Osmoregulation
15.3 Excretion
15.4 Excretory system of Man
15.5 Disorders of Urinary Tract
15.6 Thermoregulation

Learning Outcomes

Students will be able to:

- Describe three elements i.e., receptors, control centre and effectors which operate homeostatic mechanisms.
- Relate the homeostatic mechanisms with the negative and positive feedback systems.
- Differentiate between osmoconformers and osmoregulators.
- Define osmoregulation.
- Explain the problems faced by osmoregulators.
- Explain the different methods of osmoregulation found in freshwater, marine water and terrestrial habitats.
- List various nitrogenous compounds excreted during the process of excretion.
- Explain the nature of excretory products in relation to habitat.
- Explain different organs of urinary system. Describe the structure of kidney and relate it with its function.
- Explain the detailed structure of nephron.
- Explain the processes of glomerular filtration, selective re-absorption and tubular secretion as the events in kidney functioning.
- Explain that concentration of urine is regulated by counter-current and hormonal mechanisms.
- Justify the functioning of kidneys as both excretion and osmoregulation.
- Compare the function of two major capillary beds in kidneys i.e., glomerular capillaries and peritubular capillaries.
- List urinary tract infections and the bacteria responsible.
- Explain the causes and treatments of kidney stones.
- Outline the causes of kidney failure.
- Explain in detail the mechanism and problems related to dialysis.
- Describe the principles and the problems associated with kidney transplant.

- Define thermoregulation and explain its needs.
- Classify animals on the basis of the source of body's heat i.e. ectotherms and endotherms.
- Classify animals on the bases of the ability to thermoregulate i.e. poikilotherms and homeotherms.
- Describe the regulatory strategies in man for thermoregulation.

Introduction

The **environment** is everything that makes up our surrounding and affects our ability. There are two types of environments.

a) **External Environment**, that occurs outside of organism.

b) **Internal Environment**, that occurs within an organism.

All living organisms must regulate their internal environment to continue their life processes and ultimately to survive. The term homeostasis was coined by physiologist Walter Cannon in 1932 in his famous book "Wisdom of the body". The term is derived from Greek roots meaning "similar" and "a state of stability".

In this unit we will study the mechanism of homeostasis, concept of feedback mechanism, elements of homeostasis *i.e.* osmoregulation, excretion and thermoregulation and some disorders of urinary tract and their management in human.

15.1 Homeostasis

Homeostasis is the ability of an organism to maintain a relatively stable internal state that persists despite changes in the outside environment. There are three components of homeostasis *i.e.* **Osmoregulation** (maintenance of water and dissolved solutes in nearly constant state), **Excretion**, (Removal of metabolic wastes from body, especially nitrogenous wastes), **Thermoregulation**, (The maintenance of constant body temperature).

15.1.1 Mechanism of Homeostasis

The internal changeable factors of body like solutes, water and temperature are called **variables**. These are influenced by external environmental changes. The variables have ideal or normal value in the internal environment. This normal value is called **set point**. This value is "set" or "stored" in memory. There are three components of homeostasis.

i) **Receptor:** The part of control system which detects the change (stimulus). The change may be either external or internal environment (variable.)

ii) **Control Centre:** Information travels along

Extra Information

Hypothalamus plays a significant role in maintaining homeostasis by regulating, temperature, water balance regulating, hormone production, *etc.*

(afferent) pathway to the control centre which determines the approximate response and course of action. Information sent from control centre travels down the (efferent) pathway to the effector.

iii) Effector: The effector gives response which balances out the original stimulus to maintain homeostasis.

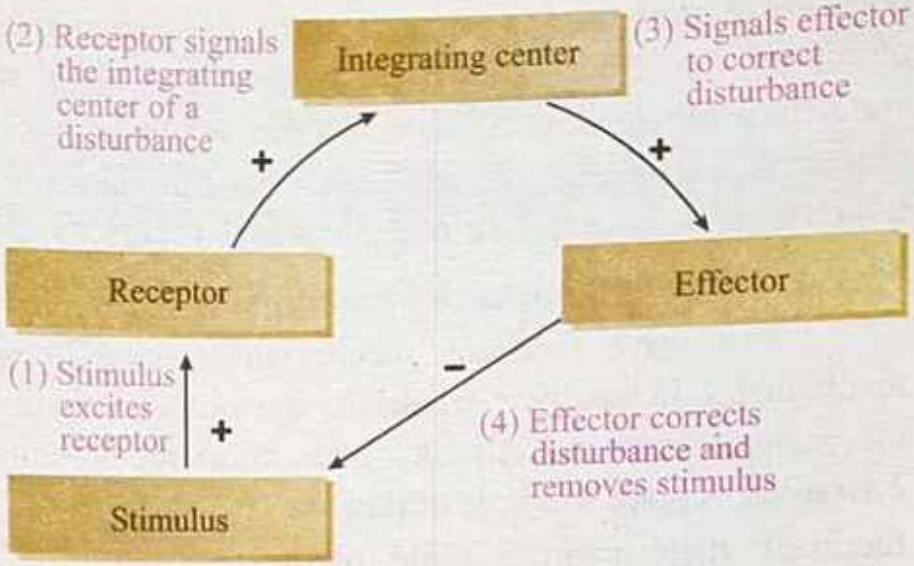


Fig. 15.1: Components of Biological Control System

Example: The maintenance of constant body temperature in human *i.e.* 98.6F. When our body temperature rises above this temperature, we start sweating to cool ourselves so that our body temperature is maintained. (Fig.15.1)

15.1.2 Concept of Feed Back Mechanism in Homeostasis

A feedback mechanism is a loop system wherein the system responds to a perturbation (change or disturbance). The response may be in the same direction (positive feedback) or in the opposite direction (negative feedback).

In **biological sense,** a feedback mechanism involves a biological process that tends to initiate or inhibit the production of any product (enzyme, hormone) in the body.

The feedback mechanism may be observed at the levels of cells, tissues and organs. It regulates homeostasis to achieve certain range of optimal conduction.

15.1.3 Negative Feedback Mechanism

Almost all homeostatic control mechanisms are negative feedback mechanisms. These mechanisms change the variable back to its original state or "ideal value" thus creates stability.

Example: The control of blood glucose by insulin is a good example of negative feedback mechanism. When blood sugar (glucose) rises, receptors in the

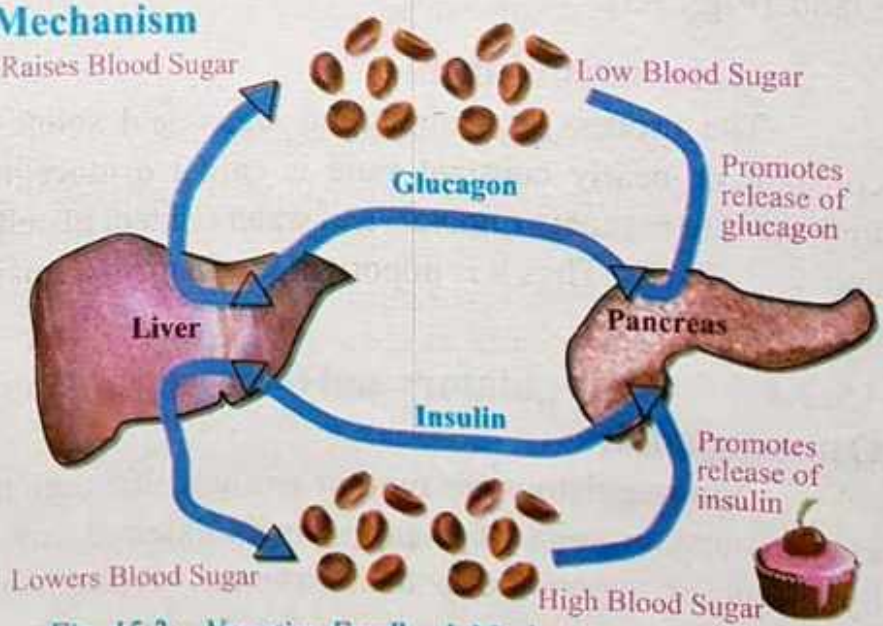


Fig. 15.2: Negative Feedback Mechanism

body sense a change. In turn, the control centre (pancreas) secretes insulin into the blood effectively lowering blood sugar levels. Once blood sugar level reaches homeostatic state, the pancreas stops releasing insulin. When there is low level of glucose in blood, the glucagon is released from pancreas. This stimulates the production of glucose in liver which increases the blood glucose level again. (Fig.15.2)

15.1.4 Positive Feedback Mechanism

A positive feedback mechanism is exactly opposite of negative feedback mechanism. In positive feedback, the output enhances the original stimulus. This mechanism is rare and only takes place in emergency situations *i.e.* creates instability.

Example: A good example of positive feedback mechanism is **child birth** (contraction of uterus send impulse to pituitary gland). During labour period a hormone called oxytocin is released from pituitary gland that stimulates the contractions of uterus wall. The increase in contractions causes more oxytocin to be released and the cycles go on until the birth process is completed. The oxytocin is made by neurosecretory cells in hypothalamus and stored in posterior lobe of pituitary gland. (Fig.15.3)

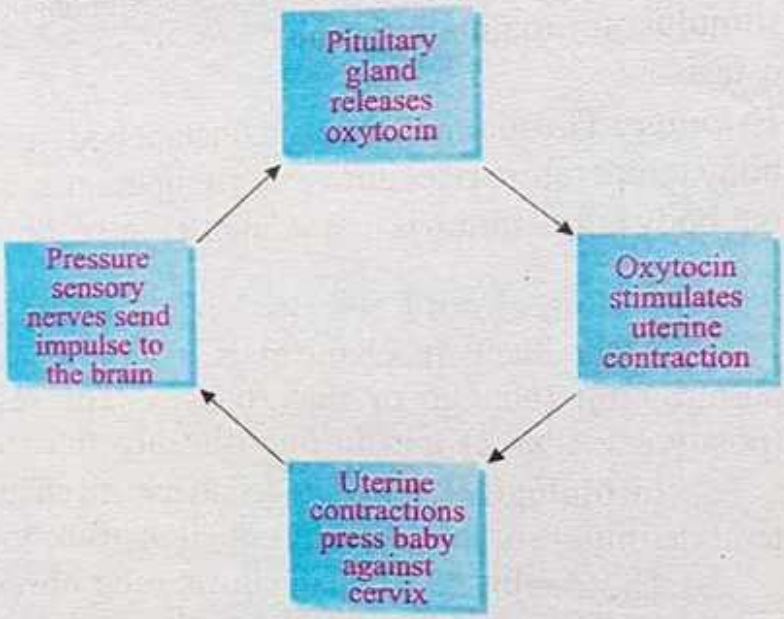


Fig. 15.3: Positive Feedback Mechanism

15.2 Osmoregulation

The process of maintaining water and solutes concentration in the body at constant or nearly constant state is called **osmoregulation**. The osmoregulation is important to maintain minerals and water content of cells and it also maintains the shape and size of cells. Thus it is important mechanism to maintain homeostatic conditions of body.

15.2.1 Osmoregulators and Osmoconformers

Osmoregualtors

Osmoregulators are type of animals that maintain a constant internal osmotic environment in spite of changes in its external environment. These organisms are hypotonic or hypertonic to their external environment. These organisms can live in almost all types of environments. *i.e.* fresh water, marine water and on land.

Osmoconformers

Osmoconformers are such organisms whose body fluids are in osmotic balance with their environment. However, their ionic composition may be different from that of external environment but their internal environment is isotonic to the external environment. These organisms can live only in marine environment. Generally, most marine invertebrates are osmoconformers.

Problems faced by Osmoregulators

Osmoregulators usually face following problems.

a) In hypotonic medium, endosmosis occurs so they have to face the problem of excess of water. Therefore, osmoregulators must eliminate excess of water.

b) In hypertonic medium, exosmosis takes place. Therefore, they must continuously take water.

c) The marine animals have to face the problem of excess of salts in their body, which come in their body along with water, so they have to get rid of extra salts.

15.2.3 Osmoregulatory Adaptations in Animals

i) Fresh-water Animals

The fresh water environment is hypotonic to animals. Therefore, the main osmoregulatory problem of these animals is excess of water. So fresh water animals show following adaptations to overcome this problem. (Fig.15.4)

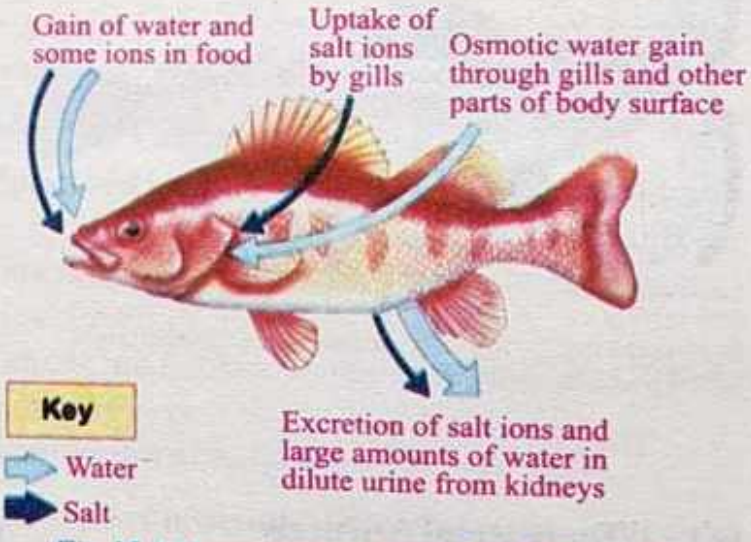


Fig.15.4 Osmoregulation in Fresh Water Fish

- These animals continuously excrete large volume of dilute urine. Their kidneys reabsorb salts that are required in the body.
- They remove extra salts in the form of ions to make their internal environment less hypertonic. The ion removing cells are called **ionocytes** which are located in amphibian skin and gills of fish.
- The animal like protists of fresh water possess contractile vacuole to store and remove extra water.

ii) Marine Animals

The marine water has high salt concentration and therefore, the animals who live in such environment have to face the problems of shortage of water and excess of salts. To

tackle these problems, the marine animals show following adaptations.

- Teleost (bony fish) continuously drink large amount of water to compensate water loss.
- Some marine fishes possess rectal glands in rectum which store and remove extra salts along with faeces.
- Some marine fishes retain urea in their body to make their internal environment less hypotonic. To counteract the toxicity of urea these fishes possess **trimethylaminoxide (TMAO)** in their blood. The urea and TMAO also act as **osmolytes** (Any substance that contributes to the regulation of osmotic pressure in cells and tissues).
- Excretion of salts ions from gills and urine.

These are low molecular weight organic compounds that influence the properties of biological fluids. *e.g.* amino acid, urea, *etc.* (Fig.15.5)

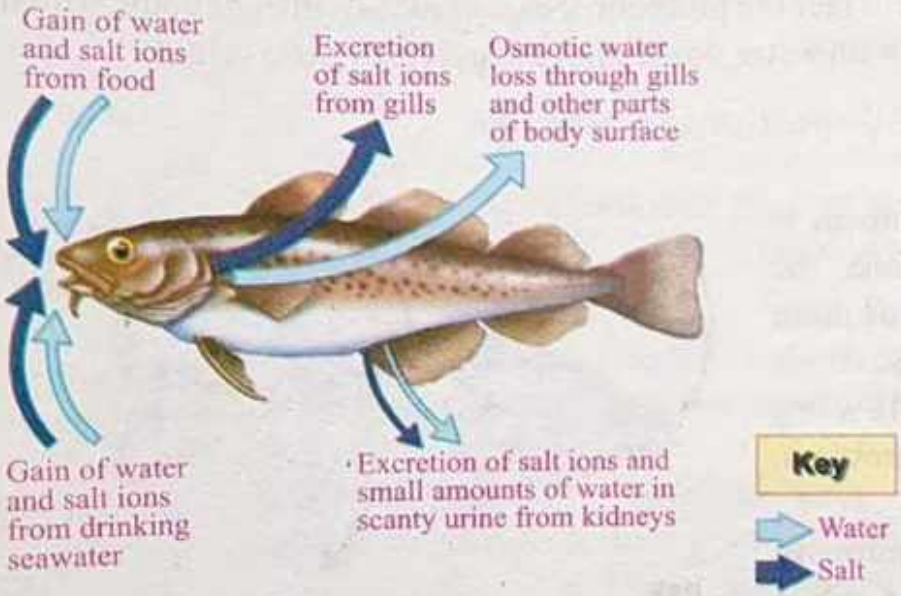


Fig. 15.5: Osmoregulation in marine water

Interesting Information

Although fishes are poikilothermic but there are some fishes such as great white shark can raise their body temperature. This help them hunt for prey in cold water.

iii) Terrestrial Animals

The insects and most mammals are the successful groups of land animals. The threat of dehydration is their major problem. Adaptations that reduce water loss are key to survival on land. These both groups of animals show number of adaptations to conserve water in their bodies.

- Insects have waxy exoskeleton, excrete their nitrogenous wastes in



Fig. 15.6: Tradigrade

the form of uric acid.

- Some insects have nocturnal habit and their eggs have impermeable membrane to prevent water loss.
- The mammals of terrestrial habitat usually have dead, keratinized, water resisting cells in their skin.
- Some are nocturnal in habit, which reduces water loss due to evaporation because of the lower temperature and higher humidity of night air.
- Camel can store water and can survive even losing 25% of water of body.
- Some mammals have developed the ability of **anhydrobiosis** (life without water). *e.g.* **Tradigrade** (an invertebrate). Infact these animals mainly feed on carbohydrates, which produce large amount of water when metabolized.
- Energy is utilized for osmoregulation activities, therefore, these animals eat more food. (Fig.15.6)

Extra Information

On average person pees about 3000 times a year. The average adult's urinary bladder can hold 16-24 ounces of urine.

15.3 Excretion

Excretion is a Latin word which means shifted out. It is the process by which animals remove metabolic wastes. The organisms through excretion, control osmotic pressure and maintain acid-base balance. In this way excretion promotes homeostasis.

15.3.1 Relationship between Excretory Products and Habitats

Most of metabolic wastes must be dissolved in water to be excreted from body, so the type and quantity of an animal's waste products mainly depends on availability of water. Most significant excretory products are nitrogenous wastes. These are produced as a result of breakdown of proteins and nucleic acids.

The main nitrogenous excretory products are ammonia, urea and uric acid. These wastes vary significantly in their toxicity and energy costs of producing them.

Ammonia

Animals that excrete ammonia as their chief nitrogenous wastes, need access to lots of water because 1 gm of ammonia needs 500 ml water for its elimination. Moreover, ammonia is most toxic and cannot be stored in the body. It can only be tolerated at a very low concentration.

This large amount of water is only available in freshwater animals. Therefore, ammonia is the chief nitrogenous waste of fresh water animals. Such animals which excrete ammonia as their chief nitrogenous wastes are called **ammonotelic** animals.

Urea

Most terrestrial animals and many marine species simply do not have access to sufficient water to excrete ammonia. Therefore, these animals convert ammonia into urea

in their liver, and excrete urea as their chief nitrogenous waste.

The main advantage of urea is its low toxicity and needs less water for its elimination. 1g of urea requires only 50 ml of water for its removal. The main disadvantage is its energy cost *i.e.* energy is consumed for conversion of ammonia into urea. Animals which excrete urea as their main nitrogenous waste are called **ureotelic**.

Uric Acid

Insects, many reptiles and birds excrete uric acid as their chief nitrogenous waste. Uric acid is least toxic and does not readily dissolve in water. It therefore, can be excreted as a semisolid paste with very little loss of water. 1gm of uric acid consumes only 1ml of water for its excretion. It is a product of the metabolic breakdown of purine nucleotides. The uric acid is even more energetically expensive than urea, requiring considerable ATPs for synthesis from ammonia. Animals excreting uric acid as their primary nitrogenous waste are called **uricotelics**.

Extra Information

In human adult males are particularly susceptible to gout, a painful joint inflammation caused by deposition of uric acid crystals.

15.4 Excretory system of man

In human, excretory system consists of a pair of **kidneys**, each about 10cm in length, a pair of **ureters** for transporting urine. The two ureters drain into a common sac called **urinary bladder**. During urination, urine is expelled from the urinary bladder through a tube called **urethra**, which empties to the outside near the vagina in females and through the penis in males. **Sphincter muscles** near the junction of the urethra and bladder regulate urination. (Fig.15.7)

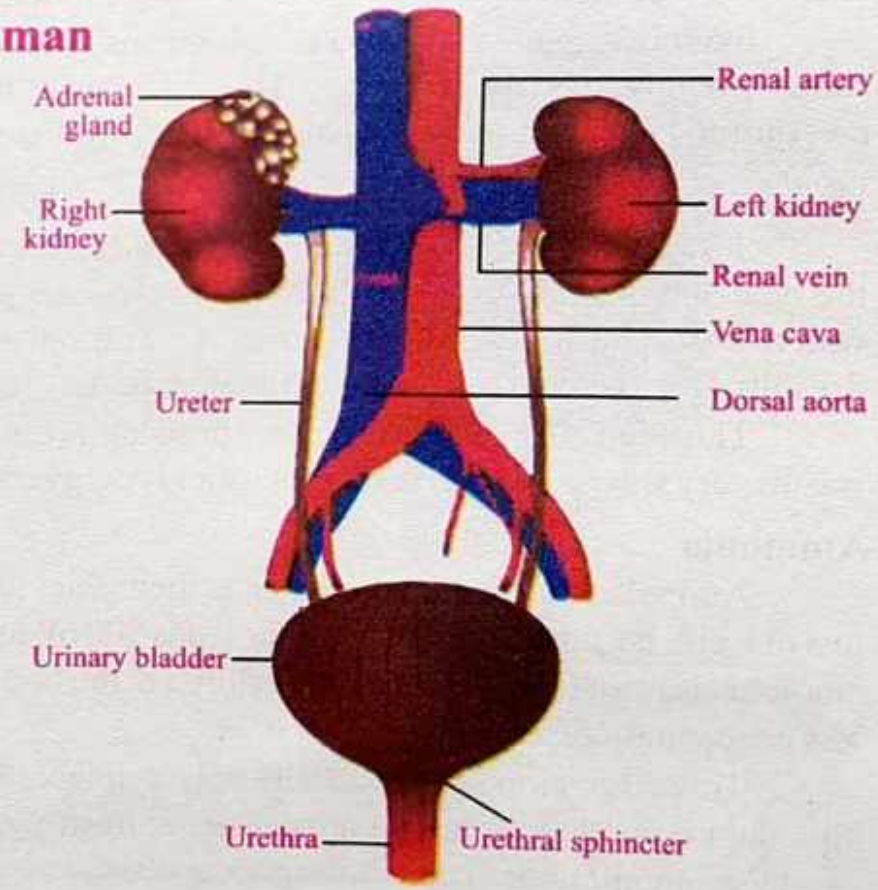


Fig. 15.7: Excretory System of Man

15.4.1 Structure and Function of Kidney

The human kidney is bean shaped structure, reddish brown in color, located in

lumber region on both side of vertebral column. The left kidney is about 1.5 – 2cm higher than the right kidney. Each kidney has an **outer renal cortex** and **inner renal medulla** region. The medulla contains cone shaped structures called **pyramids**. The pointed end of pyramid is directed towards hilus. The **hilus** is the depressed area of kidney in the middle. Both regions are supplied with blood by a renal artery and drained by a renal vein. Within the cortex and medulla lie tightly packed excretory tubules (nephrons) and associated blood vessels. The excretory tubules carry and process a filtrate produced from the blood entering the kidney. Nearly all of the fluid in the filtrate is reabsorbed into peritubular capillaries. The remaining fluid leaves the excretory tubules as urine.

Extra Information

Nephrology is the study of structure, functions and diseases of kidney.

Kidneys filter about 180-liter blood in 24 hours and only 1 – 1.5 liter urine is formed. (Fig.15.8)

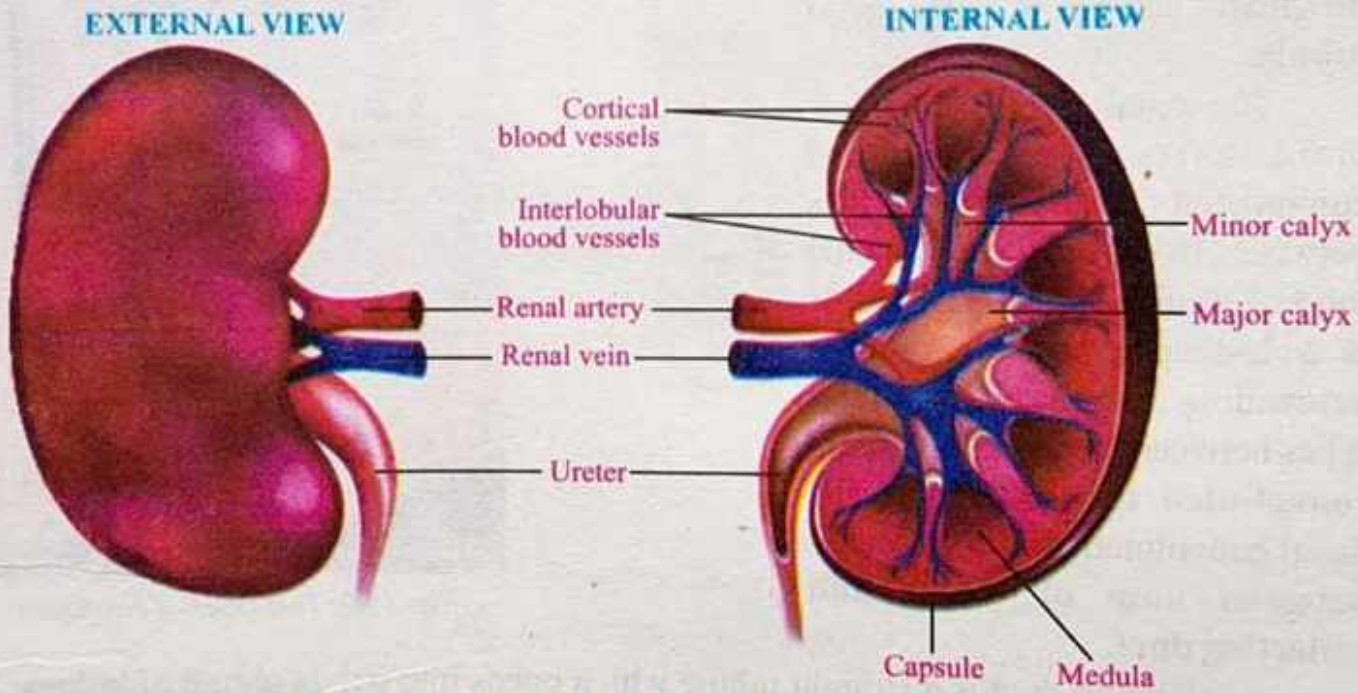


Fig. 15.8: External and Internal Structure of Kidney

Nephron

The nephrons are the structural and functional units of kidney. There are about 1million nephron in each kidney. There are two types of nephrons *i.e.* **cortical nephrons** which are located in cortex of kidney, more in number about 80-85% of total nephrons of kidney. The other type is **Juxtamedullary nephrons**. These

Information

* The blood flow in kidney is less high than the blood flow in liver but more high than brain.
* In adults, kidneys form only 0.5% of body weight.

nephrons have long **loop of Henle**, the coiled part of this nephron is located in the cortex while its loop of Henle (U shaped part) is located in medulla. The Juxtamedullary nephrons are essential for production of hypertonic urine. These nephrons are active when there is shortage of water in the body.

Extra Information

Once a person reaches the age of 40, the number of functional nephrons start falling at the rate of 1% a year.

Each nephron consists of a single long tubule as well as a ball of capillaries called the **glomerulus**. The blind end of the tubule forms a cup shape structure called **Bowman's capsule**, which surrounds the glomerulus. The part of nephron behind Bowman's capsule is called **renal tubule**.

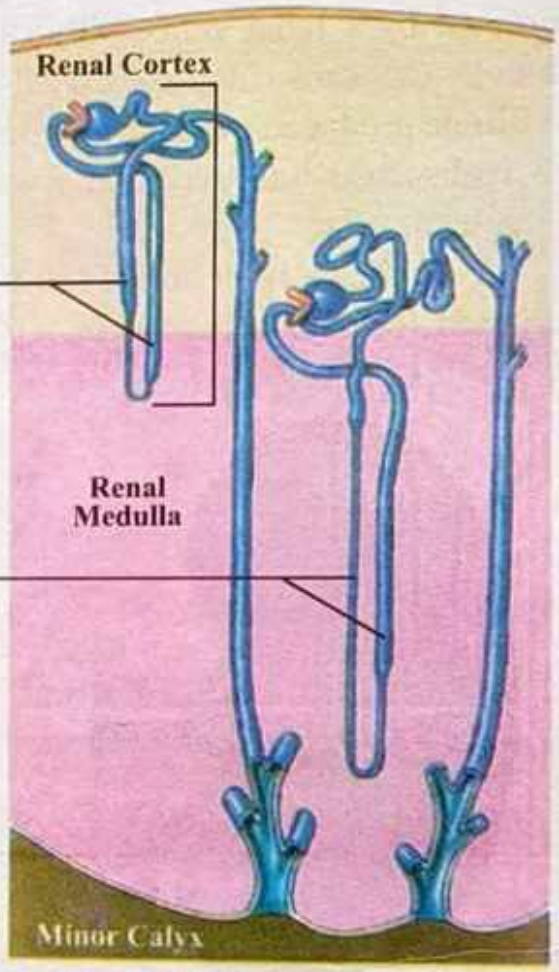


Fig. 15.9: Two types of Nephrons

The renal tubule has three main parts, *i.e.* **proximal convoluted tubule (PCT),** lies between Bowman's capsule and loop of Henle. The **loop of Henle** is a U-shaped structure with a descending and ascend-ing limbs. It lies between proximal and **distal convol-uted tubules(DCT)**. The distal convoluted tubule is located between loop of Henle and **collecting duct**.

A collecting duct is a straight tubule which opens into pelvis region of kidney. A single collecting duct receives many nephrons and many collecting ducts combine together to form large collecting duct. (Fig.15.9)

Blood Circulation in Nephron

Each nephron is supplied with blood by an **afferent arteriole** which brings blood from **renal artery**. The afferent arteriole gives bunch of capillaries called **glomerulus**. From glomerulus, **efferent arteriole** carry blood to **peritubular capillaries** which surrounds

Extra Information

The right kidney is a bit smaller and sits a little lower than your left kidney because, it is needed to make room for the liver.

the nephron and extend downward to form the **vasa recta** in the base of loop of Henle at medulla region of kidney. The peritubular capillaries drain into **renal venules** and venules drain into **renal vein.** (Fig.15.10)

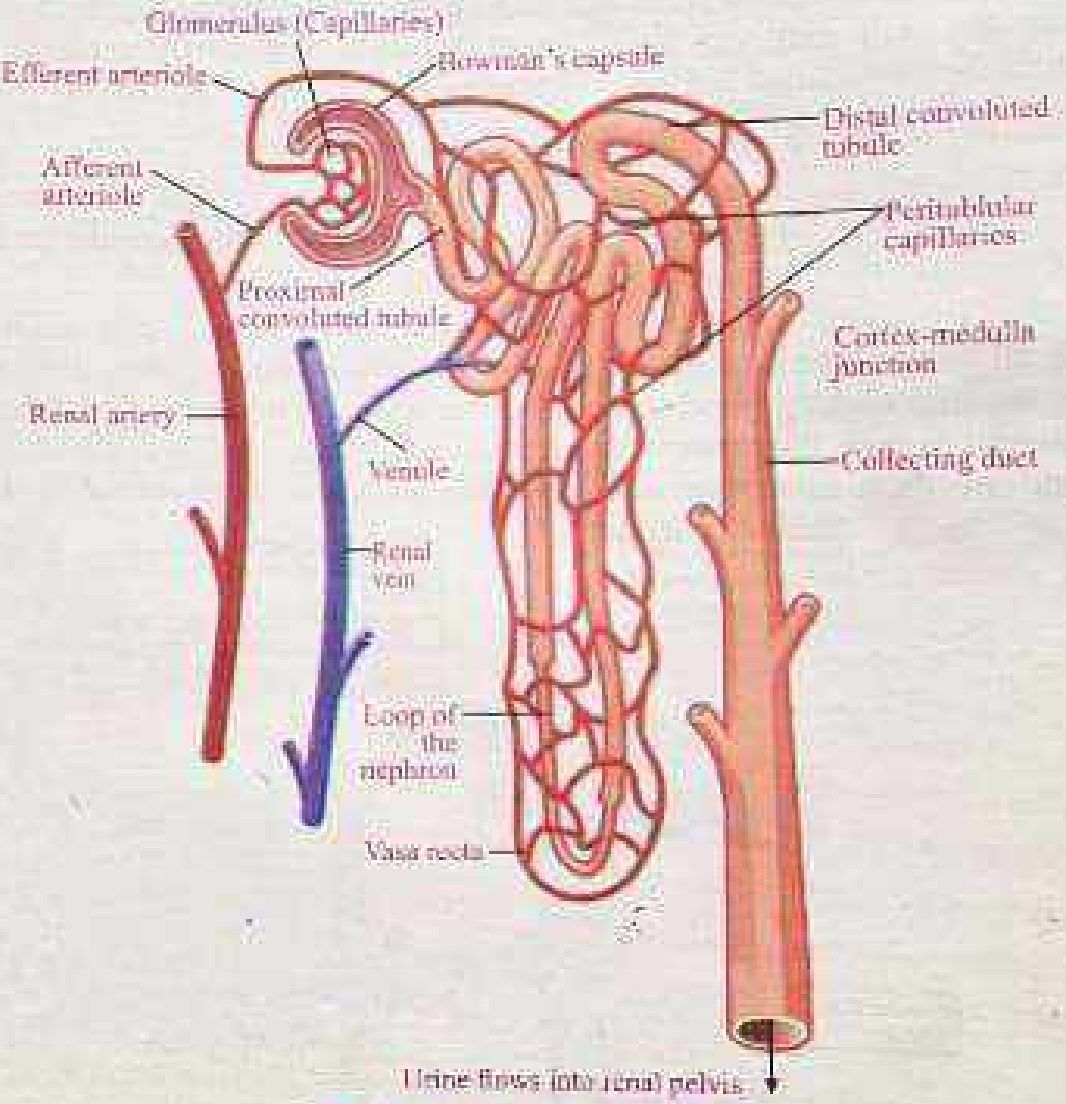


Fig. 15.10: Structure of Nephron

Function of Kidney

The kidney is a vital homeostatic organ of the body which performs number of functions. These functions include production of hormones, (*e.g.* renin, erythropoietin), regulation of fluid balance, control on blood pressure *etc.* However, the primary function of kidney is to make urine and purify blood.

Urine Formation

The kidneys filter unwanted substances from the blood and produce urine. There are 3 main steps of urine formation, *i.e.* glomerular filtration, selective reabsorption and tubular secretion.

i) Glomerular Filtration (Pressure filtration or ultra-filtration)

During filtration, blood enters the afferent arteriole and flows into the glomerulus where **filterable blood components**, such as water and nitrogenous wastes, will move towards the inside of the glomerulus and **non-filterable components,** such as cells and serum albumins will exit via the efferent arteriole. These filterable components accumulate in the glomerulus to form the glomerular filtrate.

ii) Selective Reabsorption (Tubular reabsorption)

The next step is reabsorption of useful substances. These substances include water, ions, glucose, *etc*. These substances are reabsorbed into peritubular capillaries from entire length of renal tubule and collecting duct.

Most of the water is reabsorbed by osmosis. Some mineral salts and in a normal individual, all of the glucose and amino acids are reabsorbed through the walls of the tubule into the surrounding blood capillaries. The selective reabsorption of these solutes requires energy. Hence, the process involved is active transport. It is a highly selective process, and only those substances which the body requires are reabsorbed readily.

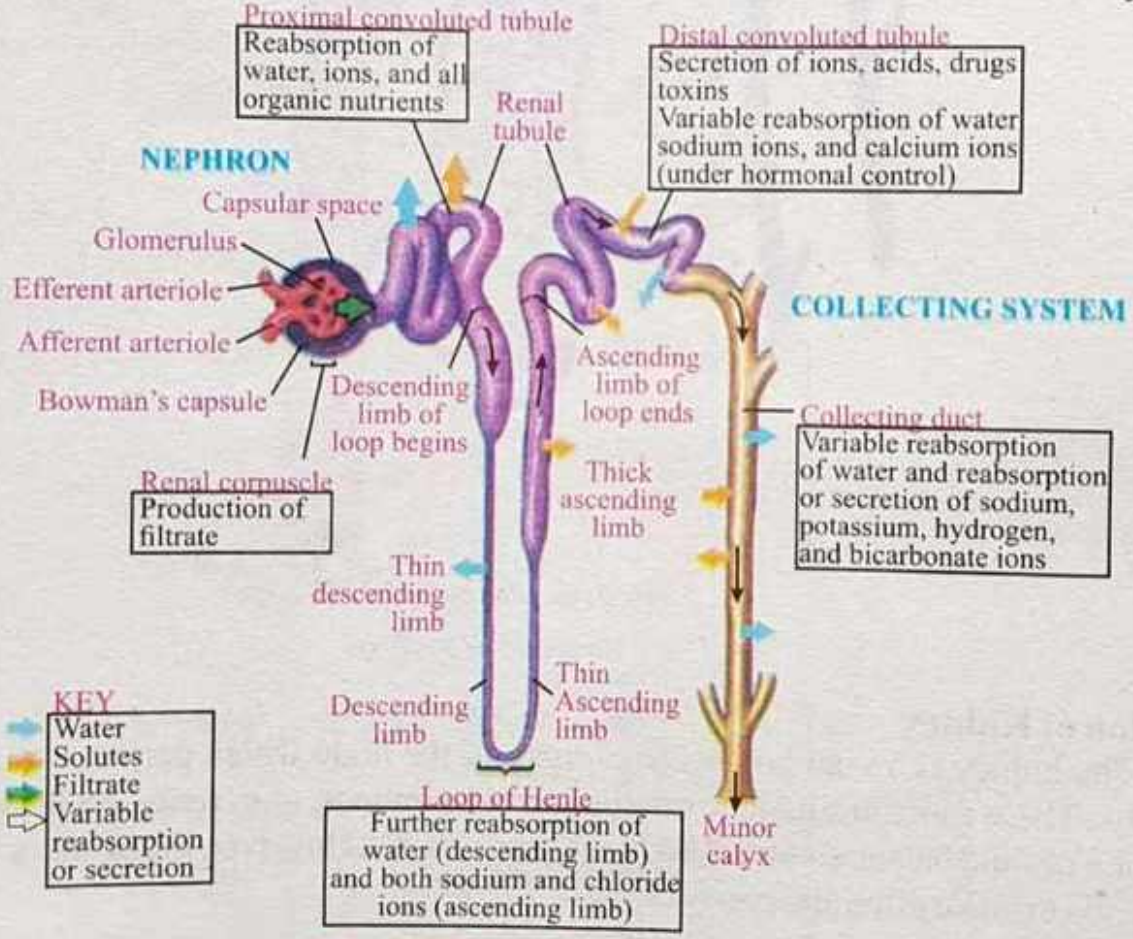


Fig. 15.11: Steps of Urine formation

Excess water, mineral salts and nitrogenous waste products (*e.g.* urea) are allowed to pass along the nephron and out through the collecting tubule into the renal pelvis as urine.

iii) Tubular Secretion

During the final step of urine formation some substances such as hydrogen ions, creatinine, and drugs will be removed from the blood through the network of peritubular capillaries into renal tubule and collecting duct. The end product of all these processes is urine, which is essentially a collection of substances that has not been reabsorbed during glomerulus filtration and tubular reabsorption. (Fig.15.11)

The Mechanism of Formation of Concentrated Urine (Counter Current Mechanism)

The mechanism in which kidneys produce concentrated urine when there is shortage of water in the body is called **counter current mechanism**.

This mechanism occurs in mammals and it is an adaptation to conserve water. The concentrated urine is formed in following ways:

- Na^+ and Cl ions are transported from the ascending limb of the Henle's loop by vasa recta.

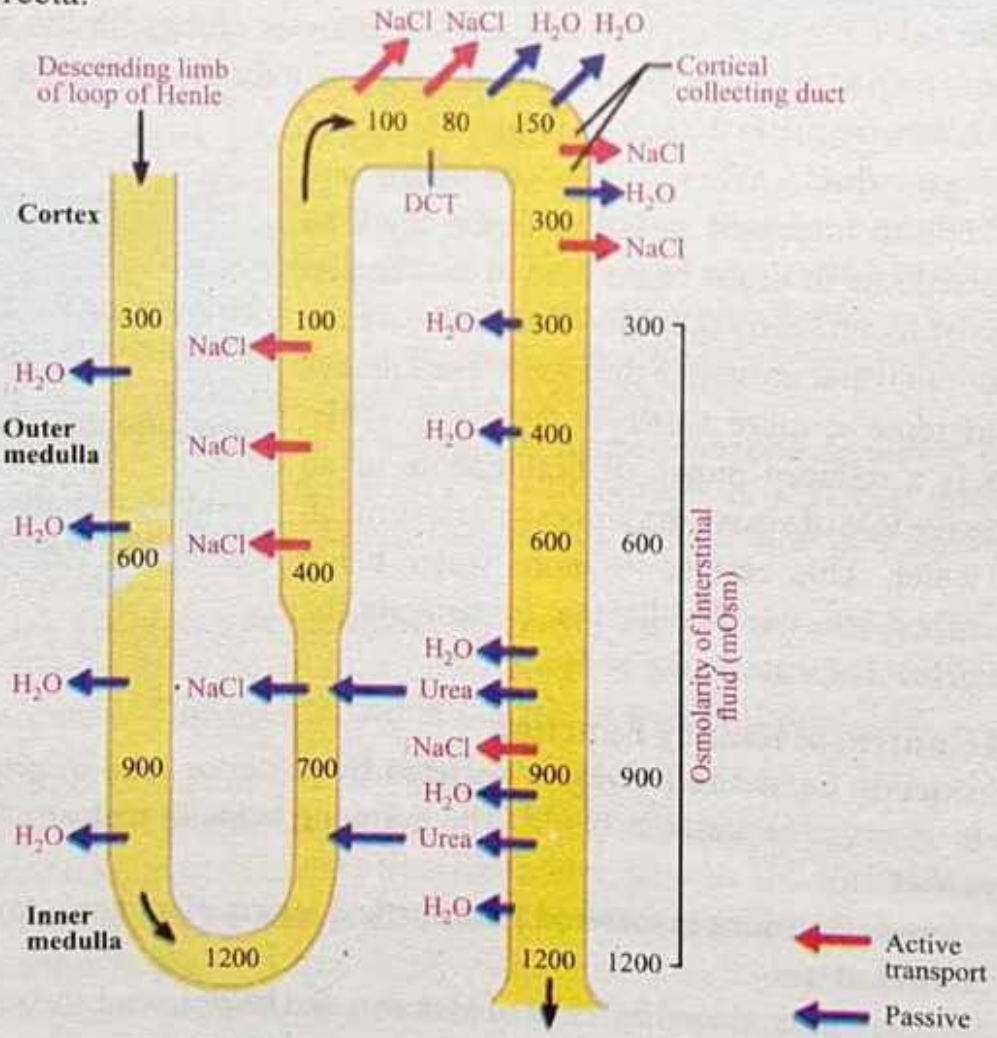


Fig. 15.12: Process of formation of concentrated Urine

- The ascending limb of the vasa recta, in turn, transport these ions to interstatium (the tissue between the loop of Henle and vasa recta).

Thus a concentration gradient of 300 mm in the cortex to 1200 mm in the inner medulla is created.

- Urea contributes to this process by being transported from the descending limb of the loop of Henle to the interstation.
- As urine flows downwards in the collecting tubule, it counters higher and higher concentration of solutes in the interstatium. Hence, it goes on loosing water due to osmosis.
- This is how urine is concentrated, the antidiuretic hormone also plays a role in making concentrated urine by reabsorbing water from kidneys. (Fig.15.12)

The functions of kidneys as both Excretion and Osmoregulation

- The kidneys are excretory organs, removing mainly nitrogenous waste products (*e.g.* urea) and excess water and mineral salts in the form of urine.
- By the selective reabsorption of useful substances alongwith the nephron, the kidneys help to maintain the pH and composition of the blood plasma.
- The kidneys regulate the salt and water balance of the body fluid. When other conditions are constant, an increased intake of liquid food, an increased rate of tissue respiration or a reduction of sweat secretion by the skin would increase the amount of water present in the blood. The kidneys would remove more water in the urine. When there is a reduced intake of liquid food, or an excessive loss of sweat, the kidneys remove much less water. This results in more water being reabsorbed into the bloodstream to maintain the normal level of water in the body.

Extra Information

Milliosmole Per Kilo-gram of water (mOsm / kg water). An osmole is an amount of a substance that contrib-utes to the osmotic pressure of a solution. A milliosmole is one thousandth of an osmole.

Hormonal Control of Kidney Function

Antidiuretic hormone (ADH) is secreted by posterior lobe of pituitary gland when there is shortage of water in blood. The hormone helps in reabsorption of water from kidneys to blood.

Aldosterone hormone is secreted from cortical region of adrenal gland and helps in reabsorption of sodium.

Insulin hormone secreted by cells of pancreas and helps to reabsorb glucose from glomerular filtrate to blood. (Table.15.1)

Table 15.1: Comparison between Glomerulus and Peritubular

S.No.	Glomerular Capillaries	Peritubular Capillaries
i)	Located in the mouth of the Bowman's capsule.	Located in the renal tubule of nephron.
ii)	Has very low blood pressure.	Have comparatively high pressure.
iii)	Impermeable to most substances.	Permeable for most substances like glucose, mineral ions, *etc.*
iv)	Has a basement membrane.	Has no basement membrane.

15.5 Disorders of Urinary Tract

The urinary tract includes kidneys, ureters, urinary bladder and urethra. The urinary tract disorders include urinary tract infections, kidney stones, kidney failure, bladder control problems and prostate problems. Some urinary tract disorders last only for a short time while other are long lasting.

Extra Information

Urology is the branch of medical science which deal with urinary tract disorders and treatment.

15.5.1 Urinary Tract Infections (UTI)

Such infections that affect any parts of urinary tract are called urinary tract infection (UTI). These are more virulent to female than male, can you guess why? It is due to shorter urethra in women, do not empty their bladder completely, and large exposed surface area of external genitalia. Ureters are less infected as compare to other parts of urinary tract due to its acidic nature. When upper site of urinary tract is infected, it is known as **pyelonephritis** *e.g.* kidney infection. When lower site of urinary tract is infected, it is known as **cystitis**, *e.g.* infection of bladder.

The most common cause of infection is *Escherichia coli*, however, other bacteria, viruses and fungi may also cause UTI. The symptoms of UTI may include, burning feeling during pee (urination), cloudy dark bloody urine or strange smelling pee, feeling tired, fever or chill, *etc.*

Taking antibiotics as prescribed by doctor and drinking more water to flush out pathogens like bacteria from urinary tract are possible treatments. Sexual contact with infected partners and unhygienic conditions are the major cause of UTI.

15.5.2 Kidney Stones (Nephrolithiasis)

The hard mineralized material that cling together and form pebbles within the kidney or any other part of urinary tract like ureter, bladder is called **kidney stone**. These are small in size about **2-3 mm** in diameter and one to many in number. These very small kidney stones may pass out from body without causing any symptoms. The symptoms may include pain while urinating, blood in urine, sharp pain in back and lower abdomen, nausea and vomiting.

Calcium stones are the most common type of kidney stones. They are usually made of calcium oxalate and calcium phosphate. **Uric acid stones** form when urine is often too acidic. Uric acid can form stone by itself or mixing with calcium. (Fig.15.13)

Treatment:- The **treatment of kidney** stone depends on size, composition and location of stone. This can be traced out by x-ray, CT scan, blood test, urine test, *etc.*

Small stones are usually treated with medicine but large and complex stones usually need surgery or lithotripsy.

Lithotripsy

Lithotripsy is a medical procedure involving the physical destruction of hardened masses like kidney stones, **bezoars or gallstones**. The term is derived from the Greek words meaning 'breaking (or pulverizing) stones".

Types of Lithotripsy

There are two types of lithotripsy:

1. Extra corporeal Shock Wave

The **lithotripsy** uses shock waves to break up the kidney stones into small pieces. After the treatment, these small pieces will pass through urinary tract and out of body. This treatment usually takes 45 minutes to one hour and may be done under general anaesthesia so that patient does not feel pain.

2. Laser Lithotripsy

Another treatment is **ureteroscopy,** in which long tube shaped tool is used to find, remove and break stone. A **laser** is used to break the stone into small pieces so that these pieces may pass through the urinary tract.

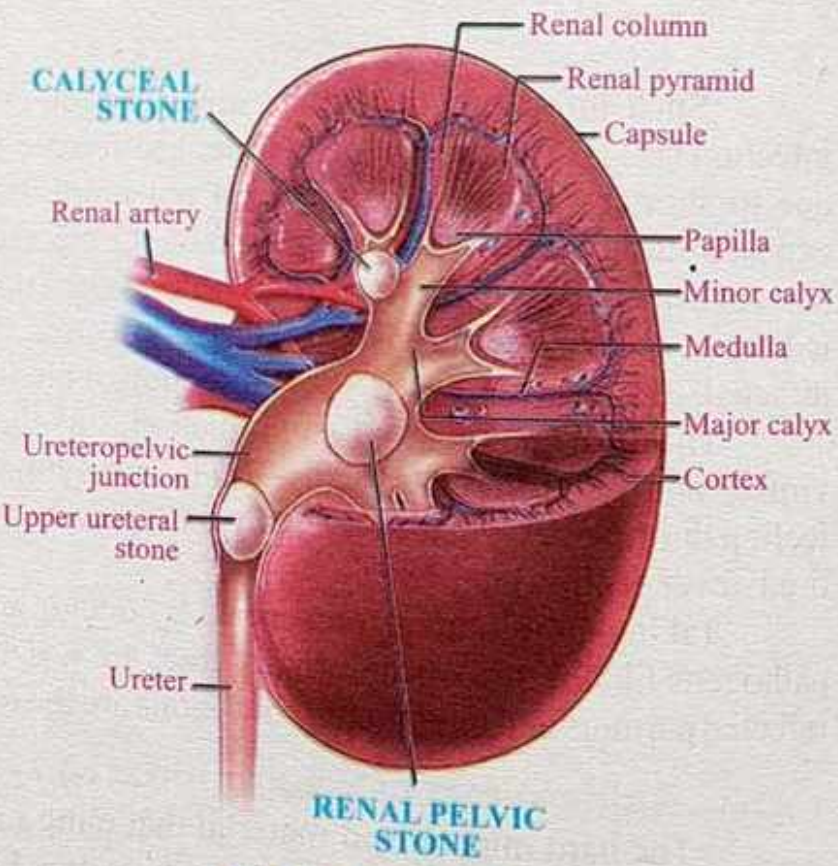


Fig. 15.13: Kidney Stone

15.5.3 Kidney Failure

Kidney failure, also called **end-stage renal disease (ESRD)**, is the last stage of chronic kidney disease. Kidney failure means that kidneys are not working well enough for survival of patient without dialysis or a **kidney transplant**.

There are many factors related to kidney failure. *e.g.* **Autoimmune diseases,** kidney stone, other health problems like diabetes, high blood pressure, use of drugs, bacterial infections.

Some of the symptoms of kidney failure are nausea and vomiting, muscle cramps, appetite loss, swelling in feet and ankles, too much urine, sleeplessness, *etc*. Acute kidney failure is usually caused by accidental injuries, vomiting, diarrhoea, shortage of water due to excessive sweating or excessive excretion of urine (diuresis), blockage of ureter due to kidney stone, severe nephritis, *etc*.

There are just few options for kidney failure patients. These include several types of dialysis and kidney transplant.

15.5.4 Dialysis

It is the temporary treatment for kidney failure patients. In this procedure, toxins and wastes are removed from the body by artificial means *i.e.* using dialyzing fluid. However, dialysis is not a permanent cure for kidney disease. There are following types of dialysis.

Extra Information

Diabetes is the leading cause of chronic kidney diseases 44% followed by high blood pressure 28%.

Hemodialysis

It is the most common type of dialysis. This process uses **artificial kidney (hemodialyzer)** to remove wastes, toxins and extra fluids from blood.

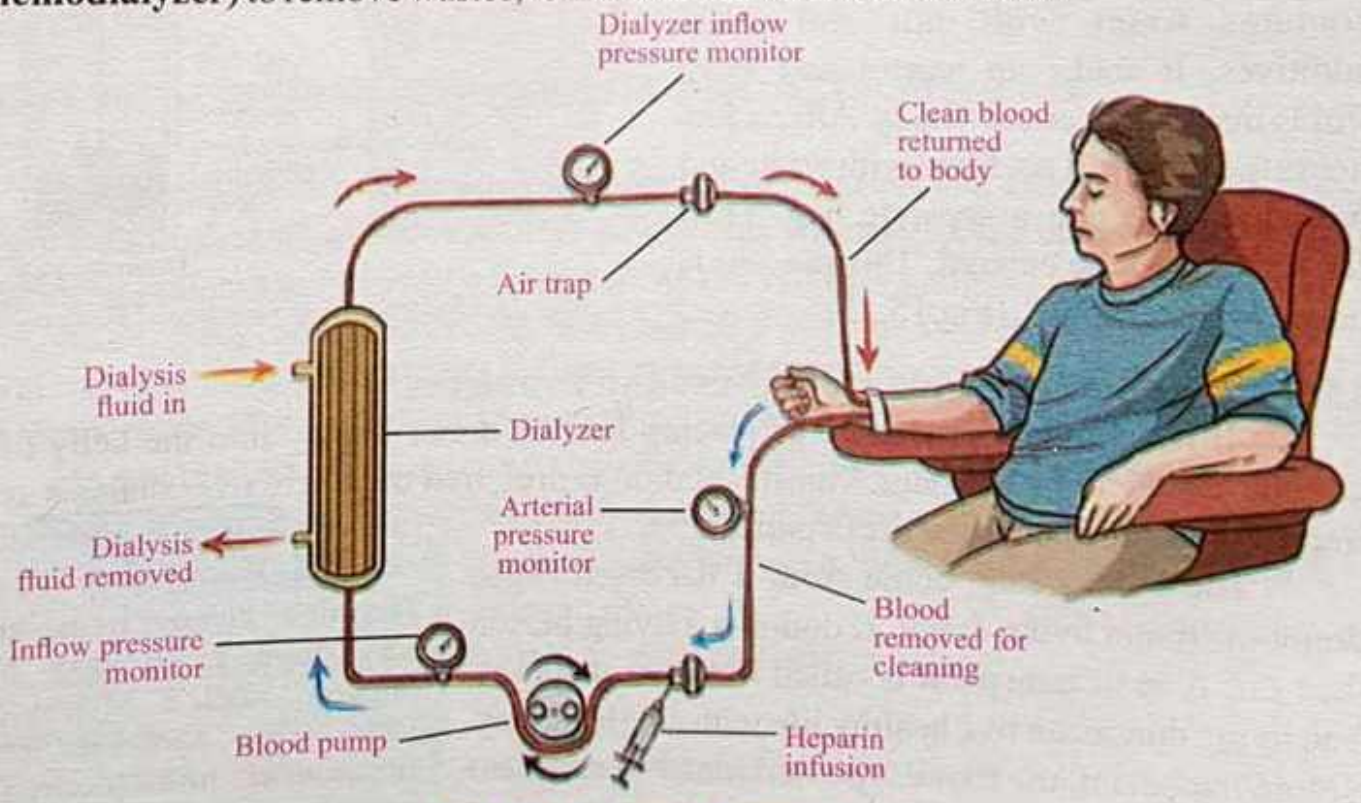


Fig. 15.14: Steps of Hemodialysis

During hemodialysis, blood passes from the patient's body to the dialysis machine through sterile tubing and into a filter called **dialyzing machine**. For this procedure, the patient has a specialized vascular tube placed between an artery and vein in the arm or leg called **gortex graft**. Sometimes a direct connection is made between an artery and vein in the arm. This procedure is called **cimino fistula**. Needles are then placed in graft or fistula and blood passes through the dialysis machine, through the filter and back to the patient. In the dialysis machine a solution on the other side of filter receives the waste products from the patient. (Fig.15.14)

Peritoneal Dialysis

This type of dialysis uses lining of abdomen called peritoneum to filter blood. A catheter is placed near the navel of patient a few weeks before the start of treatment. Once the area heals, the patient will be trained how to do peritoneal dialysis because patient can do this dialysis by himself. The catheter is used to transfer **dialysis solution** from a bag into patient's peritoneal cavity. This special fluid contains water with salt and other additives. It soaks up wastes and extra fluids inside the patient's body. After a few hours the fluid will get filled with waste and will drain out into a separate bag. Then fresh fluid will be entered. This process is called an "exchange". (Fig.15.15)

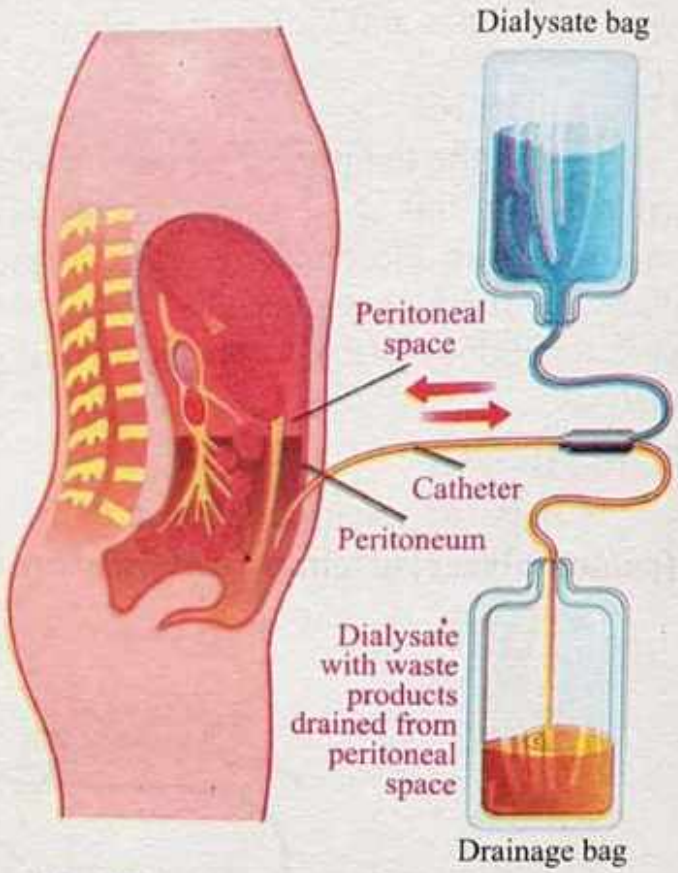


Fig. 15.15: Process of Peritoneal Dialysis

15.5.5 Kidney Transplant: Process and Problems

It is a surgical procedure of placing healthy donor kidney into the belly of a chronic kidney failure patient. Transplantation is preferred treatment over dialysis as it improves and normalize the life of patient.

The kidney may come from a deceased organ donor or from a living donor. If donor is a living person then this type of transplant is called **living transplant**. The living donor can live healthy life with single kidney. Before transplant, the tissue type of donor and recipient is made. A kidney transplant is done 3-4 hours' surgical

Extra Information

The first kidney transplant was done in Boston by surgeon Joseph E. Murray in 1954. This was the first successful human organ transplant.

procedure. A person getting a transplant most often gets one kidney. In rare cases, he or she may get 2 kidneys from a deceased donor. The affected kidney is usually left in place. The transplanted kidney is placed in the lower belly on the front side of the body and attached to a large artery. As soon as the transplanted kidney is connected to the blood vessels it will start the function of cleaning wastes from blood.

Extra Information

You don't need both of your kidneys to stay healthy. It might surprise you to learn that your body doesn't need two kidneys to perform an important job of removing wastes and regulating your metabolism. After donating your remaining kidney will take on the work of both kidneys.

Problems Associated with Kidney Transplant

A kidney transplant is a major operation. There are complications associated with kidney transplant. These include pain, delayed wound healing, bleeding and risk of infection, however, kidney rejection is the most serious problem. Medication like **cyclosporine** is given to suppress the immune system of recipient to prevent rejection of transplant kidney.

15.6 Thermoregulation

The maintenance of internal body temperature at nearly constant state so that the body can perform its metabolic activities at optimum level is called thermoregulation. Any change in temperature will affect the enzyme activity thus metabolic reactions will disturb.

15.6.1 Classification of Animals on the Basis of Temperature (Thermoregulation)

On the basis of temperature regulation, animals can be divided into two groups. **Poikilotherms** are those animals who are not able to regulate their internal body temperature, rather they depend on external source of heat (sunlight) to get themselves warm. Their body temperature changes with the change of external temperature. Therefore, they have to **hibernate** in low temperature and **aestivate** (summer sleep) in high temperature. These include fish, amphibians and reptiles.

Homeotherms are those animals who are able to regulate their internal body temperature and are not dependent on external source of heat.

These animals have high metabolic rate and need more food to generate heat in their body. These include birds and mammals.

On the basis of heat production, animals can be divided into three categories.

Ectotherms

Ectotherm animals generate metabolic heat at low level due to low metabolic rate. Therefore, they depend on external source of heat for their survival. These include

insects, fish, amphibians and reptiles.

Endotherms

Endotherms can generate enough heat to maintain their body temperature due to high metabolic rate, thus can survive in all sorts of habitats. These include birds and mammals.

Heterotherms

Heterotherms are type of animals with a thermoregulatory strategy, intermediate to ectotherm and endotherms. They produce heat in their body but also depend on external source of heat. They include small mammals like bat and small birds like humming bird.

15.6.2 Thermoregulatory Strategies in Man

The body temperature of human is regulated and stabilized by **hypothalamus** (a region of brain basically concerned with homeostasis). In case of any variation in set point, endocrine production initiates control mechanism to increase or decrease energy production or dissipation to return the temperature towards the set point. During hot (hyperthermia) conditions, following changes are noticed in body:

- Vasodilation *i.e.* expansion of blood capillaries under the skin so that more heat can be brought towards skin for dissipation of heat.
- Activation of sweat glands.
- Relaxation of hair erector muscle.

During cold (hypothermia), following changes occur to prevent heat loss and generate heat.

- Inactivation of sweat glands.
- Vasoconstriction.
- Increase in metabolic activities.
- Shivering may starts.
- Brown fats are consumed for more and rapid heat production.

Science, Technology and Society (STS)

1. Describe the importance of kidney donation for the benefit of kidney failure patients.

There is no doubt that being a living donor is a huge benefit to the recipients of living donor kidney, usually live longer, healthier life compared to those who receive a deceased donor kidney, it is important to recognize there can be benefit to donor as well. Such as, saving the life of other person giving a renewed and improved quality of

life to another person, greater understanding of your own health. If we can live with single kidney then why human being has two kidneys? Perhaps to donate one kidney to save the life of kidney failure patients.

2. Name the important kidney transplant centres in the Province.

There are many kidney transplant centre in Pakistan. These includes Shifa International Hospital, Kidney Transplant Program Agha Khan University Hospital, Kidney Transplant Doctors Hospital and Medical Centre Lahore, *etc*.

However, Sindh Institute of Urology and Transplantation (SIUT) is most prominent and pioneer in treating kidney related diseases in Pakistan. The Dr. Adeeb Rizvi has established this institute in 1971.

In the province of Balochistan only few kidney transplant centres have been established *e.g.* Balochistan Institute of Nephrology, Urology Quetta (BINUQ).

SUMMARY

- Ability of an organism to maintain internal environment at nearly constant state is called homeostasis.
- The internal changeable factors of the body are called variables.
- A feedback mechanism is a loop system within the system, responds to a perturbation.
- Almost all homeostatic control mechanisms are negative feedback mechanisms.
- The process of maintaining water and solute concentration in the body at nearly constant state is called osmoregulation.
- The fresh water environment is hypotonic to animals, therefore, the main osmoregulatory problem of these animals is excess of water.
- The mammals of terrestrial environment usually have dead, keratinized, water resisting cells.
- The process of removal of metabolic wastes from body is called excretion.
- 1 gram of ammonia needs 500 ml of water to be removed from body.
- The left kidney is about 1.5-20 cm higher than the right kidney.
- Nephrons are the structural and functional unit of kidney.
- The mechanism of producing concentrated urine when there is shortage of water in the body is called counter current mechanism.
- The urinary tract disorders include; UTI, kidney stone, kidney failure, prostate problem, bladder control problems, *etc*.
- Lithotripsy uses shock waves to break kidney stones.
- Kidney failure means that kidneys are not working well enough for survival of the patient.

- Dialysis is the temporary treatment of kidney failure patients, in which wastes are removed from body through a dialyzing fluid.
- Kidney transplant is a surgical procedure of placing healthy kidney into the belly of a chronic kidney failure patient.
- The maintenance of internal body temperature of body at a nearly constant state is called thermoregulation.
- Poikilothermic are those animals who cannot maintain their internal environment at constant state.

EXERCISE

SECTION-I: OBJECTIVE QUESTIONS

Multiple Choice Questions (MCQs)

A. Select the correct answer.

1. Body temperature regulation in human is based on complex homeostatic thermostat present in:
   (a) Thalamus (b) Pons
   (c) Hypothalamus (d) Amygdala
2. Trimethylamine oxide is produced in:
   (a) Cartilaginous / marine fish (b) Bony fish
   (c) Jawless fishes (d) Lung fishes
3. Which of the following structure of kidney is responsible for the production of concentrated urine?
   (a) Cortical nephrons (b) Juxtamedullary nephron
   (c) Vasa recta (d) Glomerulus
4. Animals that generate their own body heat through heat production as by product of metabolism:
   (a) Endotherms (b) Ectotherms
   (c) Heterotherms (d) All of these
5. The hormone affects ascending limb:
   (a) ADH (b) Aldosterone
   (c) Thyroxin (d) Both a and b
6. Concentrated urine is produced in mammals when there is
   (a) Excess of water in the body (b) Shortage of water in the body
   (c) Less urea in blood (d) Less glucose in blood
7. Water is mostly absorbed by
   (a) Proximal tubule (b) Distal tubule

(c) Loop of Henle (c) Collecting duct

8. Glomerulus are located in
   (a) Collecting duct (b) Renal tubule
   (c) Pelvis (d) Renal capsule
9. The ideal or normal value of variable is called
   (a) Set point (b) Output
   (c) Response (d) Stimuli
10. The salt secreting glands in some marine fishes are called
   (a) Sebaceous glands (b) Sweat glands
   (c) Rectal glands (d) Tear glands
11. The chief nitrogenous waste of fresh water animals is
   (a) Urea (b) Ammonia
   (c) Uric acid (d) Creatinine
12. The useful substances are reabsorbed from
   (a) Renal tubule (b) Renal capsule
   (c) Collecting duct (d) Vasa recta
13. Ureters are less affected as compare to other urinary tract infections due to:
   (a) Large surface area (b) Less acidic
   (c) Narrow tube (d) More acidic
14. The drug given to prevent kidney rejection is
   (a) Cyclosporine (b) Penicillin
   (c) Pain killers (d) Antibiotics

B. Fill in the blanks.

1. The maintenance of internal environment at constant state is called .....
2. The term homeostasis was introduced by .....
3. Those animals that can maintain their osmotic conditions at constant state are called .....
4. Marine fish usually have ..... to remove their extra salts.
5. Animals which excrete urea as their chief nitrogenous waste are called .....
6. The network of capillaries present in the mouth of Bowman's capsule is called .....
7. The process of formation of concentrated urine is called ..... mechanism.

8. Peritoneal dialysis uses the ..... cavity of body.
9. Hyperthermia is ..... body temperature.
10. The cyclosporine is used to prevent .....

SECTION-II: SHORT QUESTIONS

C. Give the short answers of the following questions.

1. Define homeostasis and write its components.
2. Write the importance of negative feedback mechanism.
3. Write the importance of positive feedback mechanism for our body.
4. Differentiate between osmoregulator and osmoconformer.
5. Describe the problems faced by osmoregulators.
6. Write the importance of urea as chief nitrogenous waste of most terrestrial animals.
7. Illustrate the two types of nephrons.
8. Write the common causes of urinary tract infections.
9. Describe the three groups of animals on the basis of heat production.
10. Define Lithotripsy briefly describe laser lithotripsy.
11. Write the problems associated with kidney transplant.

SECTION-III: EXTENSIVE QUESTIONS

D. Give detailed answers of the following questions.

1. Describe relationship between excretory products and habitats.
2. Define and explain structure of nephron.
3. Explain the steps of urine formation.
4. Define dialysis and explain the two types of dialysis.
5. Explain the kidney transplant process in detail.
6. Describe the osmoregulatory adaptations in different habitats.
7. Describe the external and internal structure of human kidney.
8. Define kidney stones. Explain types of lithotripsy.
9. Define feedback mechanism, describe in detail negative and positive feedback mechanism.
10. Explain classification of animals on the basis of temperature and also write thermoregulatory strategies in man.

UNIT 16

SUPPORT AND MOVEMENT

Major Concept

16.1 Human Skeleton
16.2 Disorders of Skeleton
16.3 Muscles

Learning Outcomes

Students will be able to:

- Describe the structure of bone and compare it with that of cartilage.
- Explain the functions of osteoblasts, osteoclasts and osteocytes.
- Identify the main divisions of human skeleton.
- List the bones of appendicular and axial skeleton of man.
- Describe three types of joints *i.e.* fibrous joints, cartilaginous joints and synovial joints and give example of each.
- Describe the disorders of human skeleton (disc-slip, spondylosis, sciatica, arthritis) and their causes.
- State different types of fractures (simple, compound and complicated) and describe the repair process of simple fractures.
- Describe the injuries in joints (dislocation and sprain) and their first aid treatment.
- Describe the first-aid treatment for fracture.
- Compare smooth muscles, cardiac muscles and skeletal muscles.
- Explain the ultra-structure of the skeletal muscle.
- Explain the sliding filaments model of muscle contraction.
- Describe the action of antagonistic muscles in the movement of knee joint.

Introduction

The movement refers to change in shape or position of body parts. Movement is different from locomotion, as in **locomotion** whole organism moves from one place to another. In animals, movement is provided by muscles. **Support** means to provide proper shape and structure to the body so that body can perform it's vital functions. In animals, **support** is provided by hydrostatic skeletons, bones and cartilages. In this unit we will study about skeletal tissues *i.e.* bones and cartilages, muscular tissues, some muscular and skeletal disorders.

16.1 Human Skeleton

Human's skeleton is the main supportive framework of the body. It mainly includes bones and cartilages. The muscles are attached to the skeleton for the production of effective movements of the body.

Skeletal tissues:- Skeletal tissues are bone or cartilage

Bone:- Bone is one-third of connective tissue. It is impregnated with calcium salts. The composition of bone tissue is different from other tissues in the body. Bone is a hard tissue, provides support to the body, gives environment for the production of blood cells and protects internal organs of the body.

16.1.1 Structure of Bone

Bone tissues are of two types; **compact** (hard and dense) and **cancellous** (spongy) tissues. The outer part of bone is hard, called compact bone while the inner part is spongy, called spongy bone.

Compact bone

Compact bone, also called **cortical bone**, is a hard white bone tissue that surrounds all the bones in human body. The fundamental units of compact bone are called **osteons** or **Haversian systems.** Each osteon consists of concentric layers called **lamellae** (singular: lamella). In the centre of each osteon, **central canal** or **Haversian canal** is present which contains blood and nerve supply of the bone. The central canal communicates with the **perforating canal** (also called **Volkmann's canal**), which transmits blood vessels from periosteum (a dense layer of vascular connective tissue enveloping the bone) into the endosteum (The thin layer of cells lining the medullary cavity of a bone).

The **osteocytes** are located in the small cavity called **lacunae** (singular: lacuna), situated between the lamellae. **Canaliculi** are the microscopic channels that create a network which transport nutrients, to the osteocytes and also remove wastes from them.

Spongy bone

Spongy bone, also called cancellous or **trabecular bone**, is a porous and highly vascular bone. It is mostly located at the end of the long bones. Unlike compact bone, the lacunae of spongy bone are found in a lattice-like network of matrix spikes called **trabeculae** (singular: trabecula). The **osteocytes** of spongy bone are irregularly placed within the trabeculae. The spaces between trabeculated networks make spongy bone lighter and less dense than compact bone. The spaces in some spongy bones contain **red bone marrow**, where the blood cells are formed. (Fig.16.1)

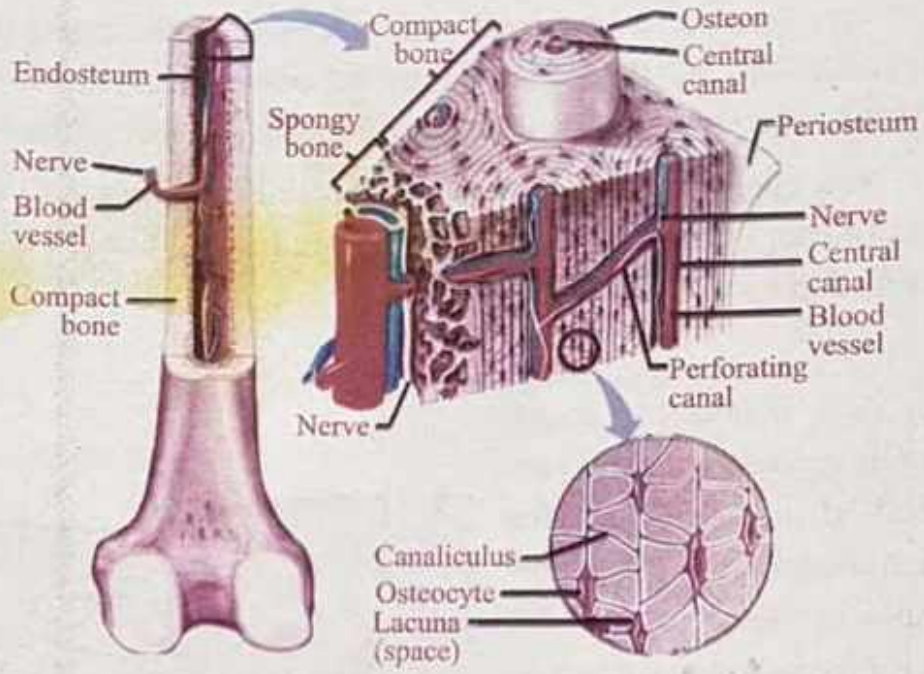


Fig.16.1: Internal Structure of Bone

Types of Bone Cells

The process of bone growth and repair is carried out by four different types of cells. These cells are involved in making and breaking the bone.

1. **Osteogenic Cells** are the stem cells that are found in the cellular layer of endosteum and periosteum. These are undifferentiated cells and have ability to divide. The osteogenic cells develop into osteoblasts.

2. **Osteoblasts** are involved in the formation of new bone. They are mostly found in the areas where bone growth occurs. These cells secrete collagen.

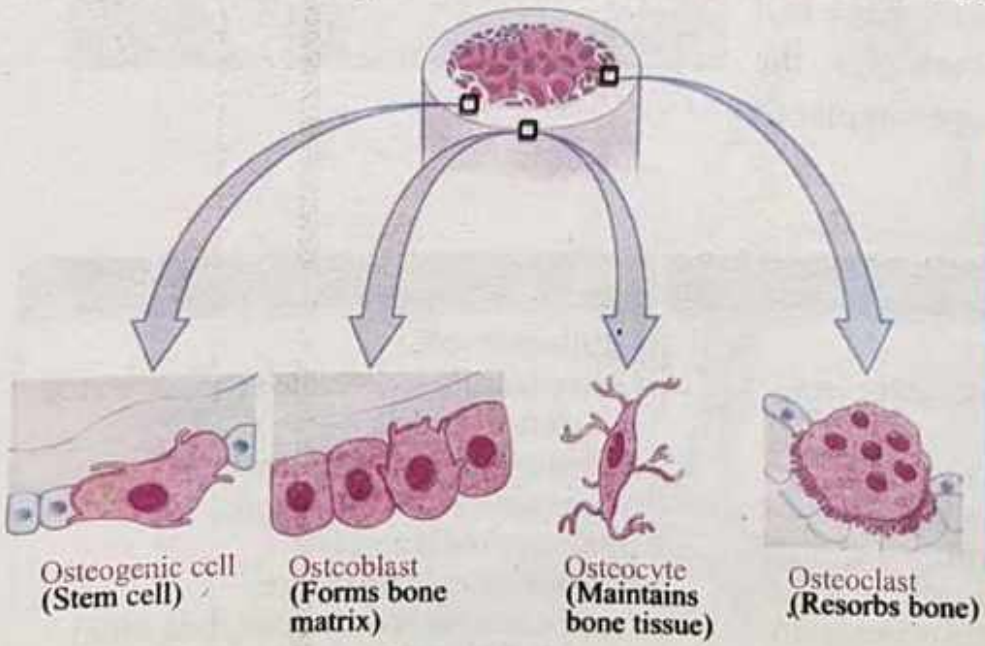


Fig.16.2: Types of Bone Cells

Extra Information

A new "inner you" is about ten years old. In adult human every year about 10% bone is replaced, that means as the mineral content in bones is renewed, we get a new skeleton about every ten years.

3. **Osteocytes** are matured bones cells and are entrapped in the matrix. When osteoblasts are surrounded by the matrix, they become osteocytes. By the help of secretion of enzymes, osteocytes maintain mineral concentration of the matrix.

4. **Osteoclasts** take part in bone resorption and breakdown processes. These cells are found at the sites of old, injured bone. Osteoclasts are multinucleated and are derived from **monocytes and macrophages**. (Fig.16.2)

16.1.2 Cartilage

Cartilage is a connective tissue compos-ed of cells called **chondrocytes** and fibers embed-ed in a firm, gel like matrix. It is much more elastic than bone. Cartilage is found in many areas of the body including joints, between the bones, *e.g.* the elbow, knees and ankles.

The general features of cartilage include that it has no blood vessels or lymphatics. The nutrition of cells diffuses through the matrix. Cartilage has no nerves, it is therefore, insensitive. Cartilage is surrounded by a fibrous membrane called **perichondrium**, which is similar to periosteum in structure and function. When cartilage calcifies, the chondrocytes die and cartilage is replaced by bone like tissue. (Fig.16.3)

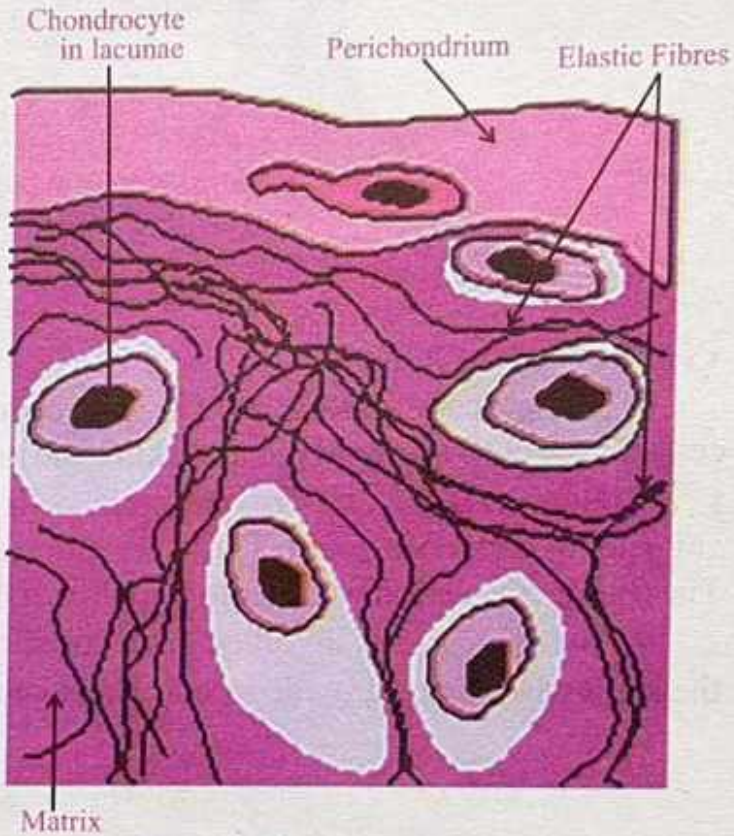


Fig.16.3: Structure of Cartilage

Table 16.1 The comparison between bone and Cartilage

S.No.	Bone	Cartilage
i)	Bone is hard.	Cartilage is soft.
ii)	Cells of bone are called osteocytes.	Cells of cartilage are called chondrocytes.
iii)	Matrix is inflexible.	Matrix is flexible.
iv)	Matrix possesses calcium salts.	Calcium salts are not present.
v)	Bone has rich blood supply.	It does not have blood supply.
vi)	Bone marrow is present.	Bone marrow is absent.
vii)	It is vascular in nature.	It is non-vascular in nature.
viii)	Outer covering is called periosteum.	Outer covering is called perichondrium.
ix)	Provide skeletal support to the body.	Provide flexibility to the body.

16.1.3 Functions of Human Skeleton

Human skeleton is located inside the organism with muscles attached outside therefore, it is called endoskeleton. It is made up of living tissues which grow with the growth of organism. It is made up of either cartilage or bone. Human skeleton performs various functions in the body. Some functions of skeleton are as follows:

- It gives support to the body. Without the skeleton, the body would be flabby and shapeless

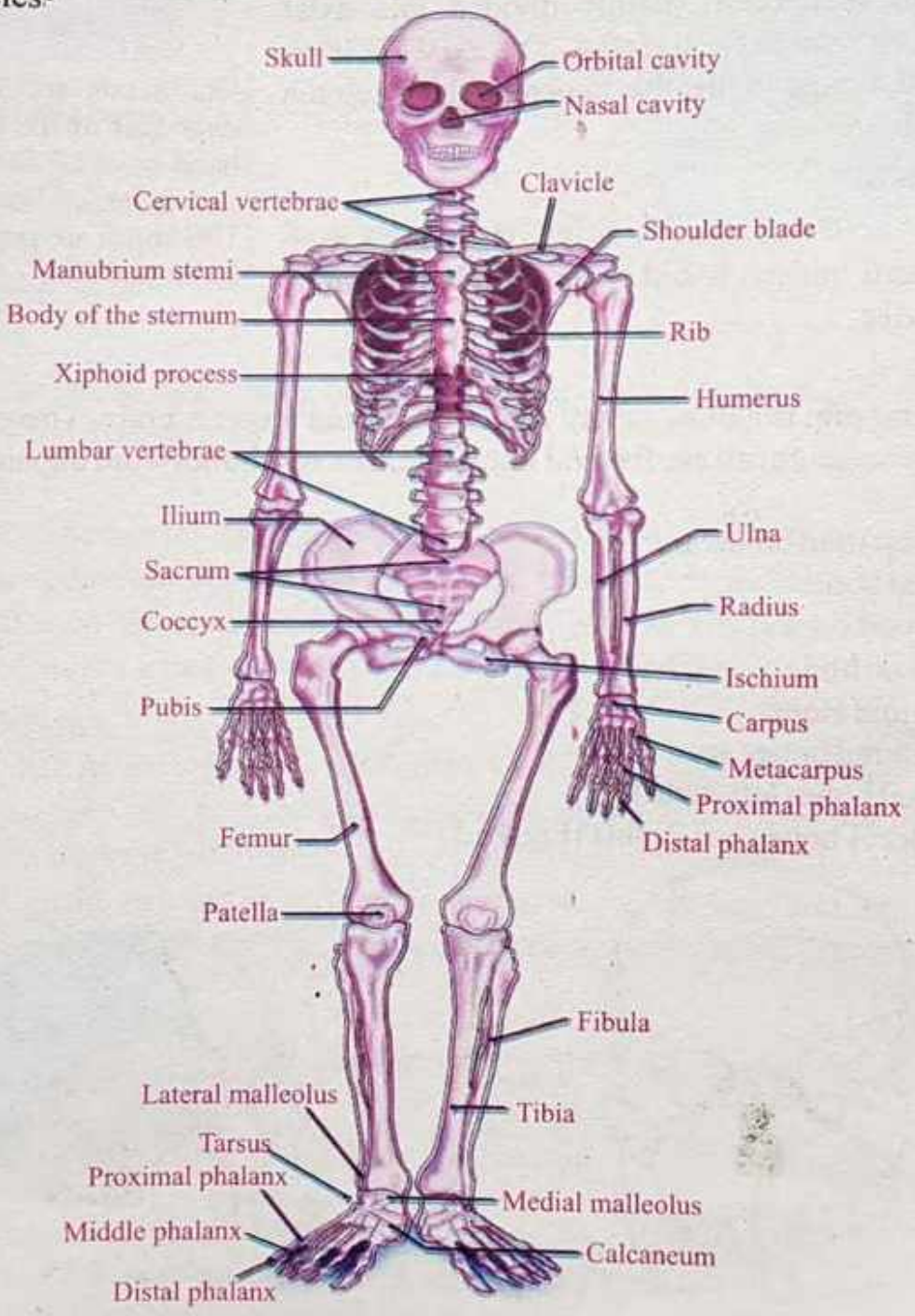


Fig.16.4: Human Skeleton

- It provides surface for the attachment of muscles, ligaments and tendons.
- It stores 97% of the body calcium and phosphorus.
- Blood cells are made in red bone marrow, which are mostly present in the ribs and limb bones.
- The bones and joints work with muscles, enable us to walk and run.

Divisions of human skeleton

Human skeleton is mainly divided into axial skeleton and appendicular skeleton. The axial skeleton consist of 80 bones while the appendicular skeleton contains 126 bones.

Interesting Information

Our hands and feet contain over half of the bones. Each hand have 27 bone and each feet have 26 bones, so total 106 bones are present only in hands and feet.

Axial skeleton

Axial skeleton is mostly fused. It includes skull (cranium, facial bones), hyoid bone, vertebral column, sternum and ribs.

Cranium

The cranium is a bony cavity that contains and protects brain. There are 8 bones present in the cranium, all are flat and immobile. Out of 8 bones 4 are unpaired and 2 are paired.

The unpaired bones are:

- Frontal bone
- Occipital bone
- Ethmoid bone
- Sphenoid Bone

The paired bones are:

- Parietal bone (left, right)
- Temporal bone (left, right) (Fig.16.5)

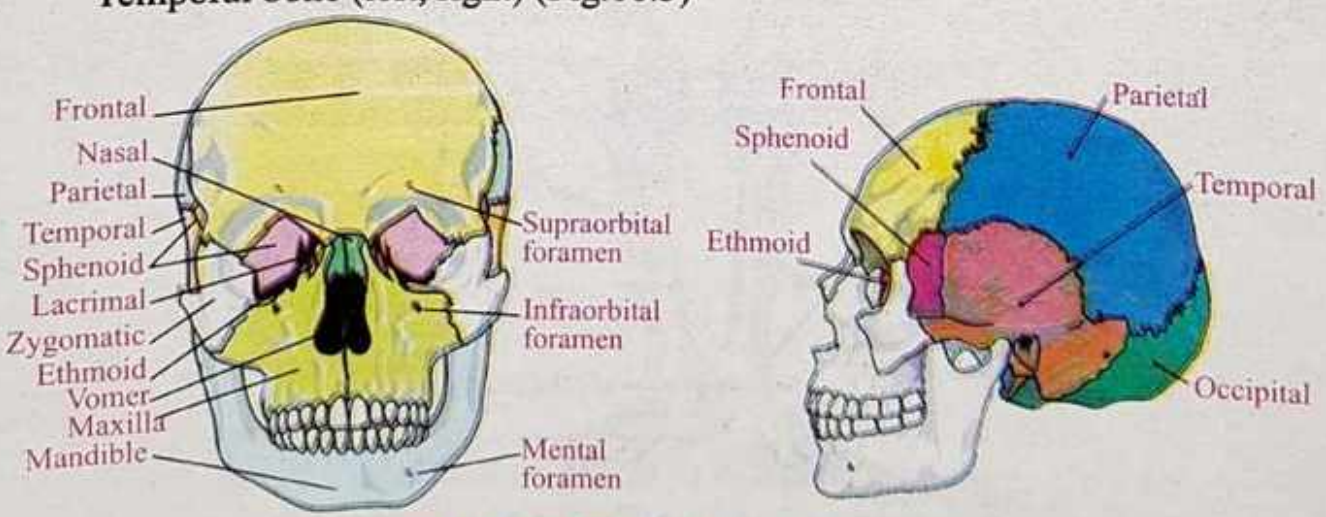


Fig.16.5: Human Skull (Front and Lateral Views)

Facial bones

Facial bones are attached to cranium. These bones give protection to the sense organs of sight, smell and taste and provide a frame for various muscle attachments. There are 14 facial bones, out of which 2 are unpaired and 6 are paired.

The unpaired bones are:

- Mandible
- Vomer (movable bone)

The paired bones are:

- Maxilla
- Zygomatic bones
- Nasal bones
- Inferior nasal concha
- Lacrimal bones
- Palatine bones

Extra Information

Bone stop growing in length after puberty. However, bone density and strength will change over the course of life.

Ear Bone

There are three pairs of ear bones collectively called **ossicles**. One pair malleus, one pair incus and one pair stapes.

Hyoid bone

Hyoid bone is also known as **lingual bone** because it gives attachment to the tongue. It also provides site for the attachment of different muscles associated with swallowing. It is a u-shaped bone present in the neck region. The unique feature of hyoid bone is that it does not articulate with any other bone of the body.

Vertebral Column

Vertebral column is also known as **back bone**. It has **four curvatures** that provide great support to the skull, pectoral girdle, thoracic cage and maintain the posture of the body. It also provides protection to the spinal cord which is present in its cavity. There are 33 vertebrae that are present in vertebral column, which are later fused to become 26. According to location, there are five groups of vertebrae which are as follows:

1. Cervical vertebrae
2. Thoracic vertebrae
3. Lumbar vertebrae
4. Sacral vertebrae
5. Coccygeal vertebrae

1. Cervical vertebrae

These are 7 in number (C1 to C7) and present in the neck region. The first two vertebrae (atlas and axis) are modified to allow the movement of the head.

2. Thoracic vertebrae

These are 12 in number and are numbered (T1 to T12). They form a backward curve down to thorax. Ribs are attached to these vertebrae. These vertebrae provide support to the rib cage.

3. Lumbar vertebrae

These are 5 in number (L1 to L5) and are present in lumbar region. These are the largest vertebrae in the vertebral column because of their weig

4. Sacral vertebrae

These are 5 in number, represented by the symbols (S1 to S5). These vertebrae later fuse to form a single bone called **sacrum.**

5. Coccygeal vertebrae

These are also called **coccyx** or **tail bone**. These are 4 in number and later fuse together to form a tiny tail like structure. (Fig.16.6)

Sternum and Ribs (Ribcage)

Sternum is the elongate, flat bone that lies in the midline of anterior chest wall. It is also known as **breast bone**. The sternum consists of three main parts: manubrium, body of sternum and xiphoid process. **Manubrium** is the upper part of sternum. It articulates with the 1st costal cartilage and the upper part of 2nd costal cartilage on each side. **Body** is the middle part of sternum and is relatively long. It articulates with the lower part of 2nd costal cartilage to the 7th costal cartilages on each side. **Xiphoid process** is the lower part of sternum. It does not articulate with the ribs and costal cartilages.

Ribs are long, twisted flat bones that form the major part of rib cage. Rib cage encloses and protects the heart and lungs. It also provides a framework onto which many muscles are attached. There are 12 pairs of ribs in human skeleton. Posteriorly, the ribs articulate with the thoracic vertebrae and anteriorly, the ribs have different relations that allow ribs to be categorized as true ribs, false ribs and floating ribs. Pairs 1 to 7 are called true **ribs** because these ribs are connected to the sternum through individual costal cartilages. Three pairs are

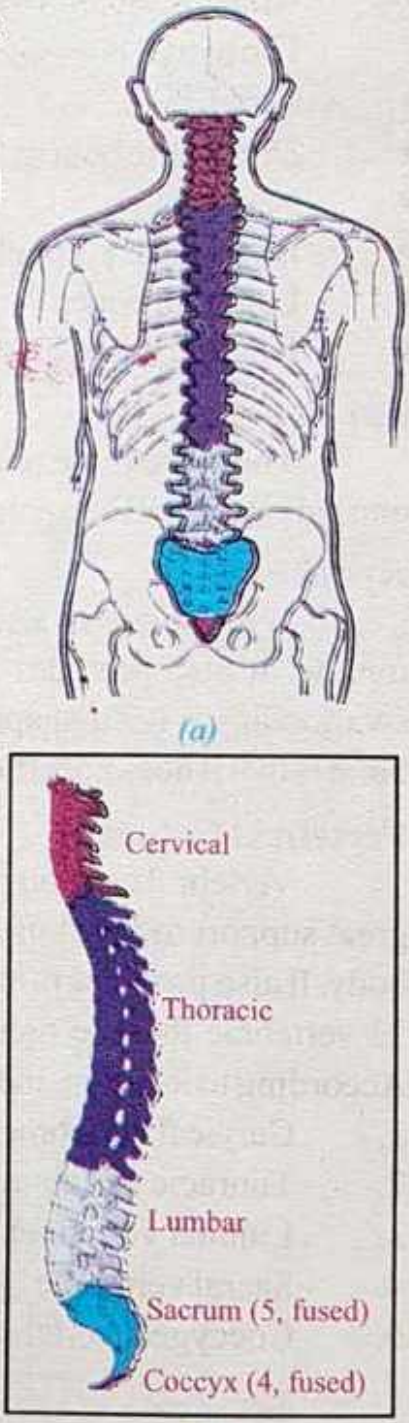


Fig.16.6: Human Vertebral Column

floating ribs (**false ribs**) (8 to 10), which are attached with 7th rib and form costal arch. The last 2 pairs of ribs (11th and 12th) are not attached to sternum. These are called **floating ribs**. (Fig.16.7)

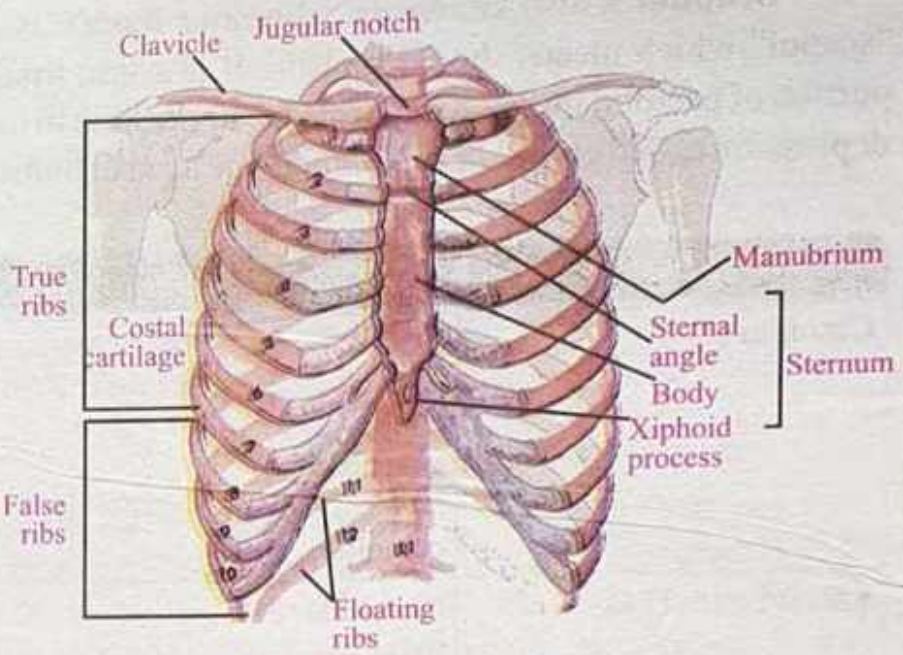


Fig.16.7 Human Rib Cage

Appendicular Skeleton

Comparing with the axial skeleton, the appendicular skeleton is unfused. It consists of **girdles** (pectoral and pelvic) and **limbs** (fore limb and hind limb).

Pectoral Girdle

Pectoral girdle is the part of appendicular skeleton. It is also known as **shoulder girdle**. In human skeleton, clavicle and scapula form the shoulder girdle which connects the arm on each side.

Clavicle is also known as **"collar bone"**. The word clavicle is derived from Latin word "clavicul" which means key. It is a curved bone which resembles with an old style key. It is present between sternum and scapula and forms the front part of pectoral girdle. It has two ends; the sternum end and the acromial end. At sternum end, it articulates with sternum and forms **sternoclavicular joint** whereas at acromial end, it articulates with the acromion of scapula and forms **acromioclavicular joint**.

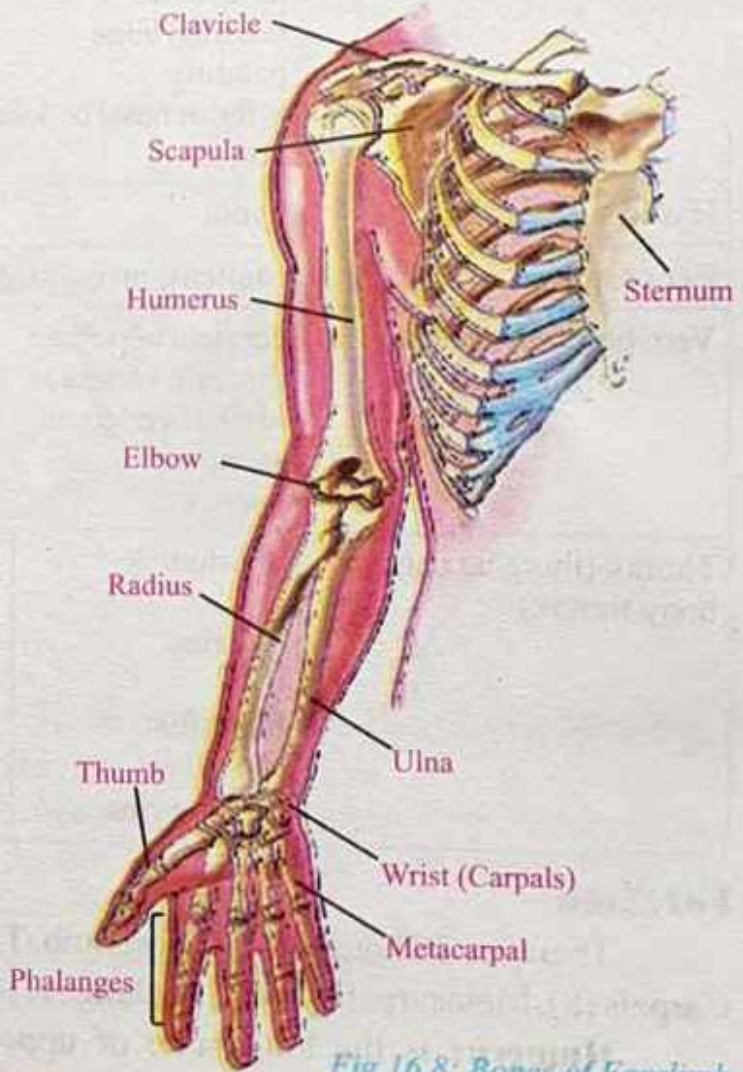


Fig.16.8: Bones of Forelimb

Scapula is also known as **"shoulder bone"**. It is also derived from Latin word "scapul" which means shoulder blade. It is a flat, triangular bone that forms the back portion of pectoral girdle. It connects the upper limb to the trunk. On lateral side, there is a depression called **glenoid cavity** where the head of humerus inserts.

Tables 16.2: The list of bones present in axial skeleton

General Description	Name of Bone		No of Bones
Cranium (8)	frontal		1
	parietal		2
	temporal		2
	sphenoid		1
	ethmoid		1
	occipital		1
Facial bones (14)	Mandible		1
	maxilla		2
	zygomatic bone		2
	nasal bone		1
	lacrimal bone		1
	palatine		1
	inferior nasal concha		
	vomer		
Hyoid	hyoid		1
Ear ossicles	Malleus, incus, stapes		6
Vertebral column (26)	cervical vertebrae		7
	thoracic vertebrae		12
	lumbar vertebrae		5
	sacrum		1
	coccyx		1
Thorax (thoracic cage or bony thorax)	Sternum		1
	true ribs	(7 pair)	14
	false ribs	(3 pair)	6
	floating ribs	(floating [2 pair] ribs)	4

Forelimb

There are 30 bones in each forelimb. These are Humerus (1), Radius (1), Ulna (1), Carpals (8), Metacarpals (5) and Phalanges (14).

Humerus is the long bone of upper arm. Proximally, the head of humerus

articulates with the glenoid cavity of scapula and forms **glenohumeral joint**.

Radius and **ulna** are the bones of forearm. Radius is present on the lateral side (thumb side) while ulna is present on the medial side of forearm.

Carpals are the bones of wrist. These are two rows of 8 short bones (4 bones in each row). The proximal row articulates with the radius and ulna while distal row articulates with the metacarpals. These bones provide stability and some movement.

Metacarpals are 5 bones that form the palm located between the carpal bones and phalanges. The bones are identified by number (1-5).

Phalanges (Phalanx) are 14 bones that form the fingers. Each finger consists of 3 bones except the thumb which consists of 2 bones.

Pelvic Girdle

The pelvic girdle is made up of three skeletal elements, the ilium, ischium, and pubis which form the **coxa**. The **ilium** is the upper flattened bone, **ischium** is lowest portion of coxal bone while the **pubis** is anterior part of the coxal bone. The two halves of the pelvic girdle are joint by pubic bones which articulate with each other at the **symphysis pubis** (Pubic Symphysis). The outer surface of the hip bone has a deep depression called **acetabulum**. It is the cavity in which the head of femur inserted. (Fig.16.9)

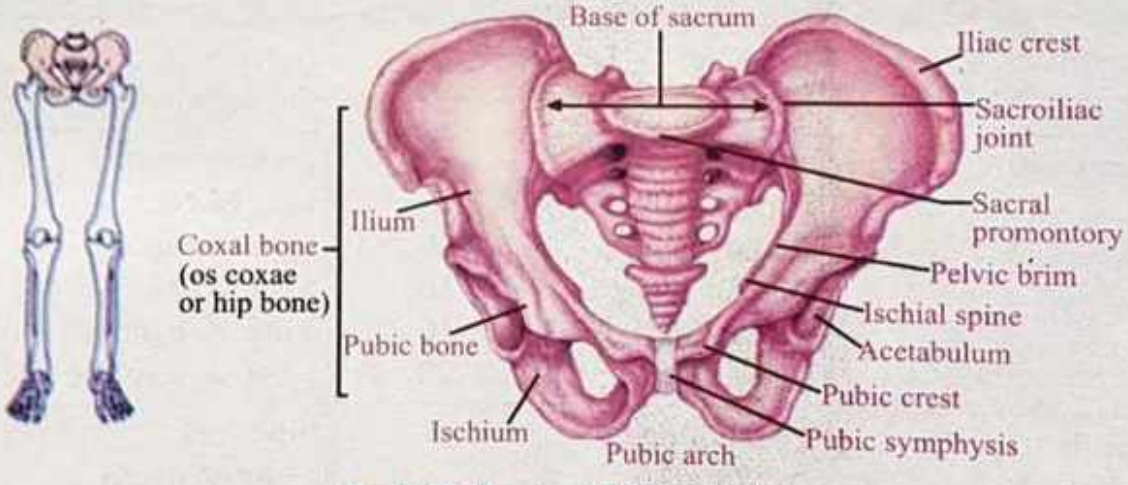


Fig.16.9: Bones of Pelvic Girdle

Hind limb

There are 30 bones in each hind limb. These are femur (1), Patella (1), Tibia (1), Fibula (1), Tarsal bones (7), Metatarsal bones (5) and Phalanges (14).

Femur is the longest and strongest bone in human skeleton. At the proximal end the head of femur articulates with the acetabulum to form the hip joint and at distal end it articulates with tibia and patella to form the knee joint. (Fig.16.10)

Patella or **knee cap** is situated in front of the knee joint. It is embedded in a long tendon which runs over the knee joint. The posterior surface of patella articulates with the **condyles** of the femur.

Tibia and **fibula** are the bones of lower leg. The tibia, or **shin bone** is the large weight-bearing medial bone of the lower leg. The fibula or **calf bone** is located on the lateral side of lower leg.

Tarsal bones are the bones of **ankle**. Proximally these bones articulate with tibia and distally articulate with metatarsals. These are seven in number and form the ankle, heel and instep of foot.

Metatarsal bones resemble with the metacarpals of the hand. The metatarsals are numbered (1 to 5) from medial to lateral side. These are present between tarsal bones and phalanges to form the **sole of the foot**.

Phalanges are the small bones that resemble with the digits in hand. Each toe has three phalanges except the big toe, which possess two phalanges.

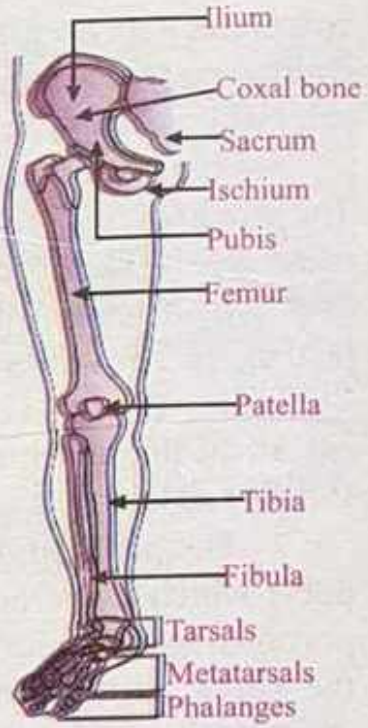


Fig.16.10: Hind Limb

Table 16.3. Appendicular Skeleton Bones (126 bones)

General Description	Name of Bone	No of Bones	Additional Information
Pectoral girdle (shoulder girdle)	Clavicle Scapula	2 2	collar bone shoulder bone
Upper limb (60)	Humerus Ulna Radius Carpals Metacarpals Phalanges	2 2 2 16 10 28	1 per upper arm 1 per forearm 1 per forearm 8 per wrist 5 in each hand 3 per digit (pollex has 2)
Pelvic girdle (hip) (2)	Coxal Bones 1. Ilium 2. Ischium 3. Pubis	2	hip bones (3 fused pairs)
Lower limb (60)	Femur Patella Tibia Fibula	2 2 2 2	1 per upper leg 1 per leg 1 per lower leg 1 per lower leg
	Tarsal	14	7 per ankle
	Metatarsals Phalanges	10 28	5 per foot 3 per digit (hallux has 2)

16.1.4 Joints

Joint is the point of attachment between two bones or bone and cartilage. There are more joints in a child than in adult because some of the bones fuse together as the growth proceeds. There are 360 joints in adult human skeleton. The scientific study of joints is called **arthrology**.

Extra Information

Ligaments are short bands of tough fibrous connective tissue that function to connect one bone to another bone in the joint.

Types of joints

On the basis of tissue present in the joint, there are three types of joints: fibrous joints, cartilaginous joints and synovial joints.

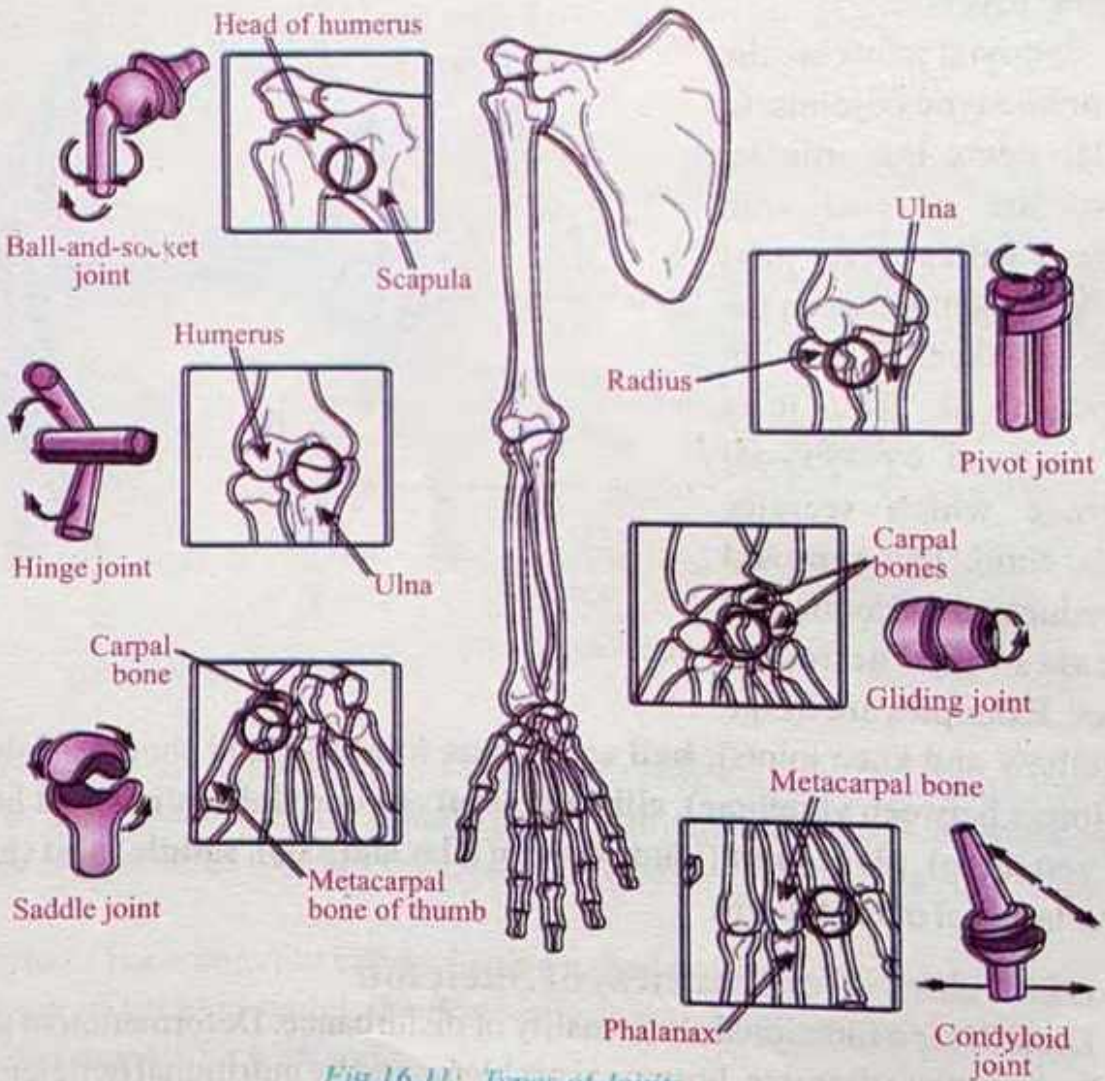


Fig 16.11: Types of Joints

Fibrous joints

When the articular surface of the bones are connected to each other by fibrous connective tissue, it is called **fibrous joint**. Fibrous connective tissue is a dense

connective tissue consisting mainly of collagen. These joints are also called immovable joints because they do not allow movement. Examples, includes joint between skull bones called **sutures**, joint between tooth and its socket and joint between long bones *e.g.* tibia and fibula.

Cartilaginous joints

When the articular surface of the bones is connected by cartilage (fibrocartilage or hyaline cartilage), it is called **cartilaginous joint**. These joints are also called **slightly movable joints** because they allow little movement. **Hyaline cartilage** is seen in the costal cartilages that attach ribs to the sternum, **fibrocartilage** is seen in intervertebral disc and pubic **symphysis**.

Synovial joints

Synovial joints are the most mobile type of joints. In synovial joints the articular surfaces are covered with hyaline cartilage. A joint cavity is present between the articular surfaces filled with synovial fluid. The joint cavity is lined by synovial membrane which secretes synovial fluid. This **synovial fluid** reduces the friction and lubricates the articular surfaces. Examples are **hinge joint** (elbow and knee joints), **ball** and **socket joint** (hip and shoulder joints), **gliding joint** (joints between vertebrae), **ellipsoid joint** or **condyloid joint** (joint between skull and 1st vertebrae), **pivot joint** (joint between atlas and axis), **saddle joint** (joint between carpometacarpal of the thumb).

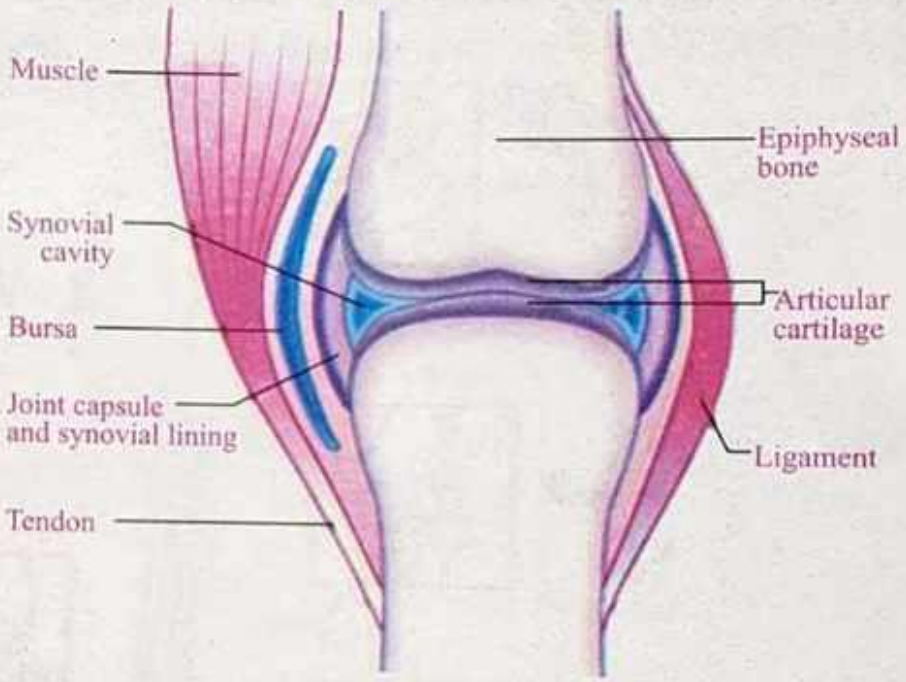


Fig.16.12: Synovial Joints

16.2 Disorders (Deformities) of Skeleton

Disorder is a functional abnormality or disturbance. Deformation of skeleton may occur due to genetic diseases, hormonal problems and by nutritional deficiencies.

16.2.1 Common Disorder of Skeleton

Some common conditions that affect the skeletal system include slip disc, spondylosis, sciatica and arthritis.

Slip disc

The bones in the vertebral column are cushioned by discs. These discs protect the vertebral column by absorbing the shocks from daily activities like walking, running, lifting, twisting, bending, *etc.*

Each intervertebral disc consists of an outer strong ring called **annulus fibrosus** and soft gelatinous inner portion called **nucleus pulposus**. If annulus fibrosus ruptures and allows the inner gelatinous portion to split out, it results in **herniation of disc**.

A herniated disc can affect and damage the nearby nerves by pressing them. This results in severe pain, numbness or weakness in the arm or leg. Herniated disc can be prevented by performing strengthening exercises, by maintaining good posture and a healthy weight. Slip disc can be treated with bed rest and pain killers. If these doesn't work, disc may be removed surgically. (Fig.16.13)

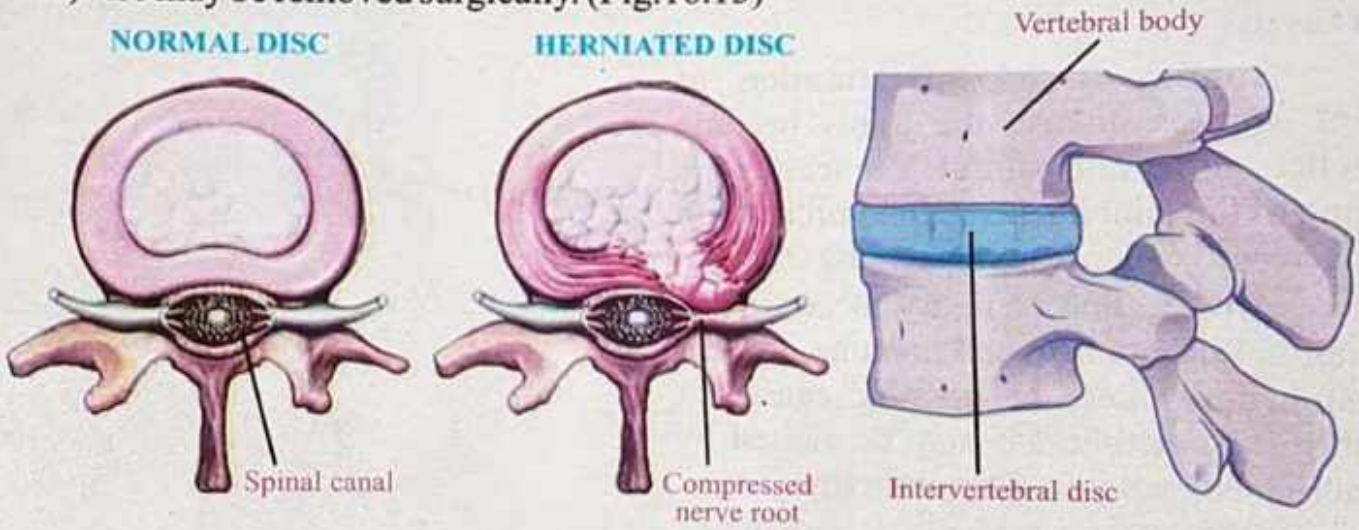


Fig.16.13: Structure of Normal and Herniated Disc

Spondylosis

Spondylosis is the immobility and fusion of vertebral joint. It occurs due to the degeneration of intervertebral discs, spinal injury, ligaments stiffness, formation of bone spurs with age and overuse of spine. Genetic disposition is also a risk factor for spondylosis.

Spondylosis is common in cervical spine called the **cervical spondylosis**. It is a painful condition of spine in which the discs of cervical spine gradually breaks down, lose fluid, and become stiffer with age.

Sciatica

Sciatica refers to the back pain caused by a problem with sciatic nerve. Sciatic nerve is a large nerve that travels from lower **lumbar spine** to the back of each leg. Any injury to sciatic nerve cause pain in the lower back that travels to the hip, buttocks and

leg. Recovery from sciatic injury is usually slow and incomplete.

Common causes of sciatica include; a herniated disc, any injury to proximal sciatic nerve, **spondylolisthesis** (a condition in which one vertebra slips forward over another one), muscle spasm in the back or buttocks, improper administration of injection into the buttocks. The pregnant women have a great chance of getting a herniated disc and develop sciatica. Diabetes can also cause nerve damage.

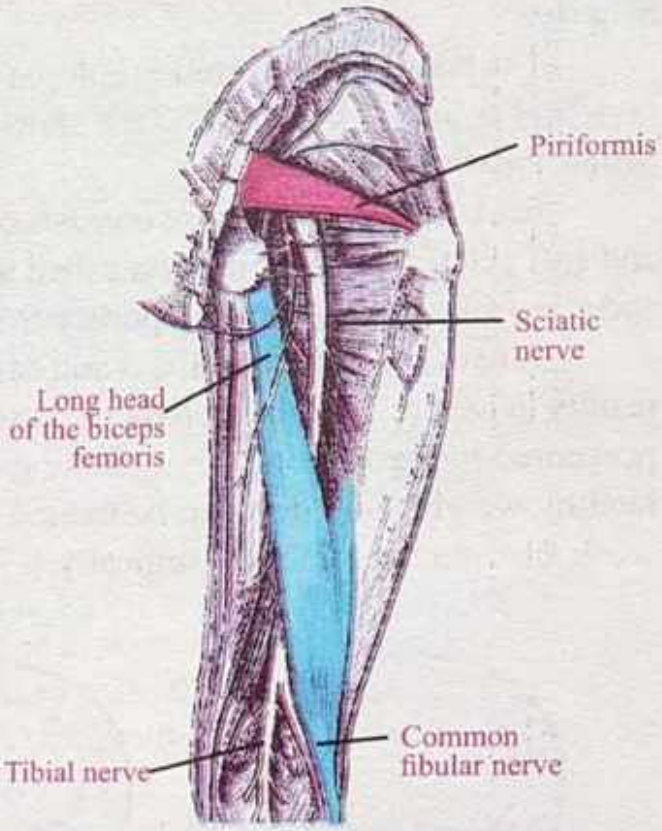


Fig.16.14: Location of Sciatic Nerve in Leg

Arthritis

Arthritis is the **inflammation of joint**. In this disease the joints become swollen, stiffer and painful. The membrane lining of the joint thickens, fluid production is decreased which leads to increase friction.

An infection or injury to the joints, abnormal metabolism and immune system dysfunction are the possible causes of arthritis. Sometimes, it may be caused by inheritance such as in **osteoarthritis**.

Chronic arthritis includes osteoarthritis, rheumatoid arthritis and gouty arthritis. **Osteoarthritis** is the most common type of arthritis. It can cause inflammation of any joint. It occurs when the joint cartilage is degenerated.

Rheumatoid arthritis is the inflammation of hand and wrist joints. **Gouty arthritis** develops in people who have high level of uric acid in their blood. It is caused by the deposition of needle like crystals of uric acid in a joint.

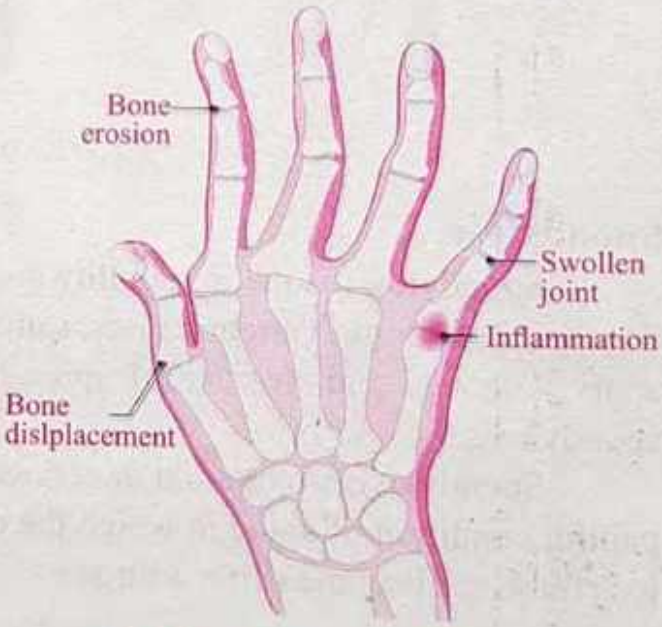


Fig.16.15: Rheumatoid Arthritis

16.2.2 Bone Fracture

When there is a partial or complete break in the continuity of the bone, it is called bone fracture. Fractures occur mostly when a bone is impacted by more force than it can

bear. There are different types of fractures. In more severe cases, the bone may be broken into many pieces. A fracture is treated by **reduction** (orthopaedic surgery).

Reduction is a procedure through which the bone fractures are repaired by realigning parts of broken bone. Reduction is done according to the type and complication of fracture. There are two types of reduction, closed reduction and open reduction.

1. **Closed reduction** is a procedure in which the bone fragments are coaxed back to their initial position by physician's hands without the surgical exposure of the bone fragments.
2. **Open reduction** is a procedure in which surgery is performed by dissecting the tissues and fracture fragments are secured together with the help of pins or wires.

Types of bone fractures

There are different types of bone fractures. Some common types are as follows.

1. **Simple fracture or Closed fracture:** The broken bones remain within the body. The skin remains intact and there is no damage to the surrounding tissues.
2. **Compound or Open fracture:** When the broken bones penetrate the skin or if the force of injury breaks the skin, causing a risk of infection.
3. **Complicated fracture:** When broken bone damages the surrounding structures (Organs). There may be a damage to arteries, veins and nerves. The complicated fracture heals more slowly. (Fig.16.16)

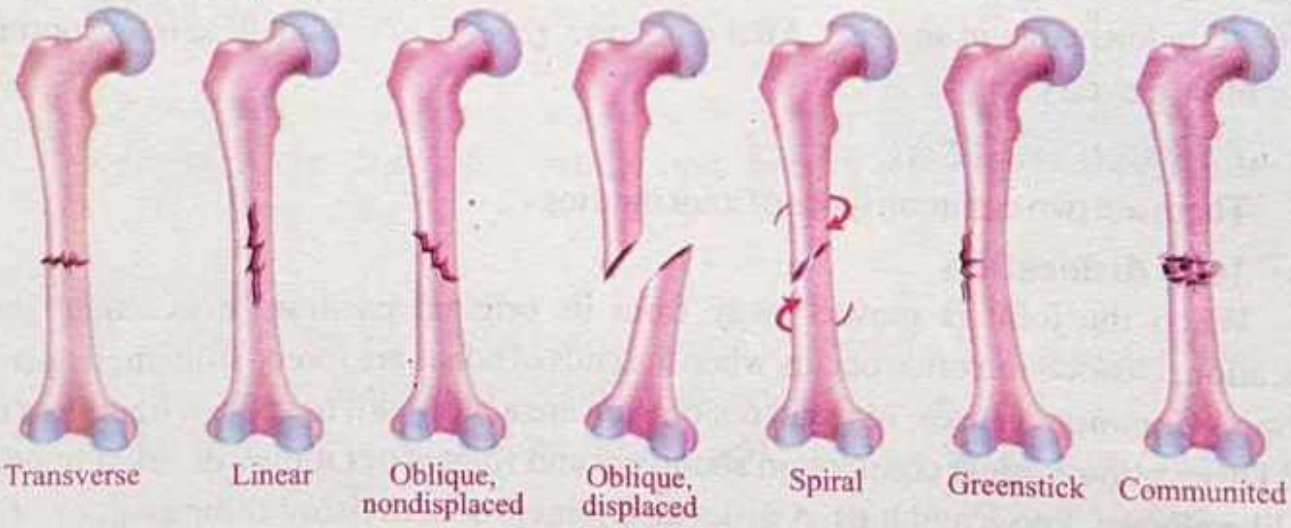


Fig.16.16 Types of Fractures

16.2.3 Healing process of a simple fracture

Bone healing is a natural process which, in most cases, will occur automatically. Healing time is usually 8-12 weeks, but it is much longer for large weight bearing bones. Healing process is usually slow in elder people due to their poor blood circulation. The repair process of a simple fracture takes place in four phases.

1. **Hematoma formation:** It is the first stage of healing after the bone fracture. Due to fracture, the blood vessels are injured, so much bleeding occurs at the fractured site. This blood starts to clot at the fractured site and forms **hematoma**. Bone cells deprived of nutrients begin to die. This also damages the nearby tissues and tissues at the fractured site become swollen and causing a lot of pain.

2. **Soft callus formation:** Within the few days after the bone is broken, the soft callus begins to produce. The capillaries grow into the **hematoma** and phagocytic cells clear up the debris (dead cells). The **fibroblast** and osteoblasts enter the fracture site and begin to reconstruct the broken bone. Fibroblasts produce collagen fibres that connect the ends of broken bone, while osteoblasts start to form spongy bone. Some bone spicules may also appear at this time. Soft callus lasts for approximately 4-6 weeks from the time of injury.

3. **Hard/bony callus formation:** During this stage, osteoblasts and osteoclasts multiply rapidly, continue to move inward and convert the soft callus into bony callus. The woven bone is transformed into the lamellar bone. In the mending process. A ring of new bone tissue is formed around the fracture, so the mended bone is slightly thicker in the region of fracture.

4. **Bone remodelling:** The bony callus is then remodelled by osteoblasts and osteoclasts. The unwanted bits are broken down and reabsorbed. The final mended bone is almost undetectable in an x-ray. After a fracture, process of remodelling may continue for months or even years.

16.2.4 Injuries to joints

There are two common types of joint injuries.

a) Joint dislocation

When the joint is moved away from its original position, it is called joint dislocation. Dislocation often occurs when the ends of bones are forced from their normal position. Common causes of joint dislocation are a blow, fall or sudden trauma to the joint. Dislocation is most common in shoulders and fingers but it may develop in other sites like elbows, knees and hips. A dislocated joint produces many compli-cations like tearing of muscles, ligaments and tendons that support the injured joint. There is also a risk of nerve or blood vessel damage in or around the affected joint. Common symptoms of joint dislocation include intense pain, swelling, bruising, joint immobility and stiffness of muscles. Most joint dislocation returns to normal function when treated properly. Sometimes surgery may be needed to repair the ligaments. However, some joints may have an increased risk of repeat dislocation, such as shoulder joint.

b) Sprain

Stretching, tearing or twisting of ligaments is called **sprain**. Common symptoms of sprain are bruising, pain, swelling and limited movement for the affected joint. Usually sprains are caused by injury. It happens when the ligaments are pushed from their normal capabilities. The most common type of sprain is an ankle sprain (such as twisting ankle). Initial treatment of sprain includes rest, ice, compression and elevation. Mild sprain can be treated at home successfully. Severe sprains require surgery to repair the torn ligaments.

16.2.5 First aid treatment for fractures

First aid treatment is very useful for fractures as it prevents further injury and promote recovery. There are following first aid treatments for fractures.

1. Apply pressure to the injured area to control any bleeding. Pressure can be applied with the help of clean cloth or bandage.
2. Immobilize the injured area by providing support. This can prevent any further damage.
3. Apply ice packs to the injured part. This will limit swelling and relives pain. Don't apply ice directly to the skin, wrap the ice in a towel or cloth and apply it to the injured area for up to 10 minutes.
4. Keep checking the casualty for signs of shock. If the patient loses responsiveness, check his/her breathing rate and help patient get into a comfortable position.

Extra Information

The largest muscle of the body is gluteus maximum which is main extensor muscle of the hip. It supports the trunk and maintain proper posture.

16.3 Muscles

The muscle is a contractile tissue found in animals. The primary function of muscle is to produce movement. Besides movement muscles also hold body parts in postural positions, movement of the body fluids and heat production. The study of muscles is called **myology**.

16.3.1 Types of Muscle

There are over 640 muscles in the body of human which are divided into following three groups:

Skeletal Muscles

These are located on skeleton so called skeletal muscles. They are **voluntary muscles**, meaning that we can control them at will. They typically control movement

through activation by the somatic branch of peripheral nervous system with a rapid speed of contraction. Skeletal muscles also play a role in temperature regulation, using rapid muscle contraction. They are striated, meaning that its tissue is crossed with light and dark bands. They get fatigue easily. (Fig.16.17a)

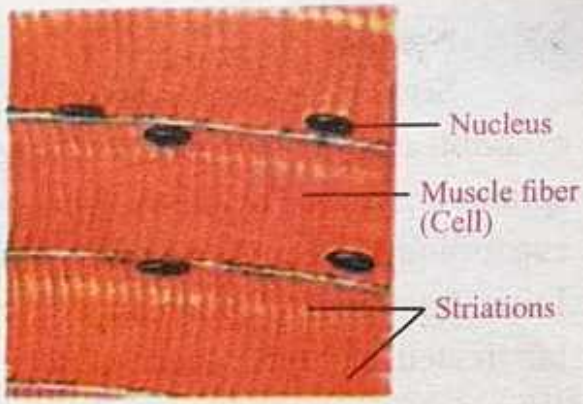


Fig.16.17(a): Skeletal Muscle

Smooth Muscles

Smooth muscles are **involuntary muscle** tissue controlled by the automatic nervous system. They are located in all visceral organs (except heart) such as the stomach, intestines, bladder as well as our blood vessels. Smooth muscle contracts more slowly than skeletal and cardiac. The function of smooth muscle is to move substance through an organ or vessel. It does so by contracting in waves, known as **peristalsis**. The cells of these muscles are **spindle shaped** with a single nucleus located in the middle of the cell. They do not get fatigue.

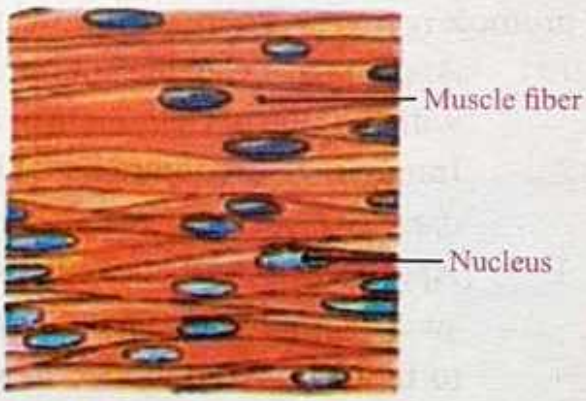


Fig.16.17(b): Smooth Muscle

Cardiac Muscles

They are located only in heart. They are involuntary muscles so controlled by autonomic nervous system. Like skeletal muscle, these muscle cells are also striated. In between its fibres are intermittent spaces, which contain connective tissues and many capillaries to ensure a constant supply of oxygen. The cells are **uninucleated** and branched. Adjacent cells joint together to form branching fibres by specialized cell to cell attachment called **intercalated discs**. The comparison of these three types of muscles are given in table 16.4. (Fig.16.17c)

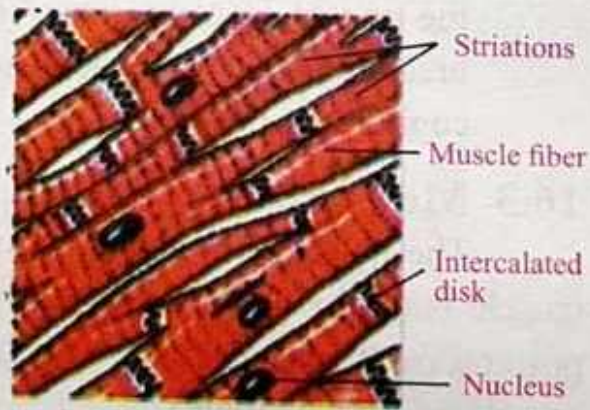


Fig.16.17(c): Cardiac Muscle

Extra Information

The hardest working muscle in the body are cardiac. The heart pump about 2500 gallon of blood per day.

Table 16.4: Comparison of Three Types of Muscles

	Skeletal	Cardiac	Smooth
Location	Attached to bones	The heart	Internal organs and skin
Shape	Elongated and cylindrical 	Branched 	Spindle 
Nucleus	Several peripherally located nuclei	Single centrally located nucleus	Single centrally located nucleus
Striation	Striated	Striated	Non-striated
Function	* Movement of bone * Heat production	Beating of the heart	Movement of the viscera
Control	Voluntary	Involuntary	Involuntary

16.3.2 Structure of skeletal muscles

Each skeletal muscle is attached with two bones. The end of skeletal muscle attached with immovable bone is called origin of muscle, while the other end of skeletal muscle is attached with moveable bone is called insertion of muscle. The muscle attaches with bone by a connective tissue known as tendon. Within a typical skeletal muscle is a bundle of long fibres running parallel to the length of muscle. Each fibre is a single cell with multi nuclei (each nucleus is derived from one of the embryonic cell). These embryonic cells fused to form the muscle cell. Inside a muscle cell lies a longitudinal bundle of myofibrils, which contain the thin and thick filaments. Each thin filament mostly consists of **actin filaments**. The thick filaments are called **myosin**. The **myofibrils** are made up of repeating sections called **sarcomeres**, which are the basic contractile units of skeletal muscle. Theborders of the sarcomere

Extra Information

The smallest muscles (stapedius) of the body lie in the ear along with smallest bone (Stapes), while the strongest muscle, based on its weight, is the masseter, in the jaw.

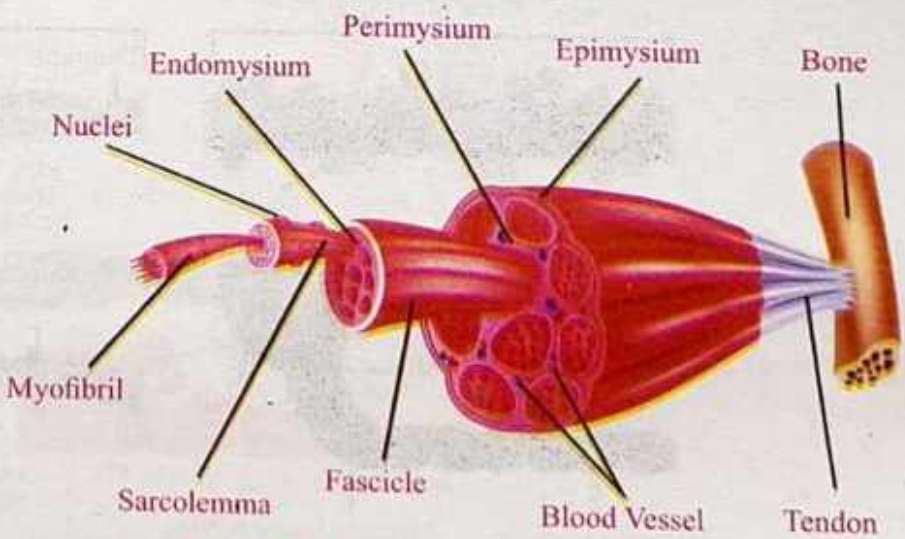


Fig.16.18: Structure of Skeletal Muscle

line up in adjacent myofi-brils, forming a pattern of light and dark bands (striations) visible with light microscope. That is why skeletal muscles are called **striated muscle**. The thin filament attached with **Z line** (zwisch line means between), while thick filaments are anchored at M-lines **(middle line)** centered in sarcomere. In relaxed state, the thick and thin filaments partially overlap. Near the edge of sarcomeres there are only thin filament and this portion of sarcomere is called I-band (isotropic). The zone of sarcomere in the center contains thick band and called A-band (Anisotropic) *i.e.* complete length of myosin partially covered by actin filament. The middle portion where only myosin filaments are present are called **H-Zone** (Hele Zone means bright). This arrangement is the key to how the sarcomere and whole muscle contract.

Ultra-structure of Skeletal Muscles

The sarcomere is the structural and functional unit of muscle fibre (muscle cell). A muscle fibre is a cylindrical cell which contains all the parts of a typical cell like plasma membrane (sarcolemma), cytoplasm (sarcoplasm), endoplasmic reticulum (sarcoplasmic retialum), mitochondria, nuclei, *etc.*

Extra Information

Muscles are built during sleep, not in gym or during exercise because at this time more blood circulation and hormones are released.

Under electron microscope, in the sarcomere two types of filaments are visible. Thick filaments are called myosin while thin filaments are called actin.

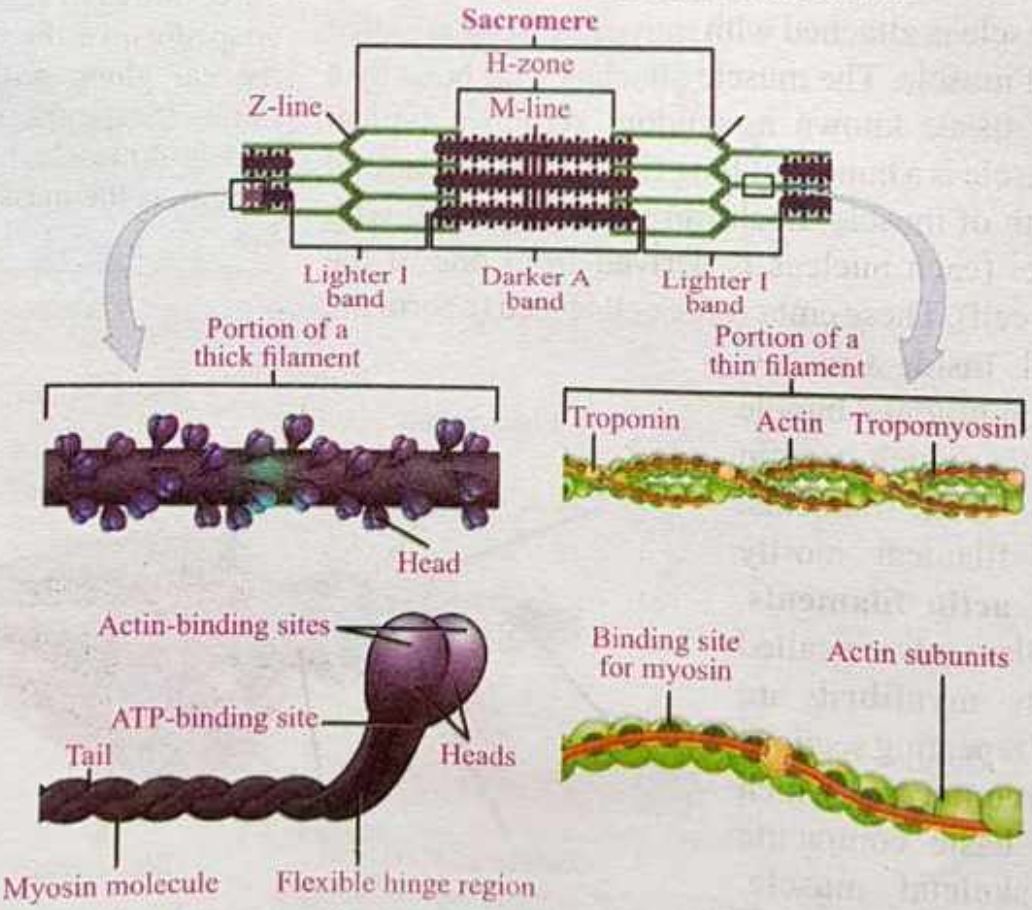


Fig. 16.19 Ultra Structure of Actin-myosin Filaments and Structure of Muscle Fibre

Myosin filament

These filaments consist of myosin protein. Each thick filament is 15nm in diameter. Each filament consists of hundreds of molecules of myosin protein. A myosin molecule is shaped like a golf club, with a tail formed of two intertwined chains and a double globular head projecting from it at an angle. Half of the myosin heads projecting from it at an angle to the left and half of them angle to the right, creating an area in the middle of the filament known as bare zone.

Actin filament

Thin filaments are called actin filaments. An actin filament is about 7nm in diameter, and consists primarily of actin protein. There are two chains of actin protein molecules twisted together, each actin filament also contains 40-60 molecules of **tropomyosin**, the protein which block the active sites of thin filaments when the muscle is relaxed. Each tropomyosin molecule has a smaller calcium binding protein called troponin, is bound to it. (Fig.16.19).

16.3.3 Muscle contraction – sliding filament model

According to sliding filament theory of muscle contraction, the actual length of actin and myosin filament does not change but actin filaments slide over myosin filaments. The actual trick is played by myosin filaments. This happens when myosin

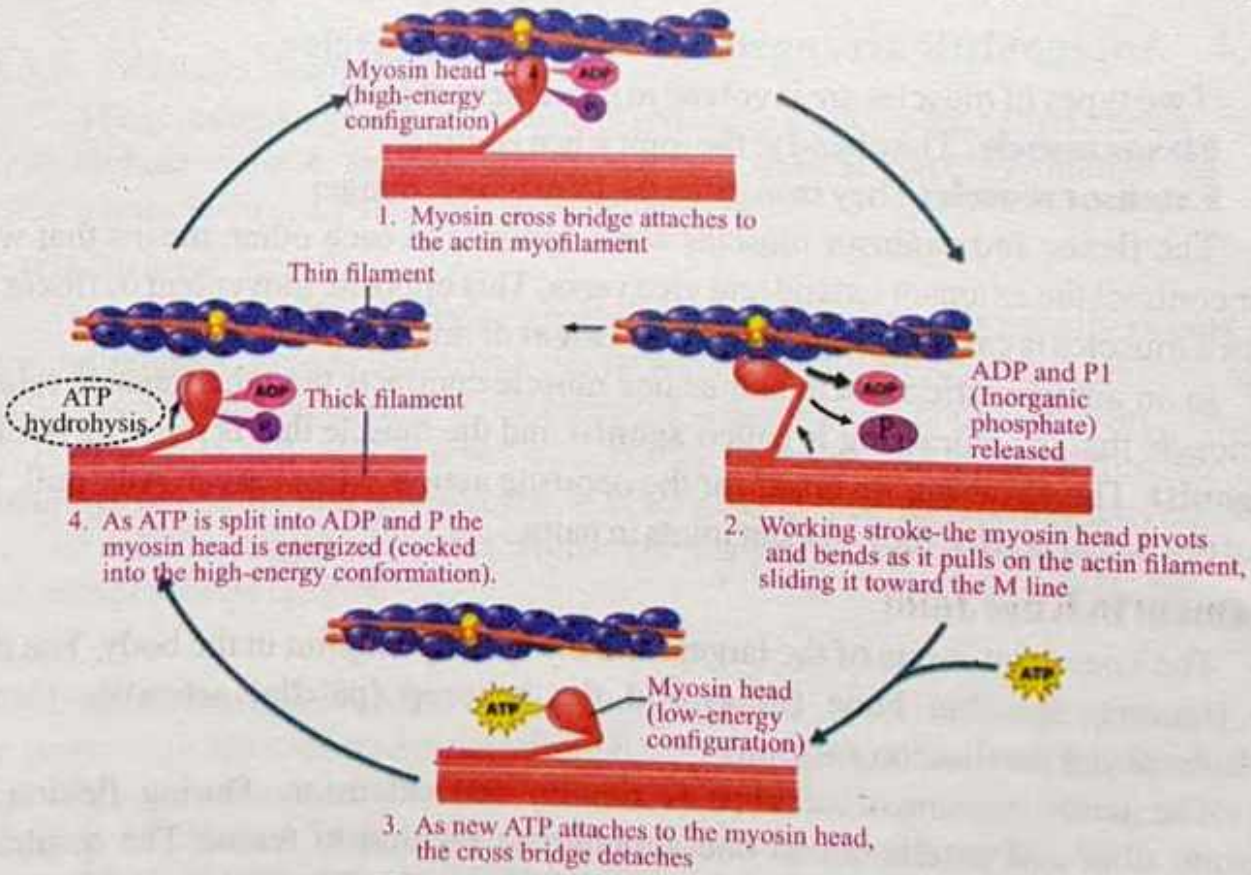


Fig.16.20: Sliding Filament Model

heads attach with actin filament at the site of troponin protein. When these heads bend, these pull the actin filaments over the myosin filaments. This theory was proposed by Z. Huxley and A.F Huxley in 1954. During full muscle contraction the I-band and H-zone disappear and only dark zone *i.e.* A-band appears. During the sliding process the Z-lines come close together and as a result sarcomere shortens. ATP provides energy for muscle contraction. The sliding filament theory or model is universally accepted. (Fig.16.20)

Control of Cross Bridges and Role of Calcium Ions

Muscle contraction is initiated when nerve impulse arrives at the **neuromuscular junction** within the muscle fibre, the action potential spreads deep into the interior, following infolding of plasma membrane called **transverse tubules** (T-tubules). These make close contact with the sarcoplasmic reticulum (SR). As the action potential spreads along the **T-tubules**, it triggers changes in SR, opening Ca^{++} channels. Calcium ions stored in the SR flow through open channels into the cytosol and bind to the troponin protein and cause them to slightly move. As a result, tropomyosin diphase and expose the binding site for myosin head. Once the myosin head attaches with actin filament, ATP is hydrolysed to adenosine diphosphate (ADP) and inorganic phosphate (Pi) and the cross bridges are broken down. The formation and break down of cross bridges occur again and again and movement of muscle occurs.

16.3.4 Antagonistic arrangement of Skeletal Muscle

Two types of muscles are involved in movement of joint.

1. **Flexor muscle:** They bend to the joint when contract.
2. **Extensor muscle:** They straighten the joint when contract.

The flexor and extensor muscles work opposite to each other, means that when flexor contract the extensor extend and vice versa. This opposite movement of flexor and extensor muscles is called **antagonistic movement** of muscle.

In an antagonistic muscle pair as one muscle contracts the other muscle relaxes. The muscle that is contracting is called **agonist** and the muscle that is relaxing is called **antagonist**. The terms are reversed for the opposite action. Muscles can only pull; they cannot push, that is why, they work at joints in pairs.

Movement in Knee Joint

The knee joint is one of the largest and most complex joint in the body. The thigh bone (femur), the shin bone (tibia) and the kneecap (patella) articulate through tibiofemoral and patellofemoral joint.

The main movement of knee is flexion and extension. During flexion and extension tibia and patella act as one structure in relation to femur. The quadriceps muscle group is made up of four different individual muscles. They join together forming

one single tendon which inserts into anterior tibial tuberosity, embedded in tendon in patella, a triangular **sesamoid** bone and its function is to increase the efficiency of the **quadriceps contractions**. Contraction of quadriceps pull the patella upwards and extends the knee. The **hamstring muscle** group consist bicep femoris, **semitendinosus** and **semimembranosus**. They are situated at the back of the thigh and their function is flexing or bending the knee as well as providing stability on either side of the joint line. (Fig.16.21)

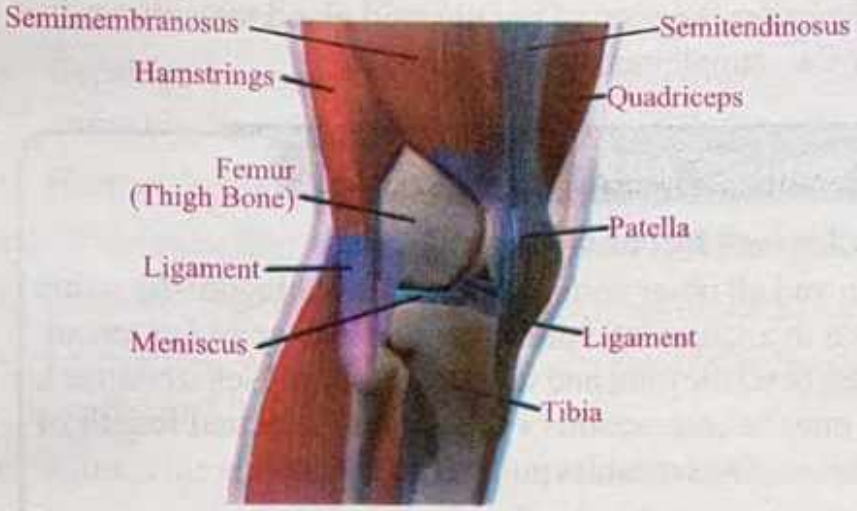


Fig.16.21: Movement of Knee Joint

Extra Information

The quadriceps and hamstrings (leg muscles) work together to move legs, when you bend your legs, the hamstrings contract and quadriceps relax and vice versa.

16.3.5 Muscle Disorders

The problems, diseases or disorders related to muscles are called muscle disorder. These include muscle fatigue, cramp, tetanus, muscle pull, myopathy, *etc.* Some common muscle disorders are discussed below.

Muscle fatigue

It is decline in the ability of a muscle to generate force. It usually occurs due to vigorous exercise. Due to heavy exercise or work anaerobic respiration starts in skeletal muscle. As a results lactic acid is produced and accumulates in muscle fibre. This drops the pH of muscle and muscle aches by breaking glucose. The other factors like muscle dystrophy, weakness and atmosphere with low oxygen concentration may also be the cause of muscle fatigue. The rest, nutritional supplement or caffeine are the possible treatment of muscle fatigue.

Cramp

Muscle cramp is sudden, involuntary contractions that occur in various muscles. The commonly affected muscles include back of lower leg, back of thigh and front of thigh. These contractions are often painful. A sudden sharp pain, lasting from a few seconds to 15 minutes, is the most common symptom of muscle cramp. There are several causes of muscle cramp *e.g.* over use of muscle as in exercise, dehydration, muscle

injuries, low level of minerals like Ca, K, Na, Mg, low blood supply, *etc*.

The muscle cramp can be prevented by limiting the exercises, warm up before exercise, drinking fresh juices and mineral water and milk regularly.

Tetany

It is a condition in which involuntary muscle cramps and contraction occur usually in the hand and feet. But these spasms can extend throughout the body and even in the larynx causing breathing problems. Tetany can be the result of an electrolyte imbalance, like low Ca^{++} level. The under function of parathyroid gland may also cause tetany. The tetany can be treated by Ca^{++} supplement and vitamin D.

Science, Technology and Society (STS)

- **Justify why do the muscles pull but do not push.**

Skeletal muscles of human and all other vertebrates work as antagonistic pairs. Two types of muscles are involved in antagonistic movement *i.e.* flexor and extensor. When flexor muscles contract, they bend the joint and when extensor muscles contract, they straighten the joint. During muscle contraction or relaxation the actual length of actin myosin filament does not change. Thus muscles pull but do not push.

- **Relate improper posture to bone joint problem.**

The regular blood supply is needed to parts of body muscles bone and joints. If we use some joints in muscles more frequently than other *e.g.* as in during study and teaching, the students and teacher may show improper postures for long time. This increases stress on their specific bones, joints and supporting structure that result in injury, pain and early degeneration of bones and joints. So proper posture is important to avoid such disorders.

- **Reason out rigor mortis.**

Rigor mortis means stiffness of death. In this condition all of the body muscles become stiff and joint become immoveable after death. It is because energy is required for movement of muscles. After death the production of ATP stops and ATP stores deplete quickly. Therefore, cross bridges lock and muscle movement stops because there is no energy to break these cross bridges. That is why eyes, mouth and part of body are immediately closed after death. The condition of rigor mortis starts after about 4 hours of death and continue up to 40 hours. After 40 hours due to decomposition of protein the muscles start degenerating and condition is reverse now.

- **Name the techniques for joint replacement.**

Joint replacement procedure is called arthroplasty. Now due to advancement in medical science, it is possible to replace natural defective joint to artificial joints. Artificial joints are usually composed of metals, in combination of modern plastics.

SUMMARY

- Skeleton is the main supportive frame work of the body. It includes bones, cartilage, tendons ligaments and joints.
- Bone tissues are of two types; compact and cancellous.
- The process of bone growth and repair is carried out by 4 different types of cells. These are osteogenic, osteoblast, osteocytes and osteoclasts.
- Cartilage is connective tissue composed of cells called chondrocytes and fibres embedded in a firm, gel-like matrix.
- Human skeleton is mainly divided into axial skeleton and appendicular skeleton.
- Hyoid bone is also called lingual bone because it gives attachment to the tongue.
- Ribs are long twisted flat bones that form major part of rib cage.
- Comparing with axial skeleton, the appendicular skeleton is unfused. It consists of girdles and limbs.
- Joint is the attachment between two bones or bone and cartilage.
- Deformation of skeleton may occur due to genetic diseases, hormonal problems and nutritional deficiencies.
- Sciatica refers to the back pain caused by a problem with sciatic nerve.
- When there is a partial or complete break in the continuity of the bone, it is called bone fracture.
- When the joint is moved away from its original position, it is called dislocation of joint.
- The muscle is the contractile tissue, found in animals and the primary function of muscle is to produce movement.
- Cardiac muscles are located in heart and these are involuntary in function so controlled by autonomic nervous system.
- According to sliding filament theory, the actual length of actin myosin filament does not change but actin filament slide over myosin filament.
- The flexor and extensor muscles work opposite to each other. This opposite movement of flexor and extensor muscle is called antagonistic movement.
- The knee joint is one of the largest and most complex joints in the body.
- The problems, disorders and diseases related to muscles are called muscle disorders.

EXERCISE

SECTION-I: OBJECTIVE QUESTIONS

Multiple Choice Questions (MCQs)

A. Select the correct answer.

1. Which one of the followings is not an unpaired bone:
   (a) Mandible (b) Vomer
   (c) Sphenoid (d) Nasal
2. The fusion of four posterior vertebrae present in the pelvic region form:
   (a) cervical (b) lumber
   (c) thorcic (d) coccgial
3. Osteoarthritis is the most common chronic arthritis which is a degenerative joint disease also caused by:
   (a) Genetic defect (b) Hormonal defect
   (c) Nutritional cause (d) Environmental cuase
4. Disease appearing due to low Ca^{+2} level in blood:
   (a) Cramp (b) Arthritis
   (c) Spondylosis (d) Tetany
5. The end of muscle which remains fixed when muscles contract:
   (a) Insertion (b) Origin
   (c) Tendon (d) Ligament
6. The human skeleton consists of
   (a) 80 bones (b) 126 bones
   (c) 200 bones (d) 206 bones
7. The mature bone cells are called
   (a) Osteoblast (b) Osteocytes
   (c) Osteoclast (d) Osteogenic
8. Cartilage is a connective tissue composed of
   (a) Lymphocytes (b) Monocytes
   (b) Myocytes (d) Chondrocytes
9. Acetabulum provides articular surface for the
   (a) Femur (b) Humerus
   (c) Fibula (d) Radius
10. The number of bones in tarsal are
    (a) 8 (b) 5
    (c) 7 (d) 3

11. Rheumatoid arthritis is inflammation of ·
(a) Knee bone (b) Elbow bone
(c) Finger bone (d) Big toe

12. Bone breaking cells are called
(a) Osteocytes (b) Osteoblast
(c) Osteology (d) Osteoclast

13. Human internal organs are protected mainly by
(a) Axial skeleton (b) Appendicular skeleton
(c) Hydro skeleton (d) Exoskeleton

14. Which of the following protein is the component of skeletal tissue
(a) Hemoglobin (b) Myoglobin
(c) Fibrinogen (d) Collagen

15. Stretching, tearing or twisting of ligaments is called
(a) Dislocation (b) Sprain
(c) Fracture (d) Reduction

16. The cardiac muscle cells are
(a) Uninucleated (b) Polynucleated
(c) Dinucleated (d) Non-nucleated

17. The end of muscle attached with moveable bone is called
(a) Origin (b) Flexing of muscle
(c) Insertion of muscle (d) Belly of muscle

18. The diameter of actin protein filament is about
(a) 16nm (b) 7mm
(c) 6cm (d) 7nm

19. The in folding muscle fibre membrane is called
(a) Sarcoplasmic reticulum (b) Z-line
(c) Dark band (d) T-tubules

20. Which ions are required for muscle contraction?
(a) Sodium (b) Potassium
(c) Calcium (d) Magnesium

B. Complete the following sentences.

1. Skeletal tissues are either bone or .....
2. Osteocytes are located in the small cavity called .....
3. The axial skeleton consisting of 80 bones and appendicular skeleton consists of ..... bones.
4. The unique feature of hyoid bone is that it does not ..... with any

other bone of the body.

5. The word clavicle is derived from Latin word .....
6. Ball and socket joint, hinge joint and pivot joint are the example of ..... joints.
7. Each intervertebral disc consists of an outer strong ring called annulus fibrous and soft gelatinous inner portion called .....
8. Arthritis is the inflammation of .....
9. When the joint is moved away from its original position, it is called joint .....
10. The study of muscle is called .....
11. The muscle is attached with bone by a connective tissue known as .....
12. The sarcomere is the structural and functional unit of muscle .....
13. The opposite movement of flexor and extensor muscles is called ..... movement.
14. Largest and complex joint of human body is ..... joint.
15. The muscle that is contracting is called agonist and the muscle that is relaxing is called .....

SECTION-II: SHORT QUESTIONS

C. Give the short answers of the following questions.

1. Describe the four types of cells associated with bone.
2. Differentiate between bone and cartilage.
3. Enlist the main functions of skeleton.
4. Write the names of the cranium bones.
5. Write the names of facial bone.
6. Illustrate the three types of ribs.
7. Differentiate between carpals and tarsals.
8. Differentiate between Fibrous and cartilaginous joints.
9. Differentiate between two types of reductions.
10. Write difference between simple, compound and complicated fractures.
11. Illustrate the first aid treatment for fractures.
12. Briefly explain sliding filament theory.

13. Define antagonistic arrangement of muscle.
14. Write short note on muscle fatigue.
15. Differentiate between tetany and cramp.
16. Describe the sciatica.
17. Define arthritis and its types.

SECTION-III: EXTENSIVE QUESTIONS

D. Give detailed answers of the following questions.

1. Describe the structure of bone.
2. Explain the bones of fore limb in detail.
3. Define joint and explain different type of joints.
4. Explain the steps of healing process of a simple fracture.
5. Define antagonistic movement and explain the movement of knee joint.
6. Describe the structure of skeletal muscle.

UNIT 17

NERVOUS COORDINATION

Major Concept

17.1 Nervous System of Human
17.2 Neurons and their types
17.3 Impulses
17.4 Synapse
17.5 Basic Organization of Human Nervous System
17.6 Effects of Drugs on Nervous System
17.7 Disorders of Nervous System and Diagnostic Tests

Learning Outcomes

Students will be able to:

- Recognize receptors as transducers sensitive to various stimuli.
- Trace the path of a message transmitted to the CNS for processing.
- Identify the three neurons (sensory, intermediate, motor) involved in nervous transmission.
- Identify muscles and glands as the effectors.
- Describe the detailed structure of a sensory neuron, associative and a motor neuron and relate the specialization in structures with functions.
- Differentiate between myelinated and non-myelinated neurons.
- Explain the function of the three types of neurons with the help of a reflex arc.
- Define nerve impulse.
- Describe the generation and transmission of nerve impulse.
- Name the factors responsible for the resting membrane potential of neuron.
- Evaluate from a graph the phenomena of polarization, depolarization and hyperpolarisation of membrane.
- Compare the velocities of nerve impulse in the axon membrane and in the synaptic cleft.
- Describe the role of local circuits in saltatory conduction of nerve impulse.
- Describe the structure of synapse.
- Explain synaptic transmission of nerve impulse.
- Classify neurotransmitters as inhibitory and excitatory and list some common examples.
- Identify the main components of the nervous system.
- Explain briefly the functions of major divisions of brain.
- Describe the architecture of human brain and compare its sectional view with that of the spinal cord.
- Describe cranial and spinal nerves in man.

- Explain the structure, types and functions of autonomic nervous system.
- Explain the structure and functioning of the receptors for smell, taste and touch/pain.
- Define narcotic drugs as agents that interact with the normal nervous activity.
- Compare the use and abuse of drugs with respect to heroine, *Cannabis*, nicotine, alcohol and inhalants like nail polish remover and glue.
- Define and explain the terms; drug addiction and drug tolerance with reference to caffeine and nicotine.
- Associate the effects of drug addiction and tolerance with the functioning of nervous system.
- Describe withdrawal symptoms of alcohol.
- Classify nervous disorders into vascular, infectious, structural, functional and degenerative disorders.
- Describe the causes, symptoms and treatment one type of each category of disorders outlined below (*e.g.* stroke as vascular, meningitis as infectious, brain tumor as structural, headache as functional and Alzheimer disease as degenerative disorder).
- Explain the principles of the important diagnostic tests for nervous disorders *i.e.* EEG, CT scan and MRI.

Introduction

All animals show some common characteristics, one of these is to produce response to **stimuli** (*i.e.* any internal and external change). The activities of different body parts in response to the stimuli must be **coordinated**. The coordination makes possible the integration of functions essential to animal behavior. It is must for animals and human to survive. In human and most animals there are two types of coordination, *i.e.* nervous coordination and endocrine coordination. This unit deals with only nervous coordination.

17.1 Nervous System of Man

The study of nervous system is known as **neurology**. The working of different body parts with cooperation to each other and under the control of coordinator (Brain, Spinal cord or ganglia) is called **coordination.**

The system of the body that provides coordination through electric signal among different body parts during the response to a particular stimulus is called **nervous system**. The most developed, advanced and evolved nervous system among all organisms is that of human.

17.1.1 Steps Involved in Nervous Coordination

Nervous coordination involves highly specialized cells known as **neurons**, which are either connected together or via centralized nervous system to form a network that is linked to the receptors and effectors.

Nervous system in human and higher animals consists of three basic elements.

- **Receptors** are cells, tissues or organs which receive stimuli and give information to sensory neurons.
- **The neuron** has the capacity to generate and conduct impulses to central nervous system where processing / analysis of information takes place and pass responses to the effectors.
- **Effectors** are structures such as cells, tissues, muscles and glands which carry out action or make responses.

17.1.2 Receptors or Transducers

Receptors are organs, tissues, cells or nerve endings that detect changes (stimuli) in the external or internal environment of an animal *(e.g.* Human). These stimuli then transmitted to the brain or spinal cord through sensory neurons.

Classification of Receptors on the Basis of Stimuli

Receptors are classified into following five types.

- **Chemoreceptors,** which detect the concentration of certain chemicals or ions, *e.g.* CO_2 level in the blood by **medulla of brain**, O_2 level by **carotid body**. The chemoreceptors for blood glucose, amino acids, fatty acids are located in the **hypothalamus of brain**, smell **(olfaction)** in the nasal epithelium, taste **(gustation)** found in tongue and osmoreceptor (detect osmotic pressure of blood) in hypothalamus.
- **Mechanoreceptors,** which detect stimuli of pressure, body position or acceleration, include **Meissner's corpuscles** in skin for touch, **Pacinian's corpuscles** also in skin, **baroreceptors** in blood vessel for pressure and stretch also in, **ear** for hearing and equilibrium.
- **Thermoreceptors** are mostly located in the skin to detect change in temperature (cold/warmth).
- **Nociceptors** are pain receptors widely distributed in the skin and other internal organs which detect damage to body tissues.
- **Photoreceptors** or **electromagnetic receptors,** detect light stimuli, such as rods and cone cells in the retina of our eyes.

17.1.3 Processing / Analysis of Information

All types of sensory inputs from various receptors are conveyed to coordinator *i.e.* brain and spinal cord by sensory neurons. The information collected by them is processed and analysed, for a suitable response by special types of neurons known as inter or associated or relay neurons.

17.1.4 Effectors

Effectors respond to stimuli by impulse coming via motor neuron, such as

muscles and glands. The glands secrete some types of chemicals while muscles respond by contracting.

Stimulus Receptor Sensory neuron Inter neuron (CNS) Motor neuron Effector Response.

17.2 Neurons

Neurons are the chief structural and functional units of nervous system. In addition to neurons, nervous system contains neuroglial cells, which nourish the neurons and also protect the neurons by myelin sheath.

17.2.1 Structure of Neuron

A typical neuron consists of three basic components, *i.e.* cell body, axon and dendrites. The **cell body** or **soma or cyton or perikaryon of neuron** contain, nucleus and various cellular organelles except centrioles. The neuron cell body contains a mass of granular cytoplasm and enclosed by cell membrane (neurilemma). The nucleus is centrally placed. The cell body contains a group of ribosomes associated with rough endoplasmic reticulum and Golgi bodies known as **Nissl's granules** (these help in protein synthesis and acetyl-choline forming enzyme) These granules are absent in axon and Dendron. (Fig.17.1)

Interesting Information

Nervous system also cont-ains about 50% of neuro-glial cells.

The cell body of neuron is surrounded by cytoplasmic fibres, which are of two main types, *i.e.* axon and dendrites.

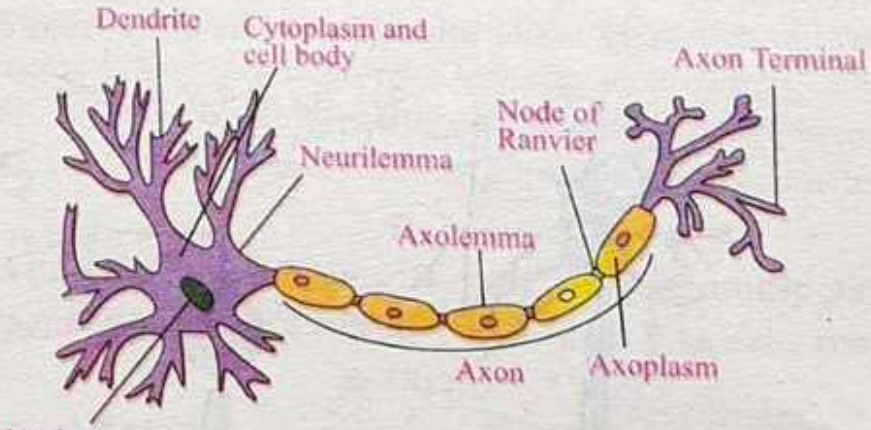


Fig. 17.1: A Typical Neuron

Axons are cytoplasmic process that conduct impulses away from cell body. Each axon is a usually thick long fibre (few mms to more than a meter in length) with a constant diameter. The cytoplasm of the axon is called **axoplasm** and cell membrane is called **axolemma**. Each axon terminates by branching to form small extension with knob like ending to cell presynaptic terminal. The neuroglia or glial cells that nourish, protect and support the neurons. In peripheral nervous system these cells are known as **Schwann cells**, which cover the axon by repeatedly wrapping it.

These cells are also covered by a fatty substance known as **myelin sheath**, which act as an insulator. Thus axons are called **myelinated fibres**. The non-myelinated portion of axon is called **node of Ranvier,** located between Schwann cells. The impulses jump from node of Ranvier to node of Ranvier, which are known as **saltatory impulses**.

Myelinated Fibres

It is transmit impulses much rapidly than non-myelinated neuron. It has larger and thicker axon because velocity of impulse depends upon the diameter, length and myelin sheath.

Dendrites are also cytoplasmic extensions that carry impulses towards the cell body. If they are single, then called **Dendron**. They are thin, short and mostly branched. The branches are gradually tapered from the base to their tips. The gap between dendrites of one neuron and axon terminals of another neuron is called **synapse**.

17.2.2 Types of Neurons

On the basis of functions, the neurons are of three types, *i.e.* sensory neurons, inter neurons and motor neurons.

i) Sensory Neurons conduct impulses form receptors to central nervous system. These are **unipolar** because only one fibre **originating** from cell body which immediately gives rise to two branches, one towards receptor and other towards central nervous system. Both fibres are structurally axon like except their terminal portions differ that is one is like dendrites and other is like axon. One (axon) carries impulse towards cell body while other (Dendron) away from cell body. Majority of sensory

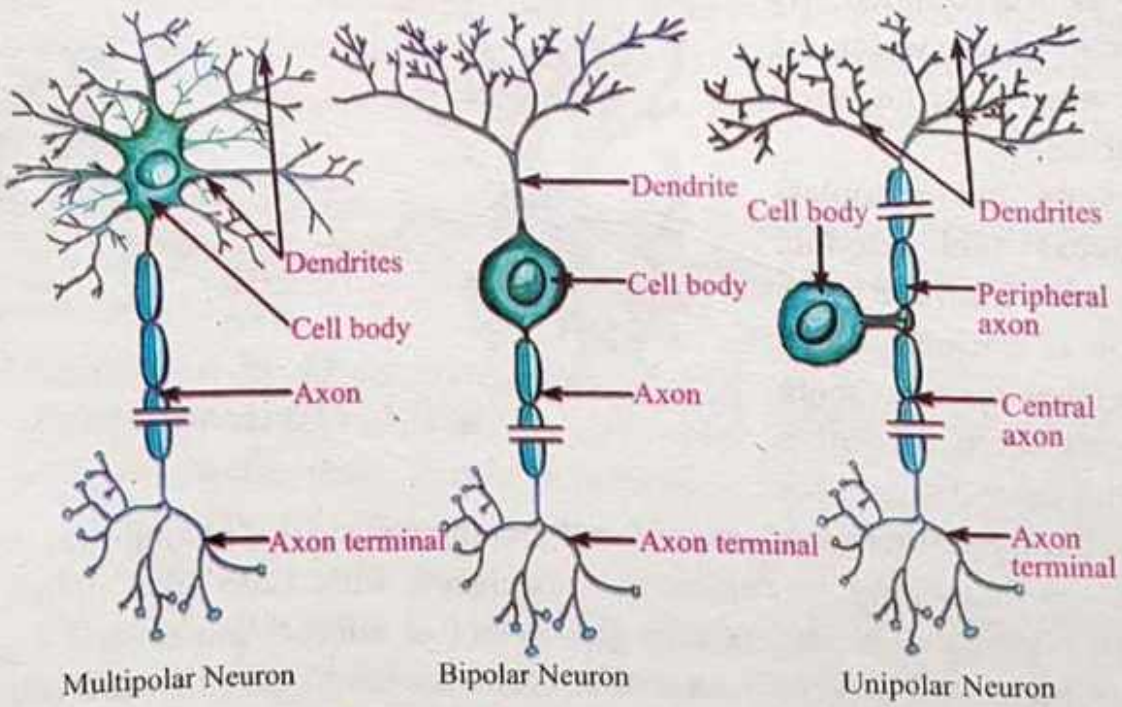


Fig.17.2: Multipolar, Bipolar and Unipolar Neurons

neuron are unipolar but some are bipolar. The unipolar neurons are found specially in dorsal root of spinal cord. (Fig.17.2)

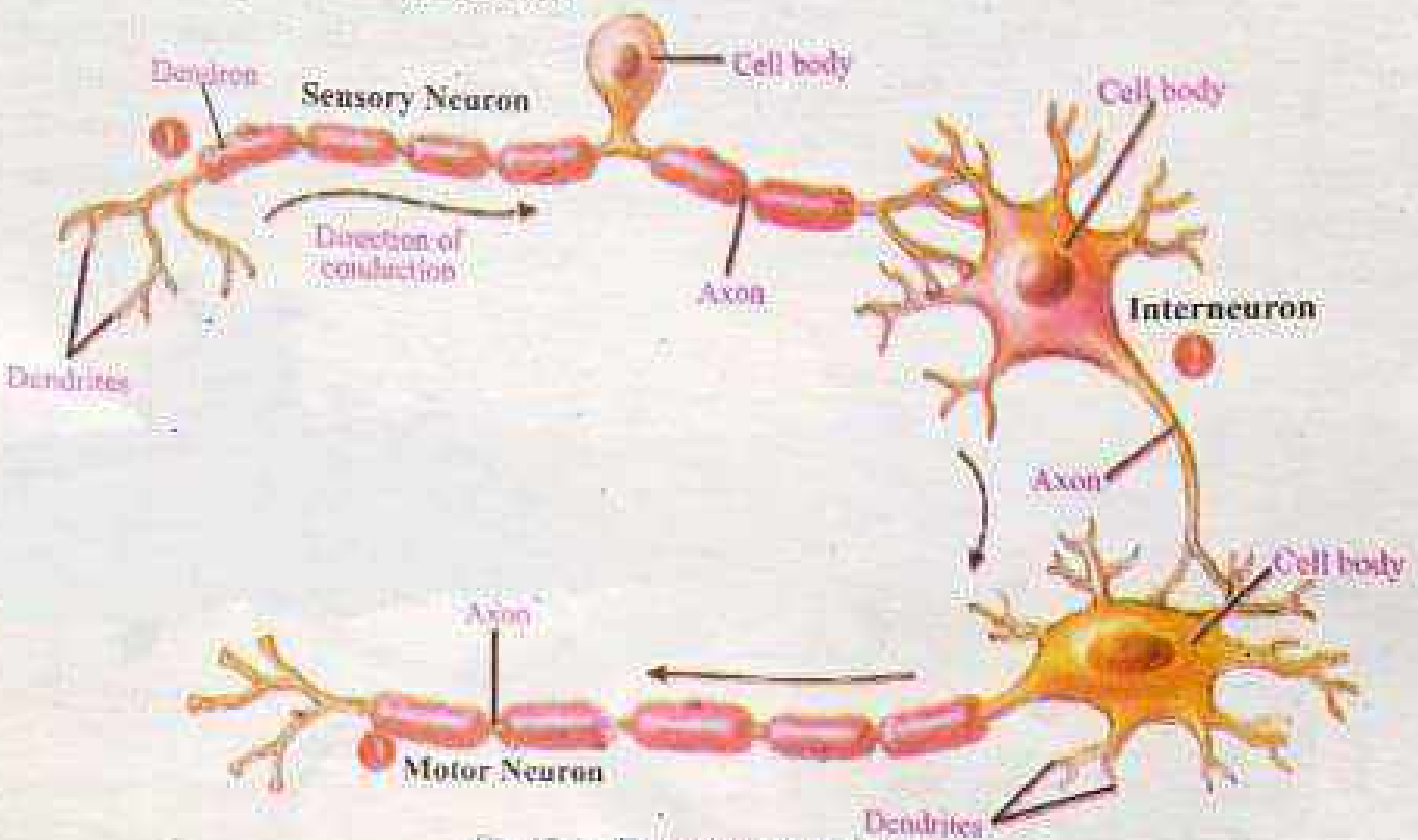


Fig.17.3 :- Three types of Neurons

ii) Associated or Interneurons are found only in the brain and spinal cord. These conduct impulses from sensory neurons to motor neurons. They also convey messages between various parts of the CNS. Inter neurons are mostly **multipolar** because many fibres arises from cell body. Their axon is thin and non-myelinated, while many dendrites carry impulses to its cell body.

iii) Motor Neurons conduct impulses from CNS to effectors. These are **multipolar** neurons. Their cell body contains many branched dendrites and a single long axon runs towards effector. (Fig.17.3)

Myelinated and Non-Myelinated Neurons

Myelinated neurons (Nerve fibres) are covered by fatty layer known as myelin sheath (axons) whereas non-myelinated neurons do not have a myelin sheath (Dendrites and Cell bodies). In myelinated neurons conduction of impulses are faster than non-myelinated neurons. Inter neurons are non-myelinated while motor and sensory neuron have myelinated portion.

Myelinated Neurons

The impulse jump from node of Ranvier to node of Ranvier. This is called saltatory impulse. Nerve impulse is 20 times faster in myelinated neuron than non-myelinated neuron.

17.2.3 Reflex action and Reflex arc

Reflex action or Reflexes are involuntary, automatic, unconscious or immediate response to external or internal environmental change or stimuli. The pathway through which a reflex travel is called **reflex arc**. The direction of reflex action is from receptor to sensory neuron to CNS to inter neuron and then through motor neuron to the effectors. Reflexes have no involvement of conscious portion of brain, therefore, the response is quick than the conscious pathway. (Fig.17.4)

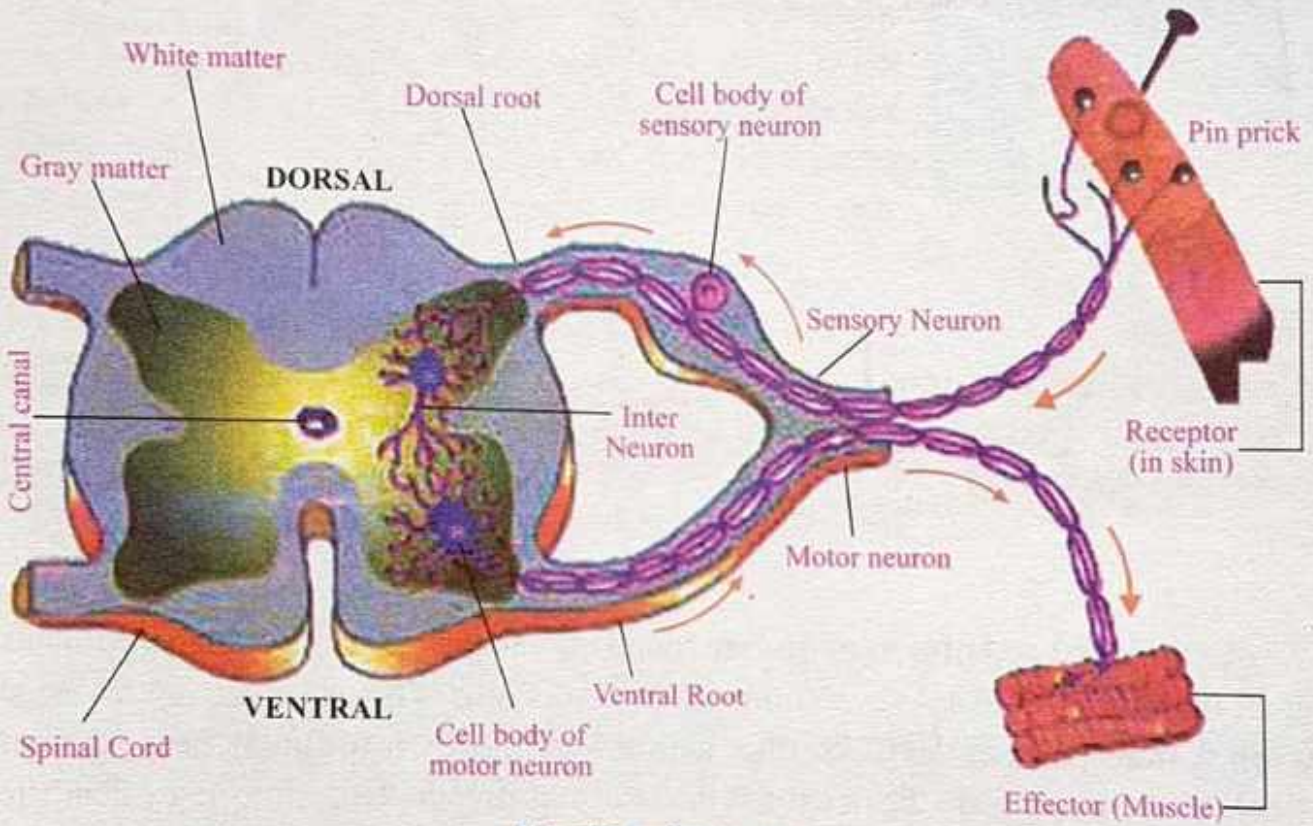


Fig. 17.4: Reflex Arc

Example of Reflex arc: If we unexpectedly touch a hot object or pin prick, our hands are rapidly removed from it. The receptors of our hands are activated by heat of the object. This impulse is conveyed to sensory neuron leading to spinal cord via spinal nerve then to inter neuron which lies entirely within the spinal cord. The inter neuron then passes this impulse to motor neuron then to effectors, *i.e.* muscles which causes them to contract. (Fig.17.4)

17.3 Nerve Impulse

Nerve impulse is the information about a stimulus that is transmitted from receptors to CNS and from CNS to the effectors. It is a wave of electrochemical change which runs along the length of the neuron,

Extra Information

Refractory period lasts for about four millise-conds so as a neuron can conduct 250 impulses per second.

involving chemical reactions and movement of ions across the **neurilemma**. The measurement of the capacity to do electrical work is known as **electric potential**. It represents a type of stored energy produces during separation of charge through a barrier. The charges are positive or negative, which act as separating barrier in the plasma membrane of neuron (Neurilemma).

Oscilloscope

It is an instrument with a screen which display changes in the voltage on both side of plasma membrane of neuron with time. The electric potential which exists across a cell membrane is known as **membrane potential**. The membrane potential is either resting membrane potential (RMP) or action membrane potential (AMP).

Extra Information

In human, normally the speed of flow of impulse in neuron is about 100-120m/ second.

17.3.1 Resting Membrane Potential

A typical neuron at rest or non-conducting neuron is called resting membrane potential. In this case a typical neuron is more positive electrically outside than inside the plasma membrane while inside is more negative as compared to outside the plasma membrane. It measures about – **70 millivolts (- 0.07 volt)**.

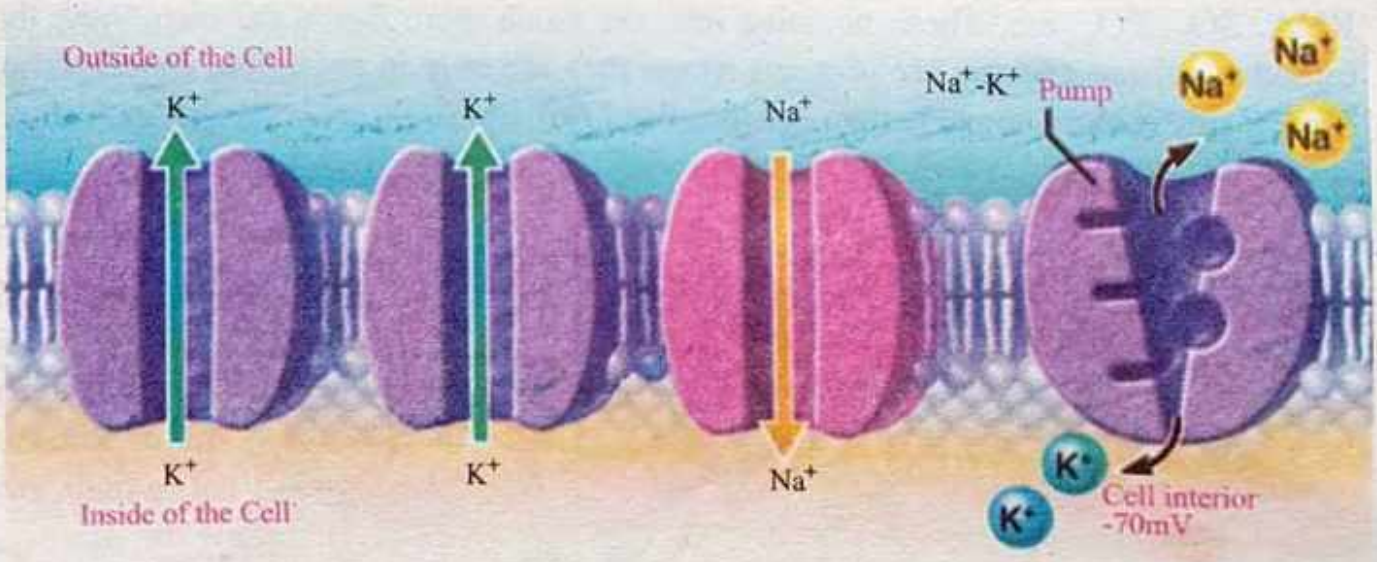


Fig. 17.5: Resting Membrane Potential (RMP)

Factors Involved in Resting Membrane Potential (RMP)

Major factors that are involved in RMP are:

Sodium and Potassium ions

There are many kinds of ions which are present inside and outside the plasma

membrane of neurons but the most important is sodium (Na^+) and potassium (K^+) ions. Sodium ions are tenfold higher in concentration outside than inside the membrane, whereas potassium ions are thirty fold higher in concentration inside than outside the membrane. The membrane of all the nerve cells possesses sodium and potassium pumps to transport these ions with the help of energy (ATP) against their concentration gradients. For every two potassium that are actively transported inside the membrane, three sodium ions are pumped out. Thus inside become more negative (70 mV) than the outside of the plasma membrane of nerve cell, which is more positive electrically than inside the membrane.

Table 17.1: Ionic Concentration Inside and Outside of Resting Neuron

Ingredients	*Concentration (mmol/L)*	
	Inside	Outside
Sodium ions	15	145
Potassium ions	150	5
Negative ions	156	30

Negative Organic Ions

Many types of large negative organic compounds are present in the both sides of plasma membrane of neurons. These organic ions include some proteins, amino acids, RNA, SO_4, PO_4, *etc*. These negative ions are much more inside the membrane than outside (outside Cl ions are present) where they are only in negligible concentration. Thus inside is more negative than outside.(Fig.17.6)

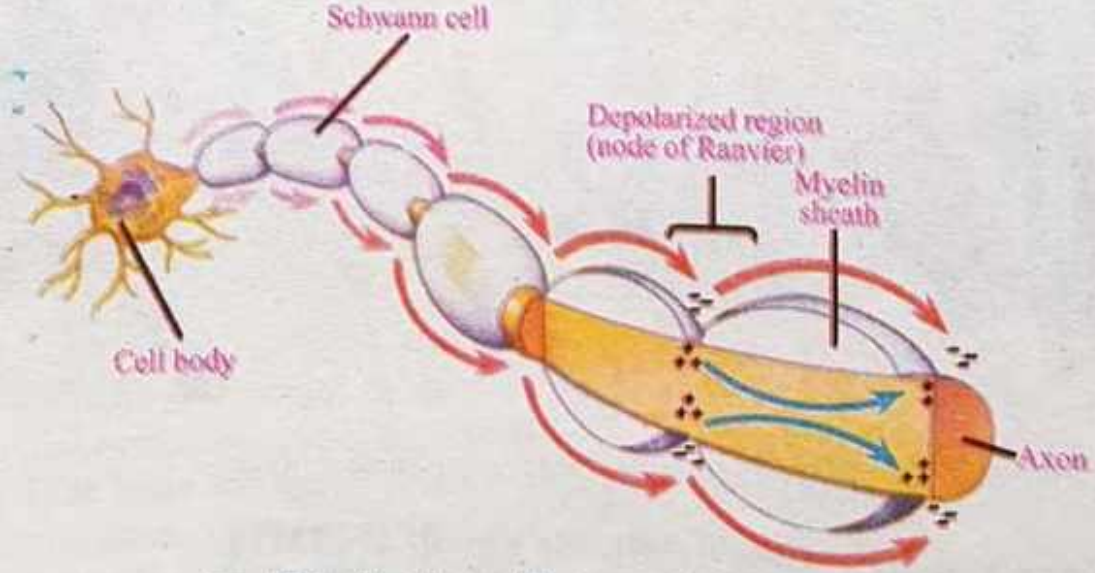


Fig. 17.6: Depolarized Region and Saltatory Impulse

Channel Proteins (Gates) in Plasma Membrane of Neurons

The plasma membrane is virtually impermeable to all ions except potassium ions.

It is slightly permeable to potassium, so it leaks out of the neuron by diffusion. That is why inside becomes more negative than outside of the plasma membrane of neuron. Thus non-conducting neuron is in **polarized state** (*i.e.* RMP – 0.07 volts or 70 mV). The resting membrane potential (RMP) will be maintained in undisturbed membrane. If it is disturbed or stimulated by a sufficient stimulus known as **threshold,** then action potential will occur.

17.3.2 Action Membrane Potential (AMP) (Depolarized State)

In action/active membrane potential, inside of neuron become more positive and outside become more negative. It is called depolarized state, which happen when appropriate stimulus receives, the positive charge sodium ion tends to move inside of the neuron. The electrochemical change is so brief (about one millisecond) that only a portion of the neuron (*i.e.* one node of Ranvier to another node of Ranvier) is in the action membrane potential state followed by the recovery of polarized state, thus impulses flow from one node of Ranvier another to node of Ranvier.

The major factors involved in changing the resting membrane potential to action membrane potential are:

1. Threshold Stimulus

It is capability of a stimulus to bring electrochemical charge on neuron or to excite a given tissue. It is also known as **adequate stimulus** (about – 50 to -55 mV electric membrane potential). If stimulus is not capable to excite or not appropriate, then it is called sub **threshold or inadequate stimulus.**

Influx of Na^+ ions

When threshold is reached, the membrane become more permeable to Na^+ than to the K^+ due to the opening of Na^+ gates. Thus influx of Na^+ ions by diffusion occurs, and electric potential of the membrane changes from -70 mV towards zero and then reach to about 50mV. This reversal of polarity

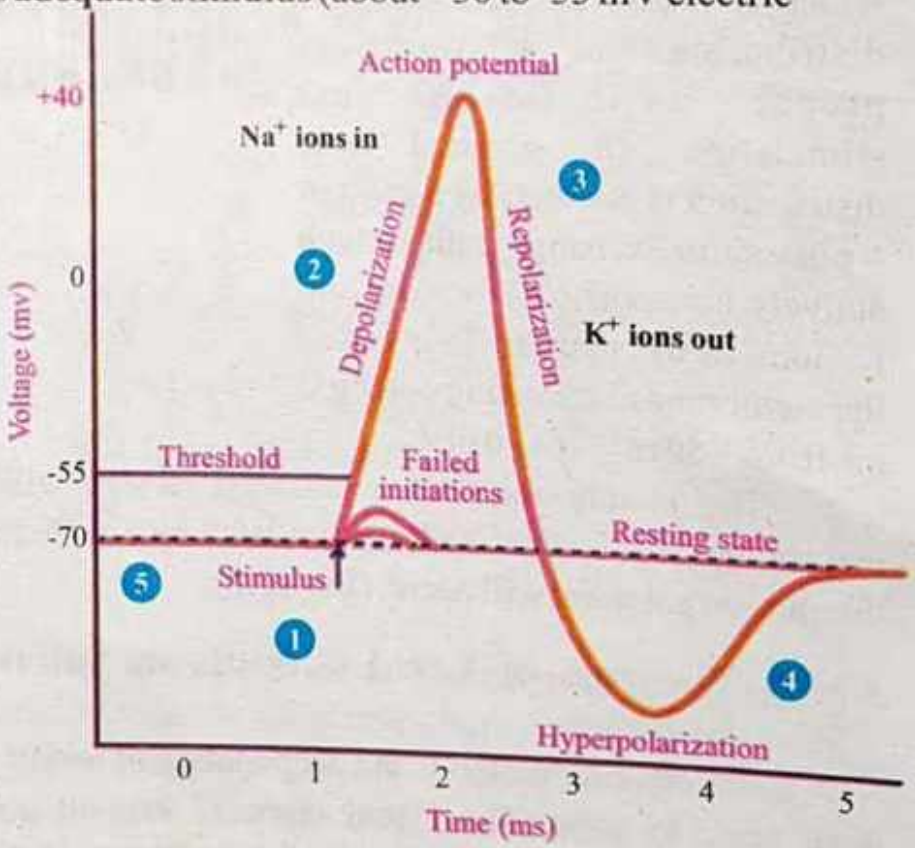


Fig. 17.7: Flow of Impulse

across two sides of membrane is called **depolarization**. This state of electropositive inside and electronegative outside lasts for about one millisecond till the Na^+ gates are not closed.

Interesting Information

The continuous impulse occurs in non-myelinated neuron fibres in which K^+ and Na^+ ions can move across the memb-rane along the length of neuron so action poten-tial flow as a wave.

Repolarized state

After the peak of action potential, called the **spike potential**, the permeability of Na^+ decreases, and now become more permeable for K^+ by opening of K^+ gates thus K^+ rapidly diffuses out from cytoplasm to extracellular fluid. The sodium gate closes and the neuron get its original polarity *i.e.* **repolarized** (inside more electro negative and outside more electro positive). Infact, there is a slight overshoot into a more negative potential than original resting potential. This is known as **hyperpolarized** state. It is due to the slight delay in closing of all K^+ gates compared with Na^+ gates. (Fig.17.7)

Refractory Period (Resting State)

It is a period when after an action potential, nerve fibre undergoes a period of recovery, in which it regain the original ionic distribution and polarity, thus prepare itself for the next stimulation. The original ionic distribution is restored by a sodium – potassium exchange pump which actively transport Na^+ ions out and K^+ ions in the neuron. This return the membrane to its resting potential *i.e.* from + 50 mV to – 70 mV.

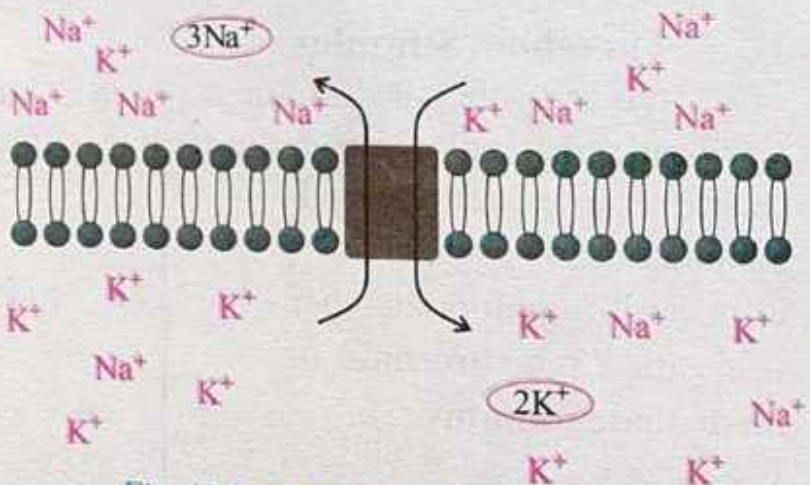


Fig. 17.8: Refractory Period of Neuron

The resting membrane potential (RMP) will be maintained in undisturbed membrane. If it is disturbed or stimulated by a sufficient stimulus known as threshold, then action potential will occur. (Fig.17.8)

17.3.3 The role of Local Circuits in Saltatory Conduction of Nerve Impulse

Saltatory conduction is the propagation of action potential along myleinated axon from node to node. The "local circuits" explain how the action potential (AP) is transmitted along the neuron. Basically an action potential at a point in the axon, develops

a local circuit because, the influx of sodium ions at that point makes that particular point positively charged. However, regions around that point are still negatively charged (because they are still in the "resting potential formation"). The sodium ions at the point of AP are then attracted to these negatively charged regions, hence setting up a "local circuit" at those regions. This circuit then opens the sodium channels at these points, sodium ions flow in and the whole AP circle continues, hence the AP moves along the axon.

17.4 Synapse

There is no cytoplasmic connection between successive neurons, however, impulses are transmitted and this transmission occur at synapse. **Synapses** are microscopic gap between successive neurons. These gaps are between axon terminal of one neuron and dendrites of another neuron. (Fig.17.9)

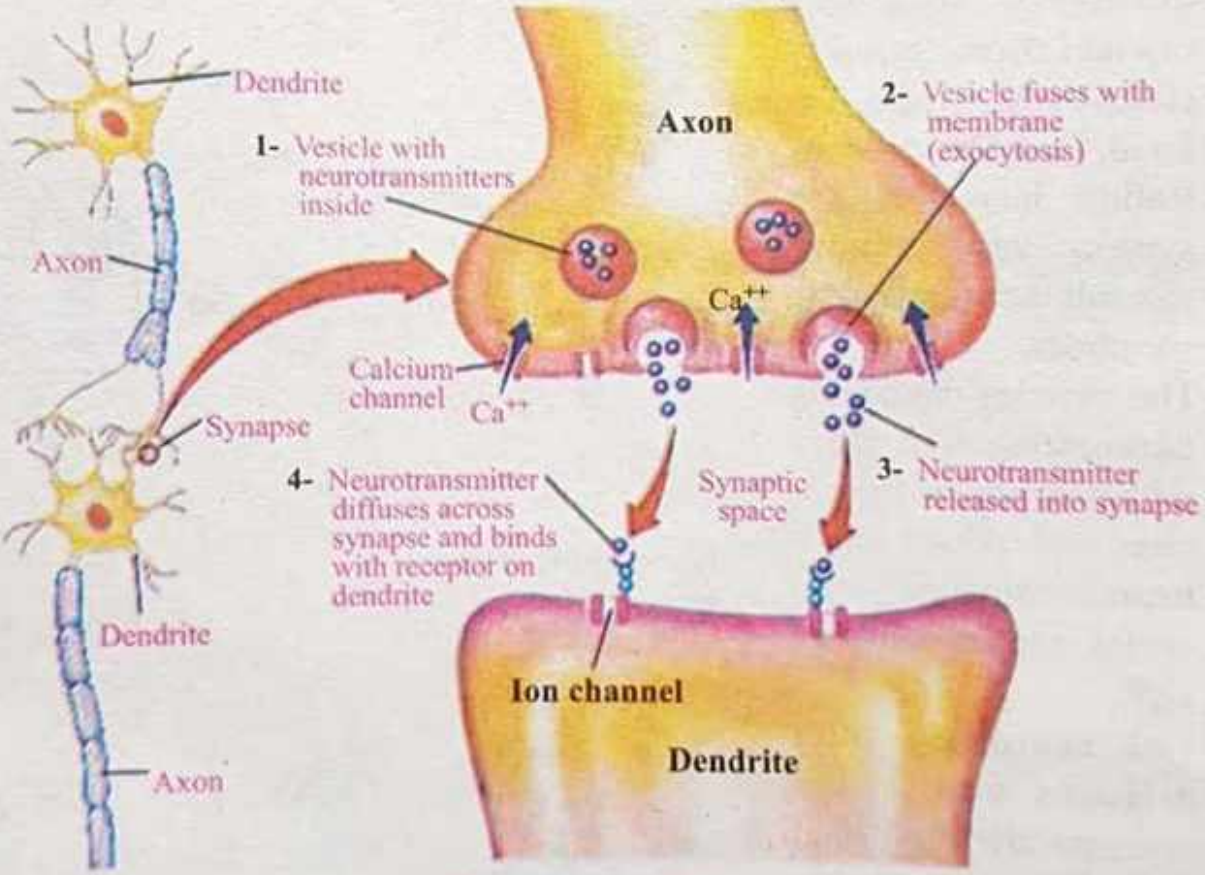


Fig. 17.9: Synapse

A single neuron may form synapses with many incoming fibres of different neurons. The gaps between successive neurons are cleave-shaped thus called **synaptic cleft.** A neuron carries information (impulse towards a synaptic cleft known as **transmitting neuron** or **presynaptic neuron** while a neuron which gets the impulse from synaptic cleft, is called **post synaptic neuron** or **receiving neuron**. The axon

terminals of each presynaptic neuron have expended endings called **knobs** which contain many spherical sacs, known as **synaptic vesicles**. Each vesicle contain as many as 10,000 molecules of chemical messengers, the **neurotransmitter substance**. The dendrite of post synaptic neuron lacks these vesicles. The transfer of impulse across the synapse is called **synaptic transmission.**

Steps of Mechanism of Synaptic Transmission

1. When action potential reaches the axon terminal, it is received by synaptic knob. The calcium channels, present in the presynaptic membrane open and calcium from synaptic cleft transfer into the knob. Thus Ca^{++} concentration increases, the synaptic vesicles move towards the pre-synaptic membrane.
2. The vesicles containing neurotransmitter fuse with presynaptic membrane and release their neurotransmitters molecules into the synaptic cleft.
3. The neurotransmitter diffuses across the synaptic cleft and bind to receptor molecules on postsynaptic membrane.
4. The receptor of post synaptic membrane, opens some channels and allow sodium ions to diffuse across the

Extra Information

There are 100 known types of neurotransmitters.

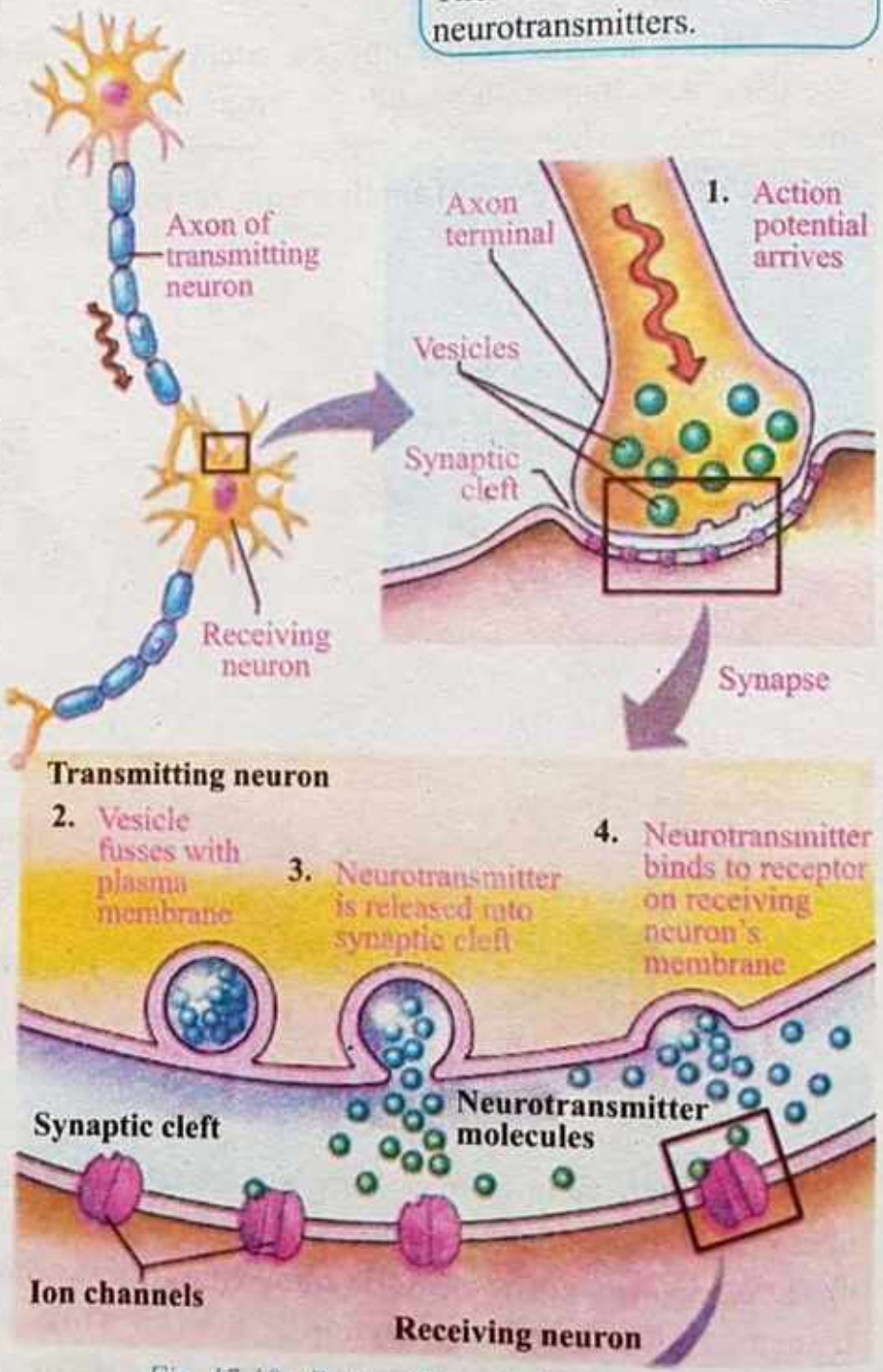


Fig. 17.10: Steps of Synaptic Transmission

postsynaptic membrane. As a result post synaptic membrane depolarizes *i.e.* (inside + outside -) and action potential is generated. Since this depolarization brings the membrane potential towards threshold level, it is called **Excitatory postsynaptic pot-ential (EPSP).**

5. After the activation of post synaptic membrane, the neurotransmitters are immediately broken down by enzymes (like acetylcholinesterase for acetylcholine and monoamine oxidases for adrenaline). (Fig.17.10)

17.4.1 Classification of Neurotransmitters

There are two major classes of neurotransmitters.

1. Excitatory Neurotransmitters

These initiate nerve impulses, cause increased membrane permeability to sodium ions. They may be **acetylcholine** for peripheral nervous system, **biogenic amine** (derived from amino acids) for central nervous system. Their types are **epinephrine** and **nor epinephrine** for heart beat rate during stress; **serotonin** and **dopamine** affect mood, sleep, attention and learning. All of these function like hormones.

2. Inhibitory Neurotransmitter

This decrease membrane permeability to Na^+ ions, which result to raise threshold of stimulus. Thus the nerve impulse does not trigger or lessens, to adjoining neuron. Examples are glycine amino acid, gamma-amino-butyric acid (GABA), while the endorphin are peptides, decreases pain reception and act both as neurotransmitters and hormones.

Interesting Information

There are two types of synapses.

1. **Electrical synapses**, which are rapid and synaptic cleft is only 0.2 nm thick.
2. **Chemical synapses**, in which gap is 20 nm. Thus transfer of impulses occurs by neurotransmitters (Chemicals).

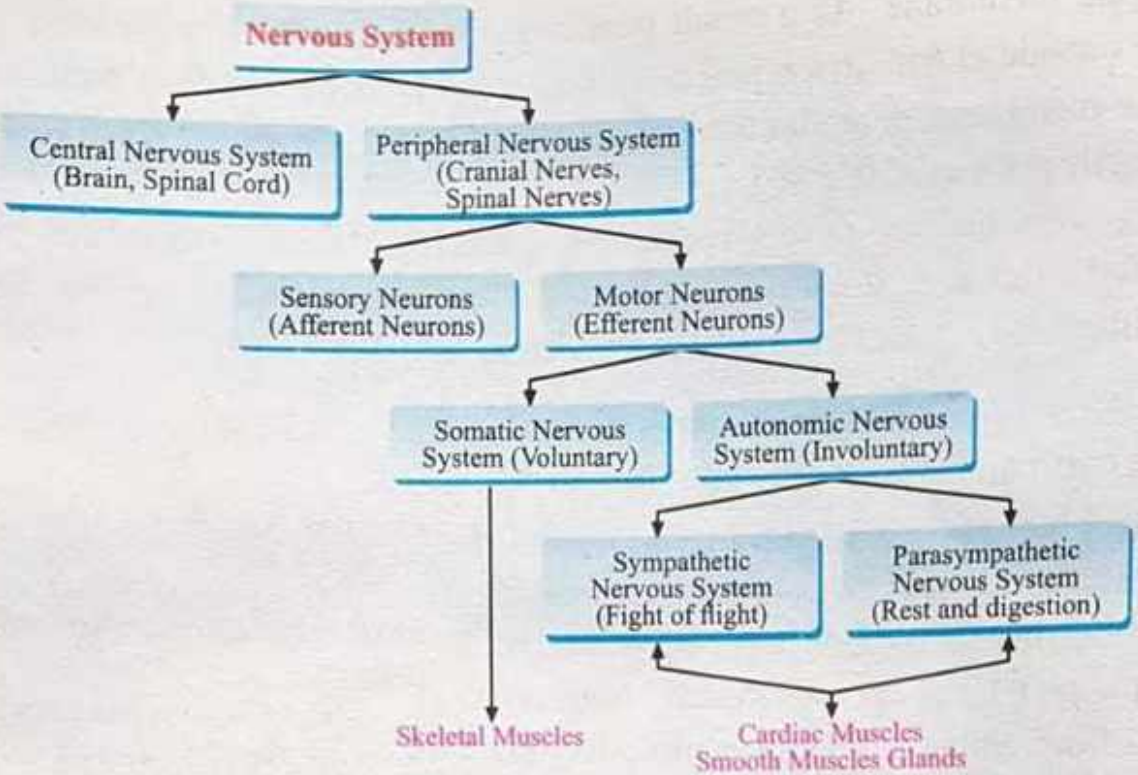
Extra Information

Coelenterates and echinoderms possess diffused nervous system.

17.5 Human Nervous System

Human and most animals (except coelenterates and Echinoderms) have centralized nervous system. Human nervous system is most advanced and also possess some unique features, *i.e.* enable us to convey our complex ideas, information and messages in the form of language, make and use various tools, preserve information (in written and video), great learning, memory storage capacities, *etc.*

Human nervous systems consist of two primary divisions, the central nervous system (CNS) and peripheral nervous system (PNS). (Flow chart 1)



Flow Chart 1: Classification of Human Nervous System

17.5.1 Architecture of Brain and Spinal Cord and their functions

Central Nervous System of Human (CNS)

It consists of brain and spinal cord, act as coordinating centre, these lies in the skull (Brain) and above the vertebral column (spinal cord) *i.e.* in midline of the body.

CNS is hollow and fluid filled. The brain has four cavities called **ventricles** while the cavity of spinal cord is known as **central canal.** The fluid in these cavities named as **cerebrospinal fluid (CSF)** (similar to blood plasma) act as cushion and bathes the neurons of CNS.

Interesting Information

Cerebrum is the largest part of brain and contains highest number of neurons than any other part of brain.

Protection of Central Nervous system

The brain is protected by bony cranium of skull while spinal cord is protected by vertebrae of vertebral column. Both brain and spinal cord are also covered by three membranes, collectively known as **meninges** (**singular; meninx**), the outer hard **Dura matter** (next to cranium), inner **pia matter,** next to brain and spinal cord and middle **arachnoid matter.** The cerebrospinal fluid is present between the piamatter and arachnoid matter.

According to "Roger Spray"

Both cerebral hemisphere of cerebrum superficially same but right and left portion function so differently that we could almost say we have two brain in one. Left cerebrum house our language centre, logic mathematical abilities while the right hemisphere imagination, spatial perception, artistic and emotional abilities.

Brain

The brain of human can be divided into forebrain, mid brain and hind brain. (Fig.17.11)

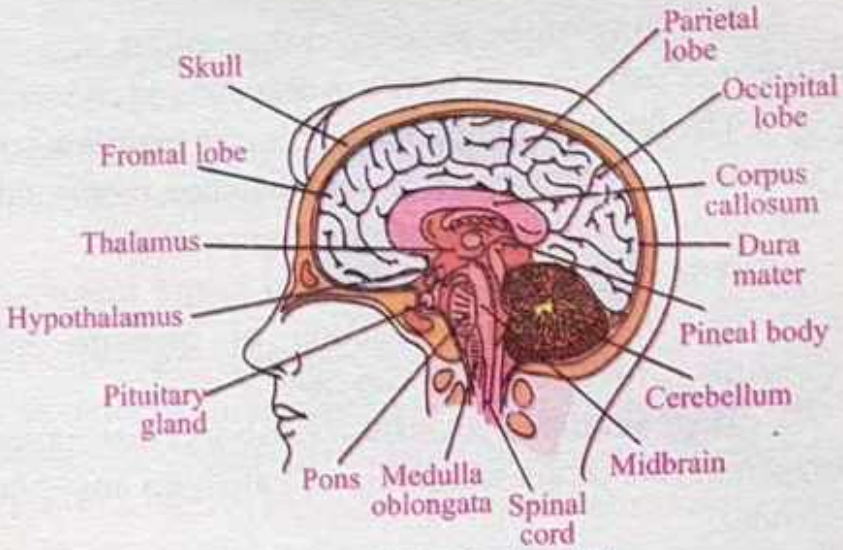


Fig. 17.11: C.S. of Brain of Man

Fore Brain

Forebrain has two sub-divisions; **telencephalon** (cerebrum) and **diencephalon** (thalamus and limbic system). The **cerebrum** of human is largest among all other animals (more than half of the brain). It is divided into two cerebral hemispheres, which are connected together by a band of axons known as **corpus-callosum**. It carries memory available on one side of the brain to the other side. Cerebrum contains four lobes, frontal, parietal, temporal and occipital lobe. The left cerebral hemis-phere controls the right side of the body while right cerebral hemisphere controls left side of the body. Functionally, cerebrum consist of **sensory area**, (receive impulses from receptors), **motor area** (give responses) and **associated area** (interprets or analyses the incoming information) cerebrum act as control centre for sight, smell, taste, speech and hearing. It also controls voluntary movements, thinking, learning, conscious sensations, judgment, reasoning, decision-making, dreams, emotional feeling, intelligence, analysis and interpretation of memory.

Extra Information

There are convolutions (groove) called gyri which are seen on outer part of cerebrum (cerebral cortex). The deep grooves are called fissure while shallow grooves are called sulcus. These grooves greatly increase the surface area of cerebrum. A longitudinal fissure is present between two parts of cerebrum.

Although the motor sensory and associated areas are located in all parts of cerebrum, however motor areas are more abundant in frontal lobe. The associated areas are most occupy the anterior of frontal lobe and wide spread in lateral portion of parietal, temporal and occipital lobes.

Diencephalon (Thalamus and limbic system): **Thalamus** lies below the cerebrum, act as relay centre and carries sensory impulse to the cerebrum and limbic system. Thalamus receives all sensory impulses (except sense of smell).

Limbic System

This system is located in an arc just under cerebrum. The limbic system consists of hypothalamus, amygdala, hippocampus and some part of cerebrum.

Hypothalamus located on the ventral side of thalamus. It is both nervous and endocrine centre *i.e.* link between nervous and endocrine centre.

The function of hypothalamus is to maintain homeostasis and contains centres for regulating body temperature, water balance, menstrual cycle, blood pressure, sleep wake cycle, hunger, sexual response and fight or flight.

Amygdalae are two almond shape masses of neurons on either side of the thalamus. It produces sensation of pleasure, sexual arousal when stimulated, punishment, love, hate, fear and rage.

Hippocampus consists of two horns that curves back from the amygdala and play important role in the formation of long term and short term memory, thus required for learning.

Mid Brain

In human this portion of brain is reduced. It contains auditory relay centre and centre that control reflex movement of eyes also contains auditory reflex centre. Mid brain contains reticular formation, which is a relay centre connecting fore brain with hind brain and is very important in screening the input information before they reach higher brain centres. (Fig.17.12)

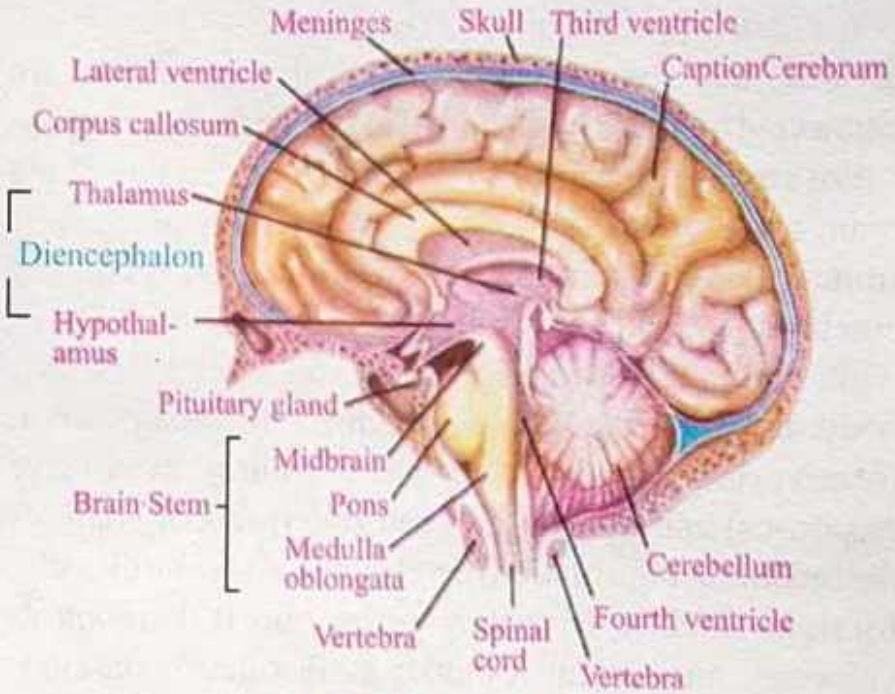


Fig.17.12: Brain Stem

Hind Brain

Hind brain includes the **pons, cerebellum** and **medulla**.

Pons is a group of neuron, located above the medulla; act as a bridge between cerebellum, medulla and cerebrum.

It is involved in rate and pattern of breathing, sleep and wakefulness.

Cerebellum is second largest part of the brain, bulb or leaf like in shape. It coordinates body movements and maintains body position *i.e.* equilibrium. The cerebellum guides, smooth and accurate motions and maintains body position. It also involves in the learning and memory storage for behavior. It is best developed in bird, which engages them in complex activity of flight.

Medulla is last part of brain but in evolutionary point of view, it developed first. It controls several automatic functions, such as heart beat rate, blood pressure, breathing and swallowing.

The mid brain, together with pons and medulla know as **brain stem**, which support the life.

Ventricles of Brain

Human brain possesses four ventricles or cavities, which are filled with cerebrospinal fluid. The first and second ventricles are present between limbic system and cerebrum known as **lateral ventricles**. Another ventricle is present between limbic system and thalamus called **third ventricle** while **fourth ventricle** is present in medulla. There is a tube between third and fourth ventricle known as **iter or cerebral aqueduct**, while an opening between lateral ventricles and third ventricle is called intra **ventricular foramen**. (Fig.17.13)

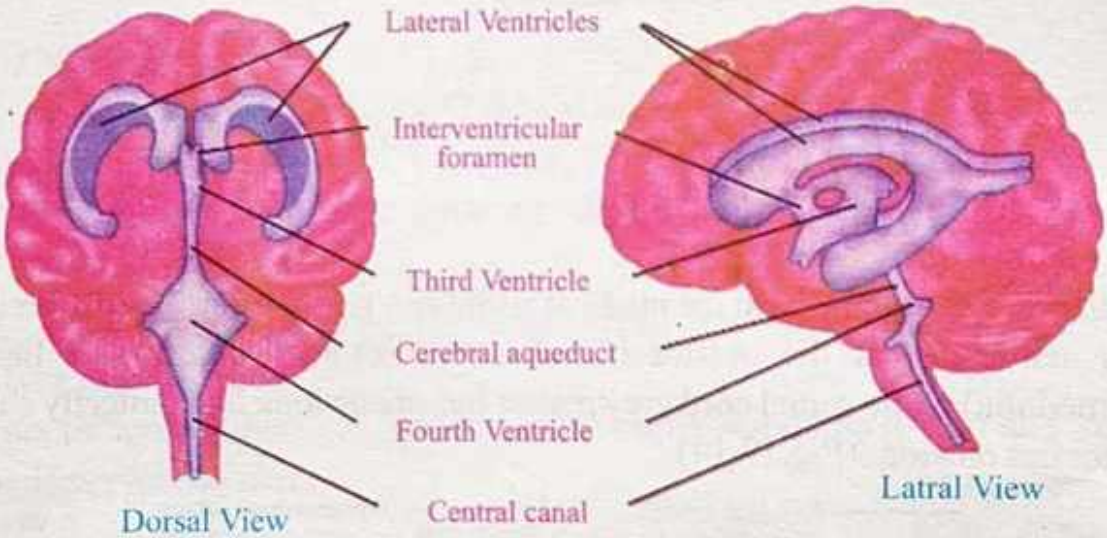


Fig. 17.13: Ventricles of the Brain

17.5.2 Spinal Cord

Medulla narrows down into the spinal cord. It is an elongated, hollow fluid filled and cylindrical structure, extends from the **foramen magnum** (a hole in the bottom of skull) lying in the neural canal of vertebral column (up to 3rd lumbar vertebrae). In a cross section of spinal cord exhibits inner butterfly shaped **grey matter** while peripheral **white matter**. There is a tiny central canal in the centre of grey matter, filled with CSF around the **central canal** is a single layer of cells called **ependymal layer**.

Interesting Information

Local anaesthesia is given at fourth lumbar, so as to protect the spinal cord.

The grey matter consists of non-myelinated portion *i.e.* mostly cell bodies of

neuron while white matter is composed of myelinated nerve fibres *i.e.* mostly axons. Spinal cord controls reflexes below the neck region. It also conducts impulses to and from the different part of the bodies and brain. Thus helps in better function of brain. (Fig.17.14)

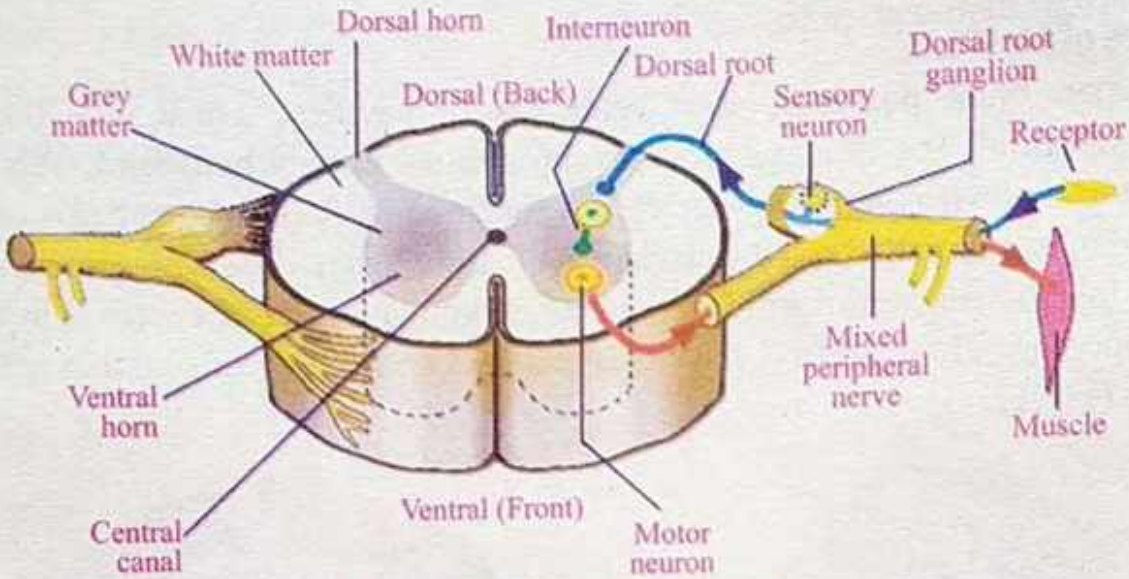


Fig. 17.14: C.S. of Spinal Cord

17.5.3 Architecture of Human Brain and compare its sectional view with that of spinal cord

Both brain and spinal cord are made of white and grey matter. The difference is in brain grey matter mostly lies outside (Cerebral cortex) and white matter lies inside (Cerebral medulla) while spinal cord grey matter lies inside look like butterfly shape and white matter lies outside . (Fig.17.14)

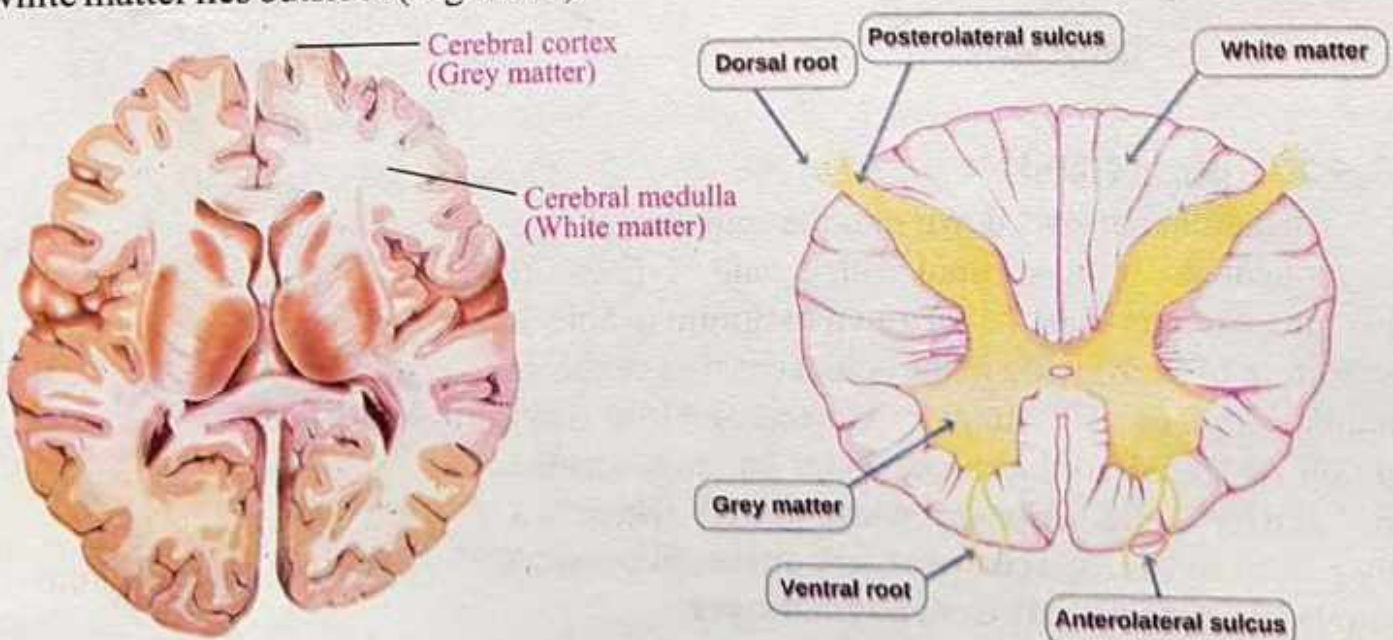


Fig. 17.15: Cross Section view of Brain and Spinal Cord

17.5.4 Peripheral Nervous System

It is the system of nerves and ganglia. The **nerves** are cables of bundles of nerve fibres (axon and dendron fibres) while ganglion is the concentration of cell bodies of neurons with in peripheral nervous system. Nerves may be **sensory nerves** (contains sensory neurons), **Motor nerves** (contain motor neurons) and **mixed nerves** (contains both sensory and motor nerves). There are two types of nerves on the basis of their origin *i.e.* spinal nerves and cranial nerves.

Spinal Nerves

In human thirty-one pairs spinal nerves, all are mixed. Each serves those regions of the body where it is located, Cervical, 8; Thoracic, 12; Lumber, 05; sacral, 05; coccygeal, 01. Each nerve has a dorsal root, contains sensory fibres and ventral root contains motor fibres. Both of these roots join just before a spinal nerve leave the vertebral column.

Cranial Nerves

These nerves are also called **cerebral nerves**. There are 12 pairs of cranial nerves arising from or lead to the brain. The cerebral nerves functionally may be sensory (three pair I, II VIII), motor (five pairs, III, IV, VI, XI, XII) and mixed in nature (four pair V, VII, IX and X). These are mostly concerned with head, neck and facial regions of the body, only 10^{th} cranial nerves, named **vagus** have branches to the pharynx, larynx and most internal organs.

The peripheral nervous system functionally subdivided into the somatic and autonomic nervous system.

Somatic Nervous System (SNS)

This subdivision controls voluntary movements which are consciously controlled, involving skeletal muscles except reflex action of skeletal muscles.

Autonomic Nervous System (ANS)

This subdivision controls involuntary responses (automatic and subconscious), consists of both sensory neurons and motor neurons that runs between central nervous system and many viscera like lungs, heart and glands. Autonomic nervous system also controls the contraction of cardiac and smooth muscles.

The motor neurons of autonomic nervous system are divided into sympathetic nervous system and parasympathetic nervous. The differences between these two system are explained in the Table 17.1. (Fig.17.16)

Table 17.1: Differences between Sympathetic and Parasympathetic Nervous System

Sympathetic Nervous System	Parasympathetic Nervous System
• It prepares the body for emergency situations and associated with "flight and flight". Increase metabolism to avoid danger.	• It promotes all internal responses which are concerned with the rest situation, and maintain body homeostasis, *i.e.* returns body functions to normal position.
• Accelerates the heart beat from set point, rise BP.	• Retards heart beat that is maintain at set point and lowering of BP.
• Dilates Pupils	• Contracts Pupils.
• Inhibits digestion of food	• Increases digestion of food.
• Most preganglionic fibre (nerves) arise from the middle portion of the spinal cord and almost immediately terminate in ganglia that lie near the spinal cord.	• A few cranial nerves, including the vagus nerve, together with fibres that arise from the sacral (bottom) portion of the spinal cord.
• Preganglionic fibres are short and postganglionic long.	• Preganglionic fibres are long and postganglionic short.

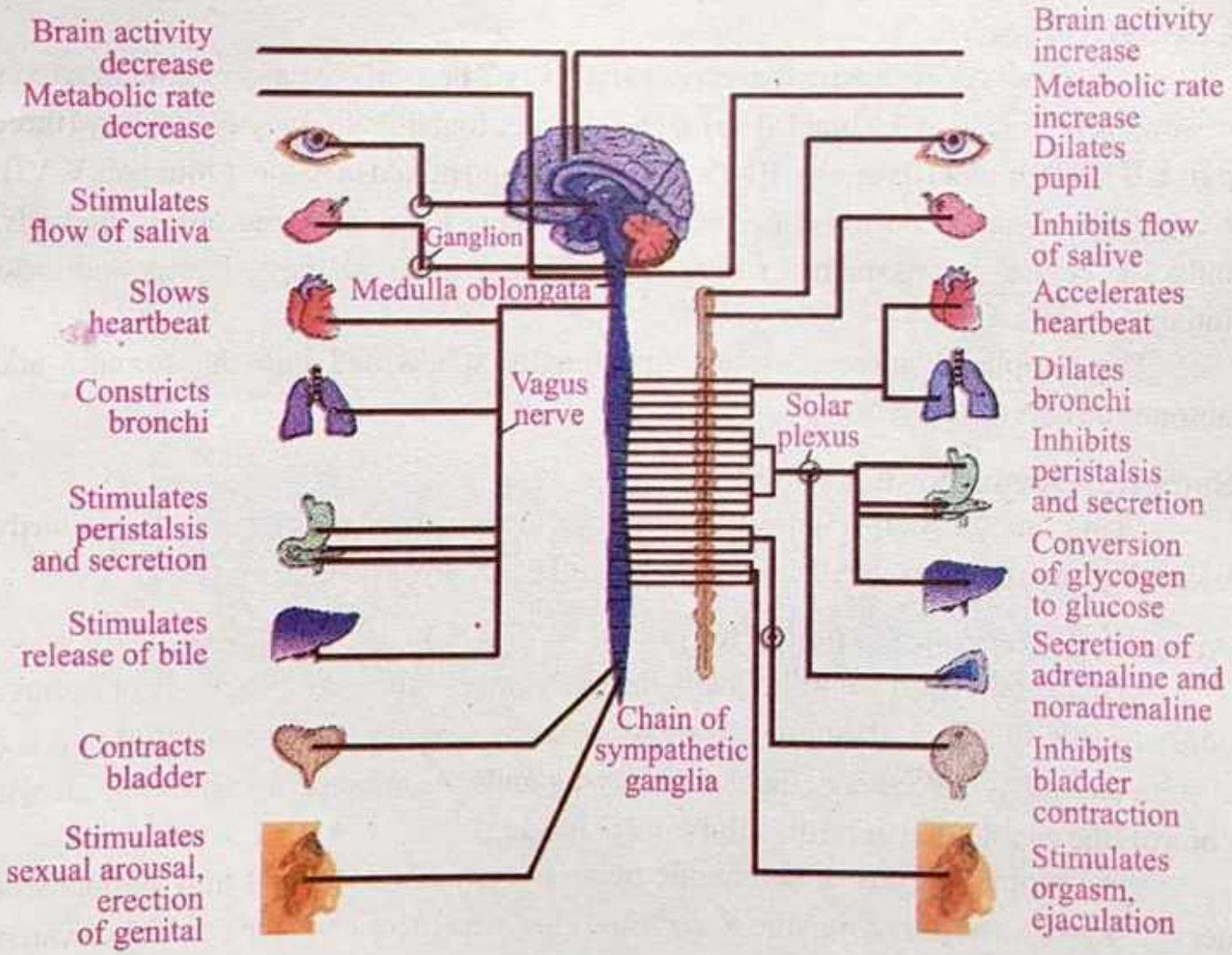


Fig. 17.16: Parasympathetic and Sympathetic Nervous System

17.5.5 Structure and Functioning of Receptors of Smell, Taste, Touch and Pain

1) Smell or Olfactory Receptors

The receptors, which are stimulated by chemicals are called smell or olfactory receptors. In human it is not as much developed or important as vision and hearing. Although in most predators sense of smell is highly developed and important to detect preys. These receptors are located in the upper part of the nasal cavity, which are neurons. The neurons are surrounded by ciliated columnar epithelial cells. Chemicals that stimulate the olfactory receptors enter the nasal cavity as gases, which dissolve in watery fluids that surround the cilia before they can be detected. The axons of neurons carry the smell impulses to the olfactory bulb of fore brain for appropriate responses. (Fig.17.17)

Interesting Information

There are about 1,000 different types of receptor protein on receptor neurons, each is sensitive to different odors.

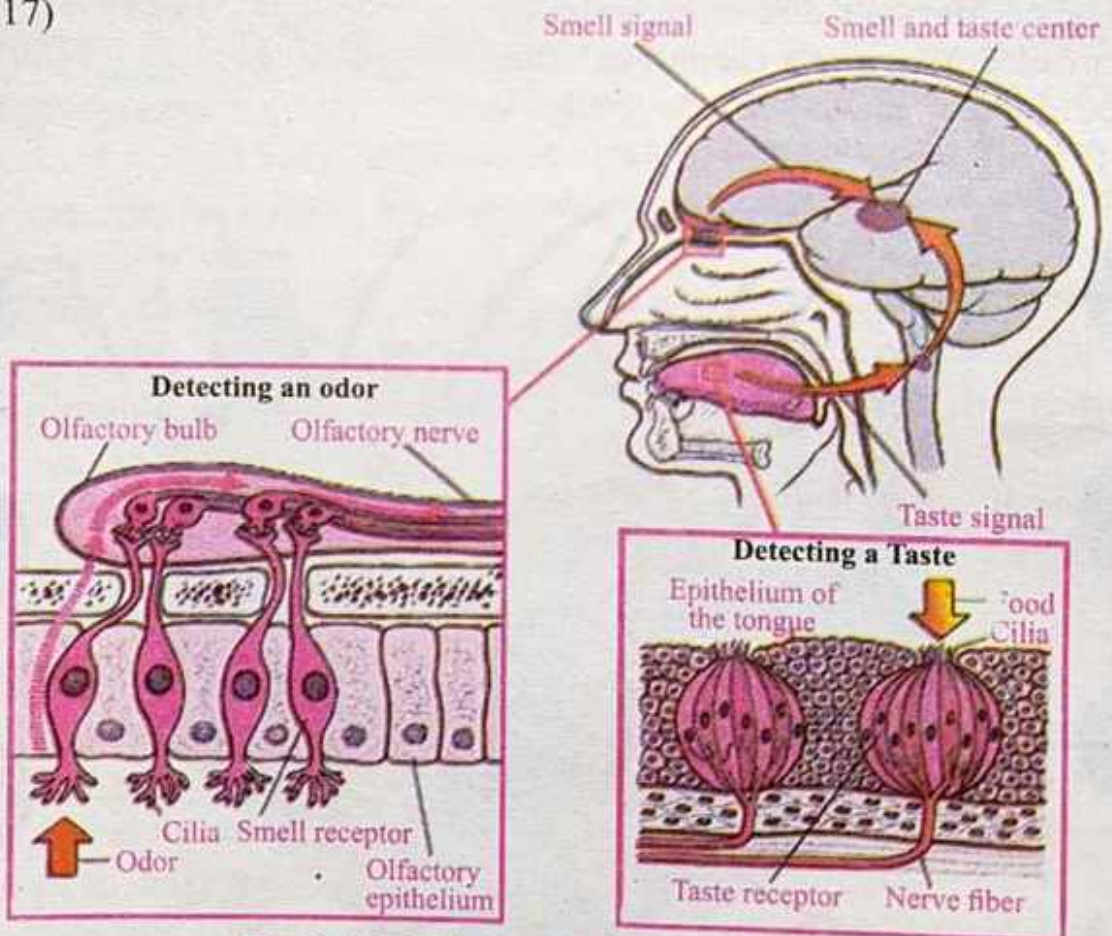


Fig. 17.17: Olfactory and Gustatory Receptors

2) Taste Receptors (Gustation)

These receptors are located on the throat and mouth especially in the upper surface

of tongue as many raised structure called **papillae or taste buds**. Each taste bud has a pore through which fluid in the mouth contact the surface of receptor cells.

There are thousands of taste buds which perceived tastes, all are combination of four primary sensations; **sweet** (elicited by sucrose, glucose and other simple sugars), **sour** (acids), **salty** (NaCl and other salts) and **bitter** (alkaloids and other potentially toxic plant substances). (Fig.17.18)

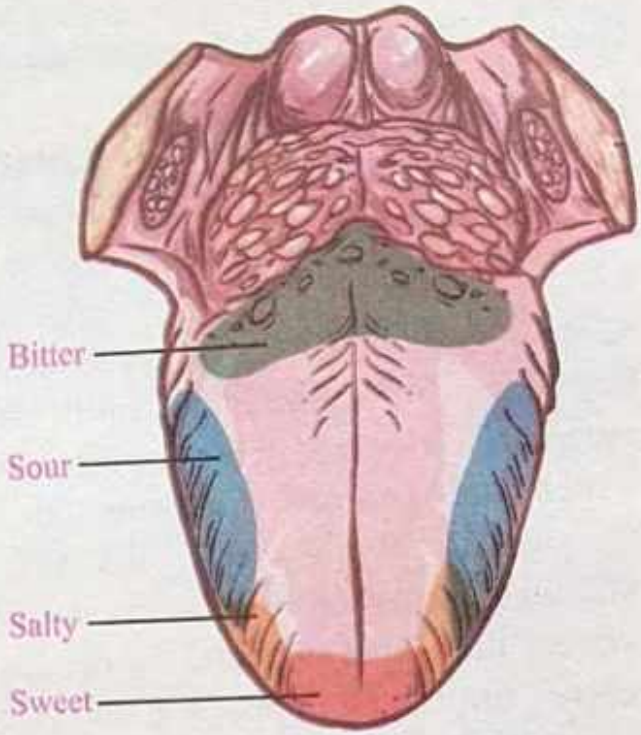


Fig. 17.18: Four Receptor on the Tongue

3) Touch (Tactile Receptor)

There are two touch receptors (also called **mechanoreceptors**) disc-shaped dendrite endings called **Merkel's disc** and egg shaped receptors called **Meissner's corpuscles'**. (the word corpuscle mean "Little body"). (Fig.17.19)

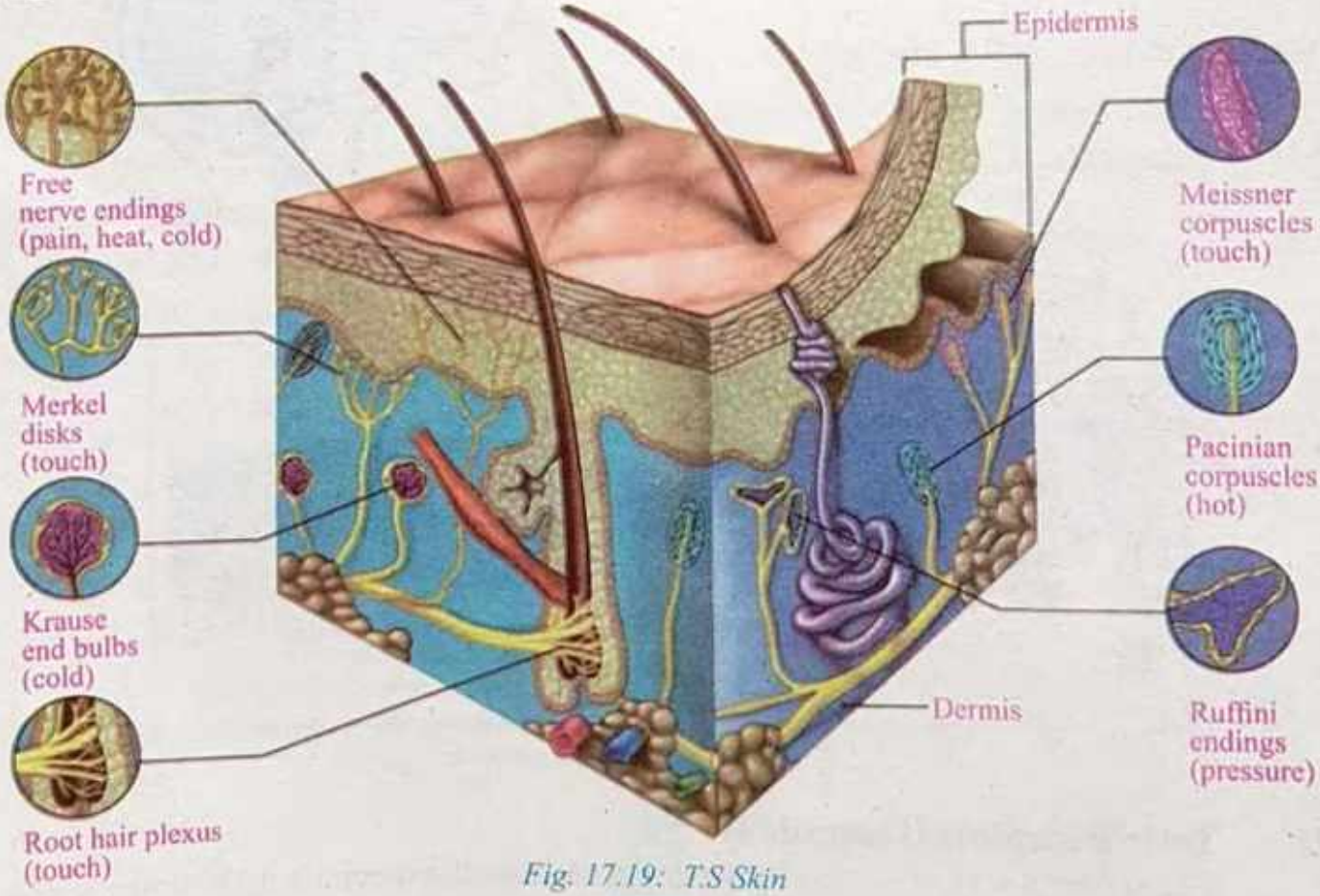


Fig. 17.19: T.S Skin

Both these receptors are widely distributed in the skin but are most numerous in the hands (finger tips), feet, and eyelids, tip of the tongue, lips, nipples, clitoris and tip of the penis. In addition, free nerve endings wrap around the roots of hairs, detect stimulus like wind or an insects that moves body hair.

Pressure receptors called **pacinian corpuscles** are placed deeper with in skin.

1) Pain Receptors (Nociceptors)

There are three types of pain receptors, *i.e.* **cutaneous** (skin), **somatic** (Joints and bones), and **visceral** (all body organs except brain). These receptors are naked dendrites that respond to chemicals released from injured tissues or excess stimuli of pressure and heat.

2) Thermorceptors

Which are encapsulated nerve endings located in the dermis of skin (for hot **Ruffini ending** and for cold **Krause end bulbs**).

17.6 Effects of Drugs on Nervous Coordination

Broadly speaking, **a drug** is a substance introduced into the body to provoke a specific physiological response. Some drugs help a person cope with illness or emotional stress. Other act on the brain, artificially fanning pleasure associated with sex and other self-grafting behaviors. Many drugs are habit-forming. **Habituation** and tolerance are sign of **drug addiction**.

A **narcotic** is a group of substances, bind to certain pain killing sites in the brain thus stop the perception of brain. Their constant use blocks the production of endorphin (natural pain killer hormone secreted from anterior pituitary gland). Thus narcotic acts as an agent which interacts with the normal nervous activity.

The **side effect of narcotics** is change in mood, drowsiness, nausea, vomiting, **euphoria** (an exaggerated feeling of wellbeing), *etc*. Some common narcotic drugs are discussed here.

17.6.1 Heroin

It is most commonly use addictive illegal drug in our country, processed from morphine (extracted from the seed pod of certain varieties of **poppy plant**). Heroin gives a feeling of euphoria and acts as pain killer. It is usually injected via intravenous or intramuscular, sniffed/snorted or smoked.

Their side effects are nausea, vomiting, **dysphoria** (abnormal depression and discontent), respiratory depression, severe itching, dry mouth and **spontaneous abortion** *etc*.

17.6.2 Marijuana, Hashish (*Cannabis sativa*)

Marijuana and hashish is made from crushed leaves, flowers and stems of the plant *cannabis sativa,* in low dose it is like a **depressant**. It slows down but does not impair motor activities. It relaxes the body and elicits mild euphoria. It also causes disorientation, increased anxiety bordering to panic, **delusion** (including paranoia) and hallucinations. *Cannabis* has very beneficial effects as medicine, (stimulate hunger in Acquired Immunodeficiency Syndrome (AIDS) patients, chemotherapy). It is also effective for treating **glaucoma** (eye disease) by reducing intraocular eye pressure.

17.6.3 Nicotine

It is an alkaloid found in tobacco, has powerful effects on nervous system (both CNS and PNS). It mimics acetylcholine and directly stimulates a variety of sensory receptors. In short term effects include water retention, irritability, and increased heart beat rate and high blood pressure. It also causes gastric upsets.

17.6.4 Alcohol

Alcohol directly acts on the plasma membrane to alert cell function. It is lipid soluble thus easily crosses the blood brain barrier to exert rapid effects. Alcohol is one of the most powerful psychoactive drugs and a major factor in many deaths. In short term, a small amount causes disorientation and uncoordinated motor functions, diminish judgment. Long term addiction can lead to liver **cirrhosis**.

Withdrawal symptoms of Alcohol

The symptoms are feeling of nervousness, anxiety, irritability, shakiness, depression, headache, fatigue, rapid emotional changes and hallucination, *etc.*

17.6.5 Inhalants

Inhalants are **volatile** (vapours / gases) organic chemicals, which enhance psychoactive effects (Mind alerting) when abused or misused by concentrating and intentionally inhaling these fumes. Examples are fuel gases nitrates and anaesthetic gases. These are found in **glue, thinner, paint, gasoline and nail polish remover**.

Inhalant provide and instant rush like alcohol, causes euphoria followed by central nervous system depression.

Deep breathing of inhalant may result in loss of self-control, violent behavior, nausea, vomiting, unconsciousness, giddiness, loss of appetite. Their high dose cause hallucination, slurred speech, loss of motor skills and heart palpitation.

17.6.6 Drugs Addiction

It is a state when a person highly dependence on illegal drugs or medication. Many people want to quit these drugs but they cannot do it on their own.

17.6.7 Drug Tolerance

If a person's diminished response to a drug, which occurs when drug is used repeatedly and the body adapts to the continued presence of the drug. Examples are daily users of tea, coffee and cigarette smokers.

> **Interesting Information**
>
> Amphetamine is a commonly used street drug. These include methamphetamine and phentermine. Cocaine (coke), is a strong stimulant, used as a recreational drug.

17.6.8 Effects of Drug Addiction and Drugs Tolerance on CNS

There are three main types of drugs affecting the CNS.

i) Depressants

Those drugs that slow down the functions of the CNS. These drugs (like alcohol, heroin) don't necessary make a person feel depressed, instead feel more relaxed if use in small quantities. Although if use in large quantities then cause vomiting, unconsciousness and even may fatal. It can disturb our coordination and concentration.

ii) Stimulants

Stimulants like caffeine, nicotine, cocaine, amphetamine and many other stimulants increase alertness and body activity, then cause depression. Caffeine, a truly common stimulant, which is present in coffee, tea, chocolate and many soft drinks. Large quantities of stimulants can "over stimulate" the user, causing anxiety, panic, headache stomach cramps, aggression and paranoia.

iii) Hallucinogens

These affect perception, the user may believe they see or hear things that are not really there, or what they see may be distorted in some way. These include, *Cannabis, Datura* which interfering with the activities of acetylcholine, norepinephrine or serotonin.

17.7 Disorders of Nervous System and Diagnostic Tests

Diseases of nervous system are also called neurological disorders. These disorders can be classified into vascular, infectious, structural, functional, and degenerative.

17.7.1 Vascular Disorder of Central Nervous system

This disorder occurs due to abnormality in blood circulation to CNS *e.g.* stroke and brain haemorrhage.

Strokes

It is also called **cerebrovascular accident (CVA)** and occurs due to rupture of small perforating cerebral arteries.

Causes: Hypertension, diabetes mellitus, thrombosis, embolism, cigarette smoking, drugs abuse, *etc.*

Symptoms: Sudden loss of function in one region of brain, which causes numbness of the face, arm or leg of one side of the body (paralysis occur).

- **Aphasia** *i.e.* inability to express through in word.
- Trouble seeing in one or both eyes.

Treatment: Mostly anticoagulants **(such as Heparin)** and platelet aggregation inhibitor (such as aspirin) are used.

- Blood pressure management and nursing is essential.

17.7.2 Infectious Disorders of Central Nervous System

This can be caused by almost any infectious agent, including viruses, bacteria, fungi, protozoa and platyhelminthes. Meningitis is a common example.

Meningitis

It is an inflammation of the **meninges**. It may be virally induced but more often bacterial, sometime other microorganisms.

Symptoms: The common symptoms are stiffness in the neck, photophobia, headache, nausea, vomiting and fever. In **severe cases meningitis** may also cause paralysis, coma and even death.

Treatment:

- **For viral meningitis** there is no specific treatment and the condition is usually benign and self-limiting.
- **Recovery** usually occurs within days.
- **Antibiotics** and corticosteroid are also used as general treatment.

17.7.3 Structural Disorders of CNS

Several disorders disturb the structure of brain are referred as structural disorders, such as tumors.

Tumor

The tumor is an abnormal **mass of neuroglial cells** produced as a result **of uncontrolled cell division**. It may be **benign or malignant tumors**.

Causes: It is caused by mutation and may occur at any age in brain and spinal cord.

Symptoms: The sign and symptoms vary widely, depending on the location of the tumor but may include, headache, vision problem, **neuralgia** (Pain along the distribution of a peripheral nerve). Some of the symptoms are paralysis, hearing problems, seizures, behavior change, coma and death.

Treatment: Tumor ir removed Surgically.

Functional Disorders of CNS

Headache: Headache or **cephalalgia** is pain anywhere in the region of the head or neck.

Symptoms: The brain tissue itself is not sensitive to pain because it lacks pain receptors. Rather, the pain is caused by **disturbance of the pain-sensitive structures around the brain.**

There are two major categories of headaches.

1. Primary Headaches

It is due to the **headache condition itself** and not due to another cause. Primary headaches include **migraine**, tension and cluster headaches.

2. Secondary headaches

It is due to an underlying structural problem in the head or neck such as bleeding in the brain, tumor, meningitis, encephalitis, sinusitis and certain drugs.

Treatment: Headache is treated by several analgesic drugs.

17.7.4 Degenerative Disorders of CNS

Many diseases cause degeneration in different part of the nervous system without an identifiable external cause or it may be genetic, example is Alzheimer's disease.

Alzheimer's disease (AD)

It was first described by Alois Alzheimer in 1907.

Alzheimer's disease is a slowly progressive disease of the brain that is characterized by impairment of memory and eventually by disturbances in reasoning, planning, language, and perception.

Symptoms: There is decline in the brain function in aged peoples. Its symptoms are similar to those diseases that cause **dementia** (memory loss/ impairment of memory/ particularly for recent events *i.e.* short-term memory).

Causes: There is a genetic pre-disposition to the disease in some people, therefore runs in families. High levels of aluminium may contribute to the onset of this disease.

Treatment: So far no effective treatment is known for this disease.

17.7.5 Diagnostic Tests for Nervous Disorders

Some common diagnostic tests for nervous disorders.

Electroencephalogram (EEG)

The neurons of the cerebral cortex continuo-usly generate electric activity. This activity can be recorded by electrodes attached to precise location on the scalp, producing **electroencephalogram (EEG).** An EEG pattern is commonly called **brain waves.** (Fig.17.20)

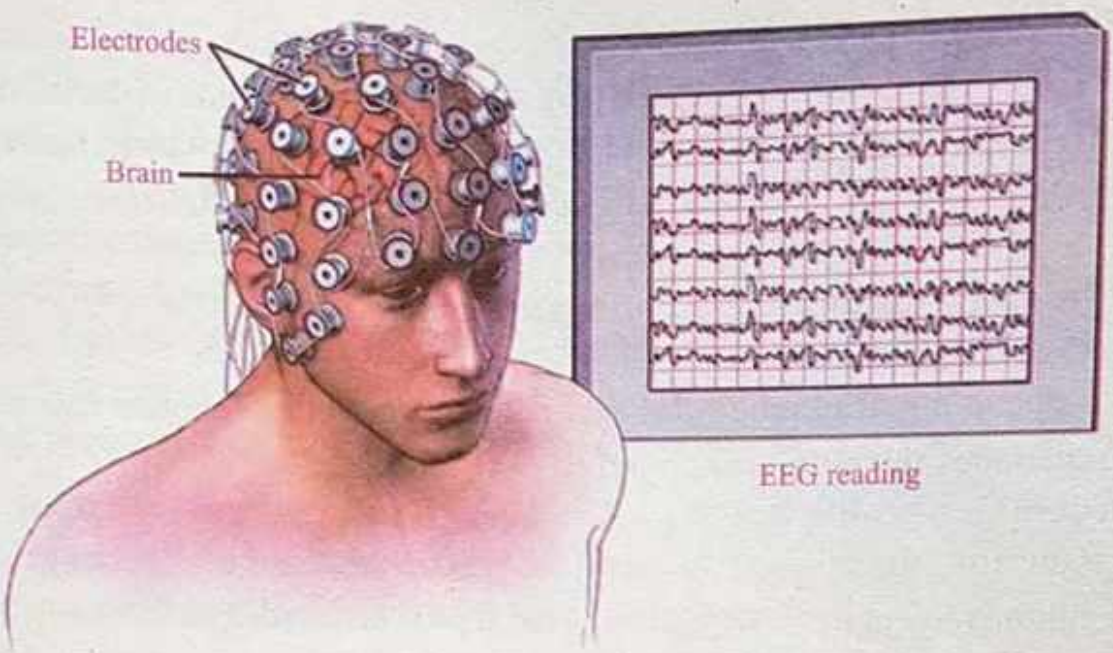


Fig. 17.20: Electroencephalogram (EEG)

Classification of Brain Waves (EEG of brain in Sleep and fully awake person)

The EEG regular patterns are classified as alpha, beta, theta and delta waves. During wakefulness alpha and beta activities are experienced in human brain.

Alpha wave: These waves consists of medium frequency waves.

Beta wave: These waves consists of irregular low amplitude waves found during highly alert and attentive state.

Theta waves: These waves can occur in adults who have drowsy brain. This is a transition stage between sleep and wakefulness.

Delta waves: These waves are of high altitude occurring in deep sleep, in infancy and in patient with severe brain disorders. Distinct types of EEG patterns can be detected in patients with specific brain disorders such as epilepsy.

Computer Tomography (CT) Scan

1. It is an **X-Ray procedure** that combines many X-ray images with the aid of computer to generate cross-section views and if needed **3d images** of internal organs and structures of the body.
2. Computerized tomography is more commonly known by its abbreviated names, **CT scan** or **CAT scan**. A **CT scan** is used to

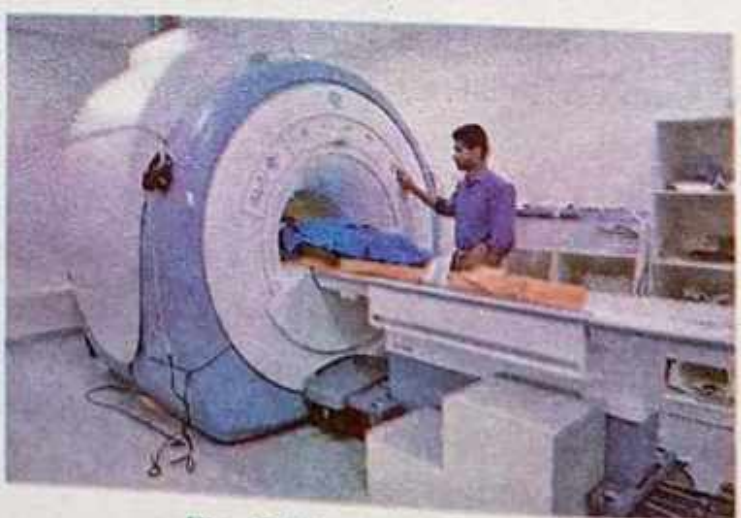


Fig. 17.21: C.T Scan

define normal and abnormal structures in the body and / or assist in procedures by helping to accurately guide the placement of instruments or treatments. (Fig.17.21)

Tomograph and Tomogram

1. A large donut- shaped X-ray machine or scanner called tomography takes X-ray images at many different angles around the body.
2. These images are processed by a computer to produce cross-sectional pictures of body. In each of these pictures body is seen as an X-ray "slice" of body, which is recorded on a film. This recorded image is called a tomogram.

Magnetic Resonance Imaging (MRI):

An MRI (magnetic resonance imaging) scan is a radiology technique that uses magnetism, radio waves and a computer to produce images of body structures.

MRI Scanner is a tube surrounded by a giant circular magnet.

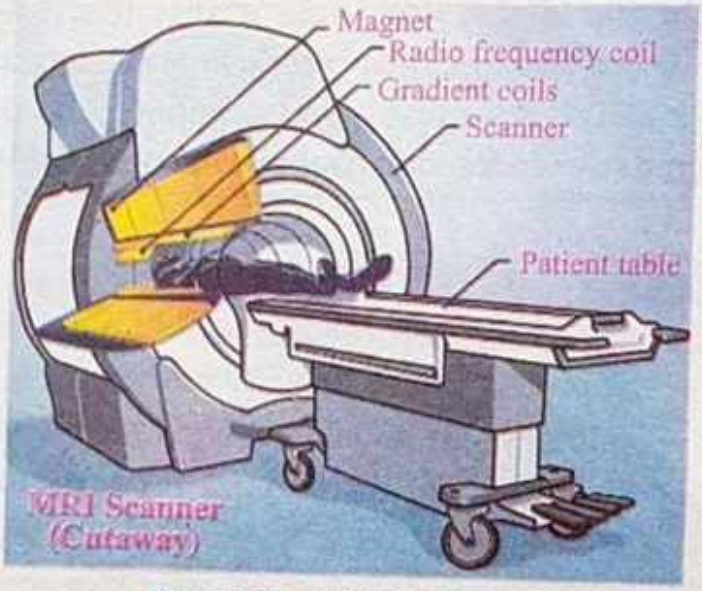


Fig. 17.22: A MRI Scanner

Mechanism

- Patient is placed on a moveable bed that is inserted into the magnet.
- The patient is exposed to strong magnetic field and beam of radio-waves.
- The receiver information is processed by a computer and an image is produced.
- Image and resolution produced by MRI is quite detailed and can detect tiny changes of structures within the body.

Science, Technology and Society (STS)

1. Justify the way nervous system helps to coordinate complex and intricate movement of hand to play a piano or write alphabets.

The information gathered by the sensory receptors in the form of electrical impulses is a process called transduction. The nerve impulses are then transmitted over peripheral nervous system to the central nervous system. There the signals are integrated; *i.e.* they are brought together, creating a sensation (preceptions), adding to the memory or helping to produce thoughts. As a result of this integrative function, conscious or subconscious decisions are made and then acted upon by motor functions.

The motor functions of the nervous system employ peripheral nerves. They carry impulses from the central nervous system to the effector *i.e.* muscles that contract when stimulated by impulses. Thus hand and fingers move, so that we may play a piano or write alphabets.

2. Ascertain the effect of nerve gas as an inhibitor or acetylcholinesterase.

The nerve gases are a class of organic chemicals that disrupt the mechanism by which nerve transfer messages to organs. The principle upon which nerve gases work is to inhibit a particular enzyme in the body, namely acetylcholinesterase which rapidly break down the neurotransmitter, acetylcholine. The reason is that the organophosphorous compound transfers a phosphate group to the enzyme, making it inactive. As a result acetylcholine build up causing a jam in the nervous system and muscle contraction continue uncontrollably. The person will die.

SUMMARY

- Nervous system detects, interprets, and issue calls for response to stimuli in the animal's (*e.g.* human) external and internal environment.
- Receptors are the parts of the body that receive stimuli from internal or external environment.
- Neurons are the structural and functional unit of nervous system.
- There are three basic components of each neuron, *i.e.* axon, cell body and dendrites.
- Based on the function, there are three types of neuron, sensory, associated and motor neurons.
- Reflex action is immediate, involuntary and automatic response to external and internal stimuli.
- Nerve impulse is a wave of electrochemical changes that travels along the length of neuron.
- Synapse is a microscopic junction between two successive neurons, which transmit impulse from one neuron to another neuron.
- Central nervous system consists of brain and spinal cord
- The brain is divided into three parts, fore brain, mid brain and hind brain.
- The peripheral nervous system includes cranial nerves and spinal nerves.
- Olfactory receptors are chemoreceptors, stimulated by chemicals dissolved in liquid.
- The receptors for touch and pressure are also called mechanoreceptors.

- Endorphins are the natural pain killer chemicals in the brain.
- Nicotine is an alkaloid derived from tobacco.
- Meningitis is the inflammation of the meninges.
- Tumor is an abnormal mass cells which produced as a result of uncontrolled cell division.
- A headache is also called cephalalgia.
- EEG, CT scan and MRI scan are commonly used diagnostic test for nervous disorders.
- Inhalants are volatile organic chemicals, commonly called "glue sniffing".

EXERCISE

SECTION-I: OBJECTIVE QUESTIONS

Multiple Choice Questions (MCQs)

A. Choose the correct answers.

1. Nissel's granules is the group of:
   (a) Mesosomes (b) Lysosomes
   (c) Ribosomes (d) Chromosomes
2. Main transmitter for synapses that lie outside CNS is:
   (a) Serotonin (b) Acetylcholine
   (c) Dopamine (d) Adrenalin
3. In human rely center is located in:
   (a) Fore brain (b) Mid brain
   (c) Hid brain (d) Spinal cord
4. The part of brain which controls breathing, heart rate and swallowing is:
   (a) Cerebellum (b) Medulla
   (c) Thalamus (d) Cerebrum
5. Which of the following receptors produces sensation of touch and pressure?
   (a) Chemoreceptor (b) Mechanoreceptors
   (c) Nociceptors (d) Photoreceptors
6. Chemoreceptors detect the stimulus of:
   (a) Pressure (b) Temperature
   (c) Light (d) Smell
7. The portion of neuron that conducts nerve impulse towards cyton (cell body) is:
   (a) Axon (b) Dendrites
   (c) Myelin (d) Soma

8. Neurilemma is the membrane of:
   (a) Muscle cell (b) cyton of neuron
   (c) Axon (d) Nerve fibre
9. The fibres at the end of axon are called
   (a) Dendrites (b) Dendron
   (c) Axon fibres (d) Cyton
10. Synapse is microscopic gap between two successive:
   (a) Neuroglia (b) Neuron
   (c) Axons (d) Soma
11. Brain and spinal cord together known as:
   (a) PNS (b) ANS
   (c) SNS (d) CNS
12. Second largest part of brain is:
   (a) Fore brain (b) Cerebrum
   (c) Cerebellum (d) Medulla
13. The number of cranial and spinal nerves in human are
   (a) 24 and 62 (b) 12 + 31
   (c) 20 + 68 (d) 20 + 62
14. The volatile organic chemicals, once commonly referred to as "glue sniffing" are
   (a) Cannabis (b) Inhalants
   (c) Narcotics (d) Caffeine

B. Fill in the blanks.

1. Neurotransmitter molecules bind to the receptors on the ..... membrane at synapse.
2. A microscopic gap between two consecutive neurons is called .....
3. The collection of axons and dendrites are called .....
4. Muscles and glands are principal .....
5. An infection of the central nervous system is called .....
6. The structures which respond by impulse coming from motor neurons are .....
7. Nociceptors detect stimulus of .....
8. Neurons are structural and functional unit of .....
9. Nissl's granules are the group of ..... in the neuron cell body.
10. Serotonin and acetylcholine are .....

SECTION-II: SHORT QUESTIONS

C. Give the short answers of the following questions.

1. Define nervous coordination, receptors and effectors.
2. Describe briefly about axon.
3. Differences between sensory neuron and motor neuron.
4. Difference between reflex action and reflex arc.
5. Define synapse, presynaptic neuron and post synaptic neuron.
6. Define neurotransmitter, write name of any four neurotransmitters.
7. Write note on mid brain.
8. Describe ventricles of brain.
9. Name the five fundamental parts of reflex arc.
10. Describe structure and function of spinal card.
11. Write any three differences between sympathetic and parasympathetic nervous system.
12. Illustrate cranial nerves.
13. Write note on gustatory receptors.
14. Write short note on heroin.
15. Prove that MRI is a better diagnostic test than CT scan.

SECTION-III: EXTENSIVE QUESTIONS

D. Give detailed answers of the following questions.

1. Describe structure of a typical neuron.
2. Define reflex arc and explain it with example.
3. Write detail note on resting membrane potential.
4. Define synapse and describe structure and write steps of mechanism of synaptic transmission.
5. Write the name of largest part of the brain and explain its structure and function.
6. Describe peripheral nervous system.
7. Write note on olfactory receptors and taste receptors.
8. Write a comprehensive note on nicotine and cannabis.
9. Describe stroke and meningitis.
10. Write note on electroencephalogram.

UNIT 18

CHEMICAL COORDINATION

Major Concept

18.1 Hormones- The Chemical Messengers
18.2 The Endocrine System of Man
18.3 Feedback Mechanism

Learning Outcomes

Students will be able to:

- State the role of hormones as chemical messengers.
- Describe the chemical nature of hormones and correlate it with important hormones.
- Trace the path of the chemical message and its release from the endocrine gland to its action at the target site.
- Explain the two modes of hormone action at the cells of target site.
- Locate the following endocrine glands in human body, pituitary, thyroid, parathyroid, pancreas, adrenal and gonads.
- Name the hormonal secretions of the above-mentioned glands.
- Outline the major functions of the hormones of above mentioned glands and also relate the problems associated with the imbalance of these hormones.
- Explain the neurosecretory role of hypothalamus.
- Describe the functions of the hormones secreted by the endocrine tissue other than the mentioned above.
- Outline the concept of Feedback mechanisms of hormones.
- Describe positive feedback with reference to oxytocin and negative feedback with reference to Insulin and Glucagon.

Introduction

Nervous system is not capable to innervate all the cells of the body thus another coordinating system is needed. Endocrine system fulfils this gap by chemical coordination.

A **hormone** is a "chemical messenger", secreted by an endocrine gland. Traditionally hormones have been described by scientists as the chemical products travel within the bloodstream to all parts of the body, causing an effect on specific cells or target

organs. It also affects exocrine glands or individual cell or tissue that secrete chemical substances. The glands that secrete hormones, pour directly into the blood stream are called **endocrine glands** or **ductless glands.** The glands which secrete other substances such as digestive enzymes, milk, sweat, bile and route their secretions to specific destinations by means of ducts are called **exocrine glands or ducted glands.**

18.1 Hormones- The Chemical Messengers

Path of chemical message (Hormone)

Hormones are "chemical messengers", secreted by cells that affect other cells. Hormones that travel within the blood stream and affect cells in another part of the body are known as "**endocrine hormones**". While those hormones that do not travel within the blood stream but only affect cells lying near the secretary cells are known as **"local hormones"** e.g., serotonin, prostaglandin, gastrointestinal hormones etc.

Role of Hormones

Hormones are small soluble organic molecules which are effective in low concentration and affect at a site where specific receptors are present therefore, hormone is either increase or decrease or modify the secretion of other glands. They also increase or decrease a body structure.

18.1.1 Chemical Nature of Hormones

Chemically, there are three basic types of hormones, which are:

1. Steroid
2. Amino acids or their derivatives, proteins and glycoproteins.
3. Few belong to the fatty acids e.g., prostaglandin

Steroid hormones are derivatives of cholesterol and secreted by cortex of adrenal gland (cortisol and aldosterone), testes (androgen), ovaries and placenta (estrogen and progesterone).

Amino acid derivatives are of two groups. The epinephrine and nor-epinephrine are secreted from adrenal gland, thyroxin and tri-iodothyronine (T_3), secreted by thyroid glands. All these are derivatives of tyrosine amino acid.

Polypeptide hormones are oxytocin, vasopressin, adrenocorticotrophic hormone, calcitonin, parathormone, melanocyte stimulating hormones.

Proteinaceous Hormones include somatotophic hormone, (STH) and insulin.

Pheromones

They are hormone-like chemical messengers but removed outside they body. These are small, volatile chemicals that function in communication among animals and fungi. They act by influencing the physiology and behaviour of the receiving individuals.

Extra Information

Oxytocin and antidiuretic hormones are peptide of only nine amino acids.

Glycoprotein hormones are Follicle Stimulating Hormone (FSH), Luteinizing Hormone (LH), human chorionic gonadotropin (hCG) and Thyroid stimulating hormone (TSH).

18.1.2 Mode of Hormone Action

There are two modes of action of hormones.

1. Fixed Membrane Receptor Mechanism

The peptide and protein hormones cannot pass through cell's plasma membrane because they are water soluble. Thus attached with the receptors on the plasma membrane of target cell and then start a series of steps in the cell. Adenylate cyclase is an enzyme of plasma membrane, which involved in ATP meta-bolism as catalyst, the transfo-rmation of ATP into second messenger, the **Cyclic Adenosine Monophosphate (cAMP).**

The cAMP triggers various changes in the cell including activation of enzymes, gene activation (another term use to describe this entire process is called **signal transduction**). (Fig.18.1)

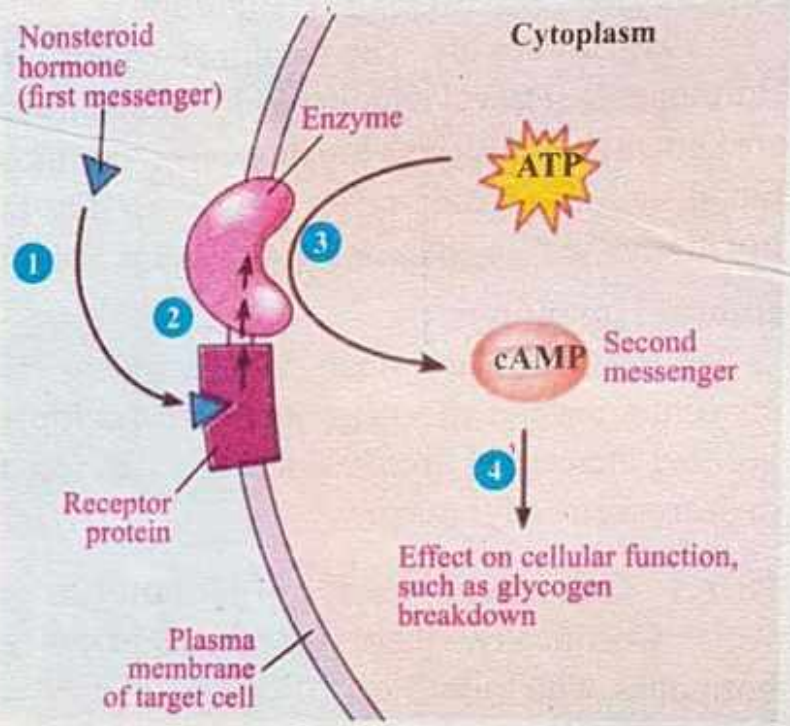


Fig. 18.1: Action of Non-steroid Hormone

2. Mobile Receptor Mechanism

(Gene/signal Modulation)

The steroid and amino acid derivative hormones can easily pass through plasma membrane because both are lipid soluble. Their receptors are placed inside target cells i.e., either in cytoplasm or nucleus. These together with target receptors form hormone-receptor complex, which then travel to the particular gene, acting as transcrip-

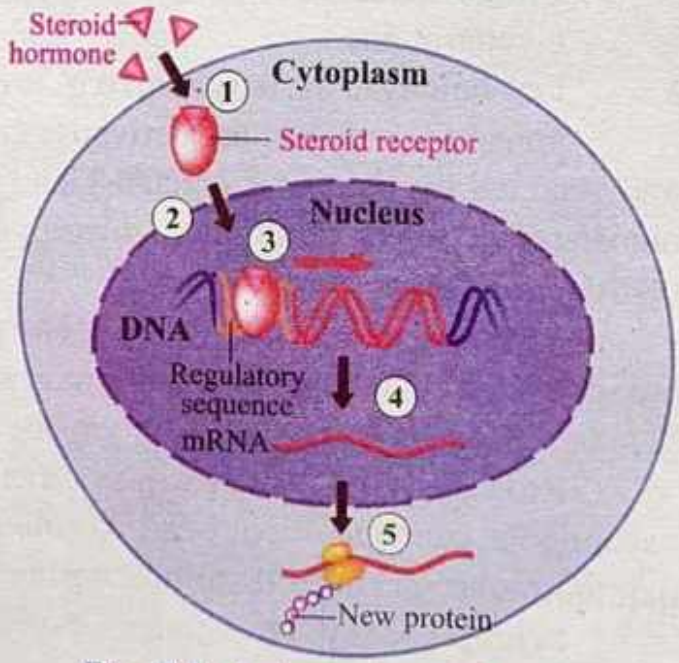


Fig. 18.2: Action of Steroid Hormone

tion factor. The target gene is transcribed into messenger RNA then it is translated into polypeptide (protein) in cytoplasm. Thus the activities of target cells are modified by the alter gene expression. (Fig.18.2)

18.2 Endocrine Glands (System) of Human

Human endocrine system includes about 20 different endocrine glands, some of which are hypothalamus, pineal, pituitary, thyroid, parathyroids thymus, adrenal, pancreatic islets and gonads. (Fig.18.3)

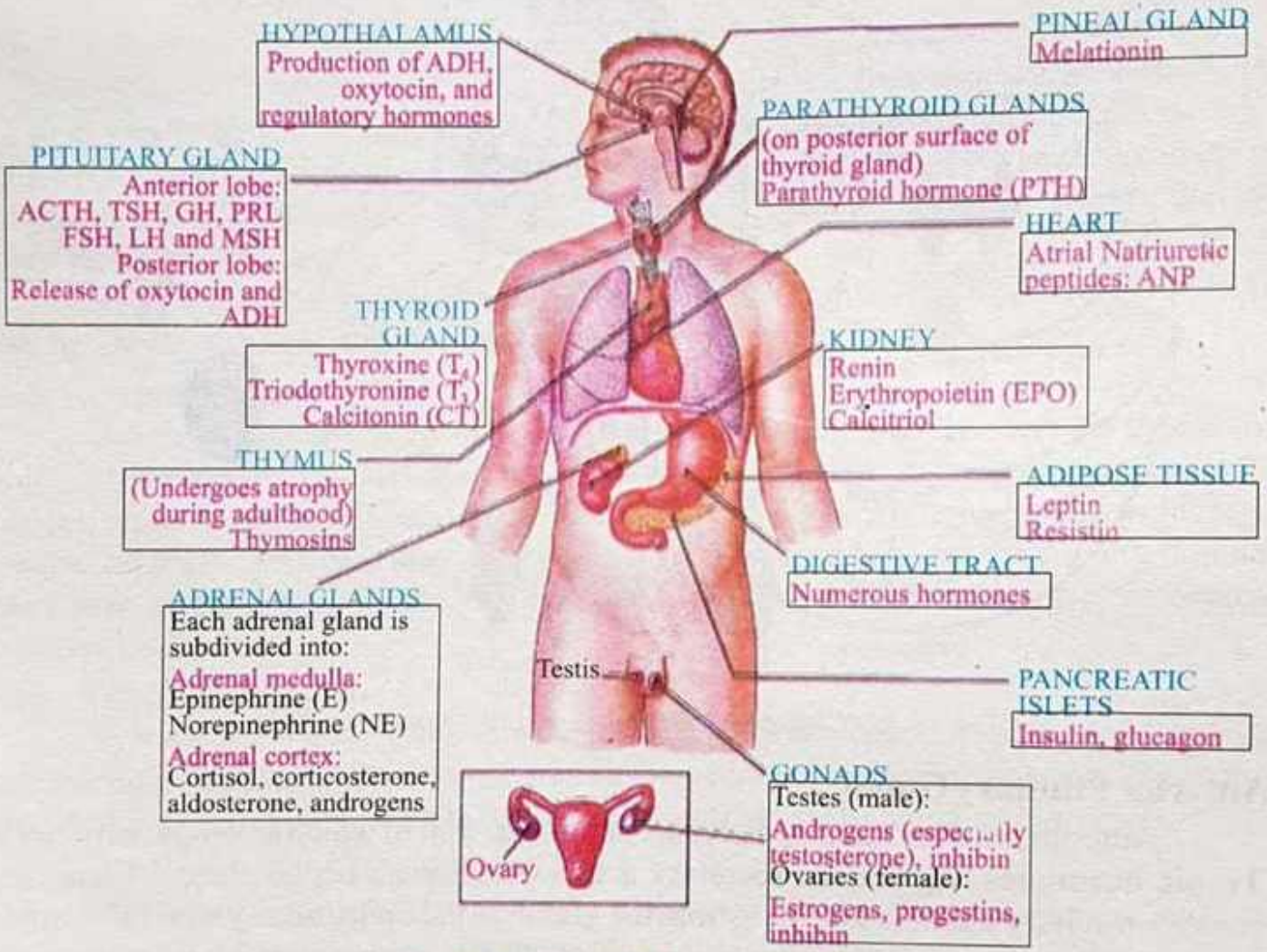


Fig. 18.3: Major Endocrine Glands

18.2.1 Pituitary Gland

Pituitary gland is small pea-sized gland, (about 0.5gram) lies in the brain. It is attached with hypothalamus by a stalk known as **infundibulum**, which is made of blood vessel and the nerve fibres of neurosecretory cells. Pituitary gland is divided into three lobes, the anterior pituitary (**adenohypophysis**), posterior pituitary gland (**neurohypophysis**) and intermediate pituitary (**Median lobe**). (Fig. 18.4)

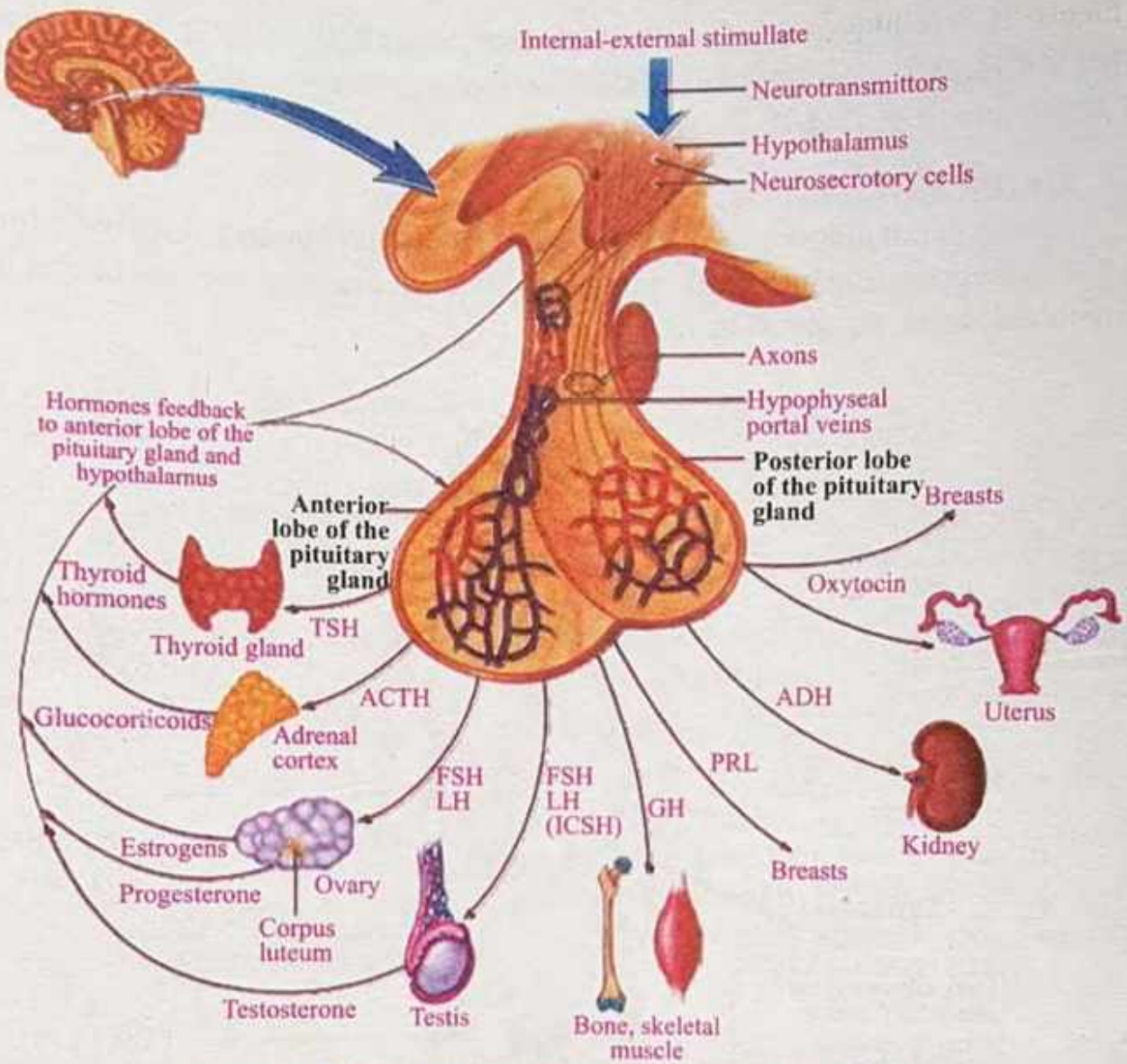


Fig. 18.4: Hormones of Hypothalamus and Pituitary Glands

Anterior Pituitary Gland

Anterior pituitary gland secretes six hormones, four of which are tropic hormones. **Tropic hormones** regulate the secretory action of other endocrine glands. Therefore, anterior pituitary gland is known as **master gland** of the endocrine system. The tropic hormones are thyroid stimulating hormone **(TSH)**, adrenocorticotropic hormone **(ACTH)**, follicles stimulating hormone **(FSH)** and luteinizing hormone **(LH)**. Other two anterior pituitary hormones are called **primary hormones**, such as growth hormone **(GH)** and prolactin **(PRL)**, these directly affect body structure or exocrine gland.

i) Growth Hormone (GH) or Somatotrophic Hormone (STH)

Its stimulating factor is **somatotropin releasing factor (SRF or GHRF)**, which is secreted from hypothalamus throughout life and inhibited by hypothalamic **somatostatin** (Inhibitor Hormone).

Growth hormone has a direct effect on growth of the body, skeleton and skeletal muscle. It also stimulates cell growth and cell division, increases movement of amino acids to the cells i.e., helps in protein synthesis.

Disorders due to over secretion of GH in **early life** is called **gigantism.** It causes extraordinary elongation of bones and person becomes giant.

While in **adulthood**, the bones grow in thickness, thus enlargement of hand, feet, skull, nose and Jaw bones occur. This condition is called **acromegaly**.

Deficiency of GH leads to **pituitary dwarfism**, the development is much slower than normal. The individual has short stature, but the development of brain and Intelligence Quotient (IQ) is not affected.

ii) Thyroid Stimulating Hormone (TSH)

TSH controls the secretion and development of thyroid gland. Its secretion depends on the level of thyroxin in the blood. Hypothalamus detects the level of thyroxin, if it is less then hypothalamus secretes **thyroid releasing factor (TRF) or thyrotropin**, which in turn stimulates pituitary gland to release TSH that affects the activity of thyroid gland.

Low TSH level may be harmful for health, heart disease and osteoporosis may occur. While high TSH level in blood indicates hypothyroidism.

iii) Adrenocorticotropic Hormone (ACTH)

It acts on adrenal cortex and stimulates the secretion of **corticosteroids** (cortisone and aldosterone). The secretion of ACTH is stimulated by **adrenocorticotropic releasing factor (CRF)** from hypothalamus as a result of stress e.g., pain, cold, fear, stress, infection and pregnancy. Cushing disease is caused by a pituitary gland tumour, that over secretes the hormone ACTH, thus over stimulate adrenal cortex to secrete cortical production.

iv) Gonadotropins

Gonads are the male and female sex organs (testes/ovaries). The gonadotropins are hormones that affect these sex organs, thus considered endocrine glands because they secrete sex hormones i.e., follicle stimulating hormone and Luteinizing hormones.

Follicle Stimulating Hormone (FSH)

In human females, FSH targets the ovary and triggers the maturation of one egg (sometime more than one egg) per month. In addition, it stimulates cells in the ovaries to secrete female sex hormones called estrogen.

In males, FSH targets the testes and triggers the production of sperms. The secretion of FSH is stimulated by gonadotropin releasing hormone (GnRH) from the hypothalamus.

Luteinizing Hormone (LH)

Its secretion is also controlled by gonadotropin releasing hormone (GnRH). **In**

females a surge of LH near the middle of menstrual cycle stimulates the release of an egg from grafian follicle of ovary. In addition, LH triggers the development of cells within the rupture follicle to form a glandular structure called **corpusluteum** which secretes a hormone known as **progesterone** (to prepare uterus for coming embryo). LH is also responsible for multiple births. **In male**, LH is also known as **Interstial Cell Stimulating Hormone** (ICSH). It promotes production of the male sex hormone **testosterone**.

Low secretion of both FSH and LH leads to delay sexual maturation. The GnRH deficiency may be by birth or acquired.

Prolactin Hormone (PRL)

It works in conjunction with estrogen, progesterone and other hormones. It causes enlargement of the mammary glands and prepare them for the production of milk (lactation) after birth. It stimulates mothers to care their young ones. During the menstrual cycle, milk is not produced or secreted because prolactin level in the blood is very low. Its secretion is inhibited by **Prolactin Inhibiting Factor (PIF)** from hypothalamus.

Posterior Pituitary Lobe (Gland)

The posterior lobe of the pituitary is nonglandular, it stores and releases two hormones that are produced by the hypothalamus. These are **Antidiuretic Hormone (ADH)** and **Oxytocin**.

Interesting Information

Lack of antidiuretic hormone causes "diabe-tes insipidus". As a result, there is the production of large quantity of watery urine and person feels great thirst and dehydrated.

i) Antidiuretic hormone (ADH)

It helps to regulate volume of the blood by regulating the amount of water reabsorbed by the kidneys. For example, osmoreceptors in the hypothalamus can detect a low blood volume by detecting when the solute concentration of the blood is high, then the neurosecretory cells of hypothalamus make ADH, which is transported within axon to the posterior pituitary, then releases into the blood stream. ADH binds to target cells in the collecting ducts of the nephrons of the kidneys, increasing their permeability for water reabsorption, thus urine becomes concentrated. ADH also acts on the smooth muscles surrounding arterioles, an action that helps to raise the blood pressure. Alcohol suppresses ADH release that is why excessive drinking leads to the production of excessive quantities of urine and eventually to dehydration.

ii) Oxytocin

It is also produced in hypothalamus and transported within axons to posterior pituitary for secretion. **In women,** it is secreted **during birth** process, triggered by stretching of the cervix of uterus at the beginning of the birth process, oxytocin binds to target cells of the uterus, increasing the contraction which is already taking place. It is

also used artificially to induce labor. In **lactating women**, suckling causes the release of oxytocin, which targets muscle cells around the duct of mammary glands, thus promote milk ejection. **In male,** it helps to eject semen during copulation.

Median Lobe of Pituitary

It is smallest in human, made of thin layer of cells between anterior and posterior pituitary gland. It secretes **Melanocytes Stimulating Hormone (MSH).** The MSH releases due to influence of external light and more secretion during pregnancy. It stimulates melanocytes in skin and hair to produce brown pigment, the **melanin** that darkens the skin.

18.2.2 Hypothalamus

Hypothalamus is a part of fore brain, which is both nervous and endocrine. Thus it receives many sensory stimuli of the nervous system and are converted into hormonal responses. It is master control centre of endocrine system because it monitors metabolites and hormonal level in the blood. It directly controls the pituitary gland. Hypothalamus has nerve cell clusters that produce and secrete many types of hormones. One of these centres produces and secretes a variety of releasing (Tropic) and inhibiting hormone or factor. Thus act as regulatory hormones, which regulate the synthesis and secretion of other endocrine glands.

Extra Information

1. The suckling of the infants triggers the production of great amount of oxytocin, that aids in nursing process and contracts the uterus to its normal size.
2. Over secretion of oxytocin during child birth may cause rupture of uterine wall.
3. Under secretion of oxytocin inhibits normal labor process.

It has another nerve cluster which synthesizes antidiuretic hormone and oxytocin hormone, then transported and stored in posterior pituitary gland. (Table.18.1)

Table 18.1: The Function of Hypothalamus and Response with Pituitary Gland

S.No.	Hormone From Hypothalamus	Anterior Pituitary Response
i)	Growth hormone releasing factors (GHRF).	Secretion of growth hormone (GH).
ii)	Somatostatin.	Inhibits growth hormone (GH).
iii)	Gonadotrophin releasing hormone (GnRH).	Secretion of FSH, LH and ICSH.
iv)	Adrenocorticotropic releasing factor (CRF or ACRF).	Secretion of adrenocorticotropic hormone (ACTH).
v)	Prolactin inhibiting factor (PIF).	Stop secretion of prolactin.
vi)	Thyrotropin releasing factor (TRF).	Secretion of thyroid stimulating hormone (TSH).
vii)	Secretes oxytocin and ADH.	Store these hormones in posterior pituitary lobe.

18.2.3 Thyroid Gland

Thyroid gland is located at the base of neck, attached to trachea below the larynx. It is bilobed structure, butterfly-shaped and both lobes are connected by a bridge of thyroid tissue known as **isthmus**. Thyroid gland is made of spherical cells filled with three types of hormones. (Fig.18.5)

1. Tri-iodothyronine or T3 (about 10% but four time more potent than T4). It is more active in mammals.
2. Tetra-iodothyronine or T4 (about 90% thus major hormone also called thyroxin).
3. Calcitonin hormone.

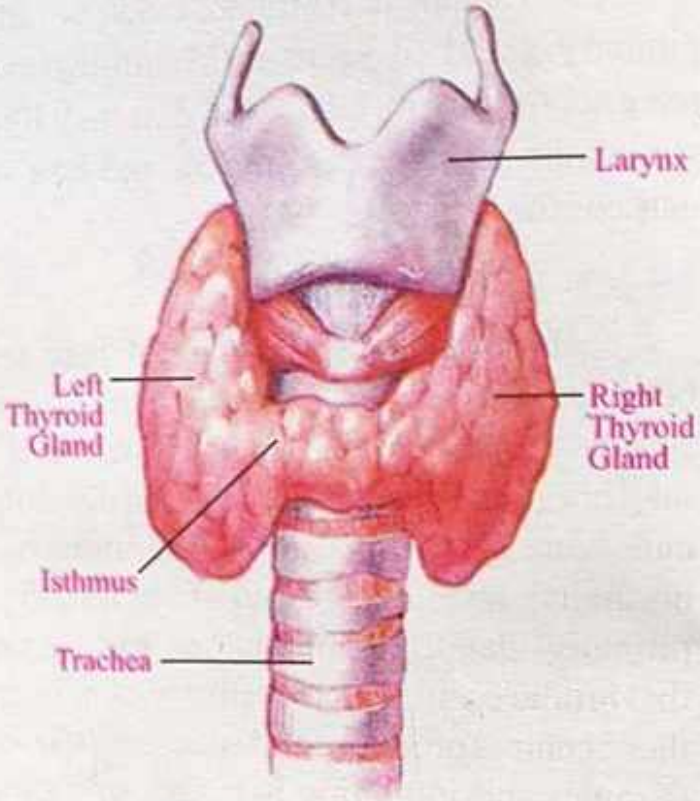


Fig. 18.5: Thyroid Gland

Both T3 and T4 have similar structure and function, but T3 has three iodine while T4 has four iodine. The duration of action duration of T4 is four times more than T3. Their secretion is controlled by TSH from anterior pituitary gland. The T3 and T4 act on **Basal Metabolic Rate (BMR)** by stimulating the breakdown of glucose, release of heat, generation of ATP and synthesis of cholesterol in the liver.

Thyroxin, in conjunction with Growth Hormone (GH) acts on physical growth and mental development. Thus causing them to differentiate between foetus and infant. It also promotes normal motility of the gastrointestinal tract.

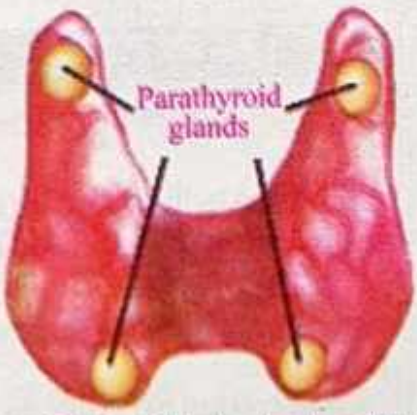


Fig. 18.6: Thyroid Gland (Back view) and Parathyroid Gland

Extra Information

Thyroxin helps in metamorphosis of tadpole to adult frog. If its concentration is less, then tadpole does not metamorphose to adult frog instead remains a large size tadpole.

Effect of Over secretion of T3 and T4 (Hyperthyroidism)

The excess secretion of thyroxin causes a condition known as **grave's disease.**

This disease causes **exophthalmic goitre** (bulging of the eye ball), which is a classical symptom of hyperthyroidism. If the patient's basal metabolic rate (BMR) increases, this can lead to cardiac failure, profuse perspiration and weight loss. It is an autoimmune disease, the blood serum of patient has abnormal antibodies to mimic TSH and continuously stimulates thyroxin release.

Effect of Under Secretion (Hypothyroidism)

The less secretion of T3 and T4 (thyroxin) causes **Cretinism, Goitre** and **Myxoedema**. Hypothyroidism may be due to absence of iodine or failure of enzyme system, which is involved in the production of thyroid hormone or due to lack of TSH.

Cretinism: In infant, less secretion of thyroxin causes dwarf condition known as **cretinism**. It is characterized by stunted growth, mental retardation, coarse facial features, coarse scanty hair, retarded sexual development.

Myxoedema: (Mean mucous swelling) In adult, low secretion of thyroxin causes myxoedema. The patient has lower metabolic rate, thickness of skin of hands, brittleness of hair and nail, intolerance to cold, mental lethargy, weight gain, low pulse rate and low body temperature (Myxoedema also called **endemic** or **colloidal goitre**).

Goitre: The deficiency of iodine causes enlargement of thyroid gland known as goitre. It is more common in mountainous areas where iodine is less in the soil or water. (Thus table salt with iodine is recommended). Thyroid gland works hard to produce sufficient amount of thyroxin. Goitre may lead to lying down of excess of fat and weight increases.

Calcitonin hormone

Thyroid gland also secretes calcitonin hormone, which plays an important role in controlling extra level of calcium ions. If calcium level rises in the blood, then it promotes the deposition of calcium in bone or prevent their reabsorption from nephrons of kidneys. It also inhibits calcium absorption by the intestine.

The **over** and **under secretion of calcitonin** leads to disturbance of calcium metabolism. Thus affects skeletal muscle (become weakened), nervous system (impulses become irregular) and blood calcium composition is disturbed, this leads to massive kidney stone.

18.2.4 Parathyroid Glands

Parathyroid glands are very small glands, which are embedded to the posterior surface of thyroid gland. They are four in number and oval in shape. Parathyroid secretes a hormone known as **parathormone**, which regulates level of calcium and phosphorous in the blood and influence gene activation. Lower calcium level of blood stimulates the parathyroid directly to increase parathormone secretion. It absorbs calcium from intestine and kidney while high level suppresses its production. (Fig.18.6)

Deficiency of Parathormone decreases blood calcium level which result excitability in nerves, muscles and convulsion. The nerves become very sensitive to stimuli, spasm and even death may occur, in case of severe deficiency.

Over Secretion of parathormone causes increase of calcium level in the blood, low phosphate concentration. It causes weakness of skeleton similar to rickets. Nerve and muscle do not response well to stimuli (movement of Ca^{++} to extracellular fluids). It increases reabsorption of Ca^{++} by the kidneys, causes massive kidney stone formation. These both conditions may be fatal. The removal of these glands causes death.

18.2.5 Pancreas: (Islets of Langerhans's)

Pancreas has both exocrine and endocrine tissues. **Exocrine tissues** secrete pancreatic juices containing digestive enzymes. The **pancreatic acinar cells** are their functional units. The endocrine clusters of cell known as **islets of Langerhans's** secrete two main types of hormones by two major types of cell i.e., **beta cells about (60%) secretes insulin** and **alpha cells about (25%) secrete glucagon hormones**, both hormones are protein in nature. The secretion of hormones is controlled by pituitary hormones STH and ACTH and responds directly to blood glucose level. (Fig.18.7)

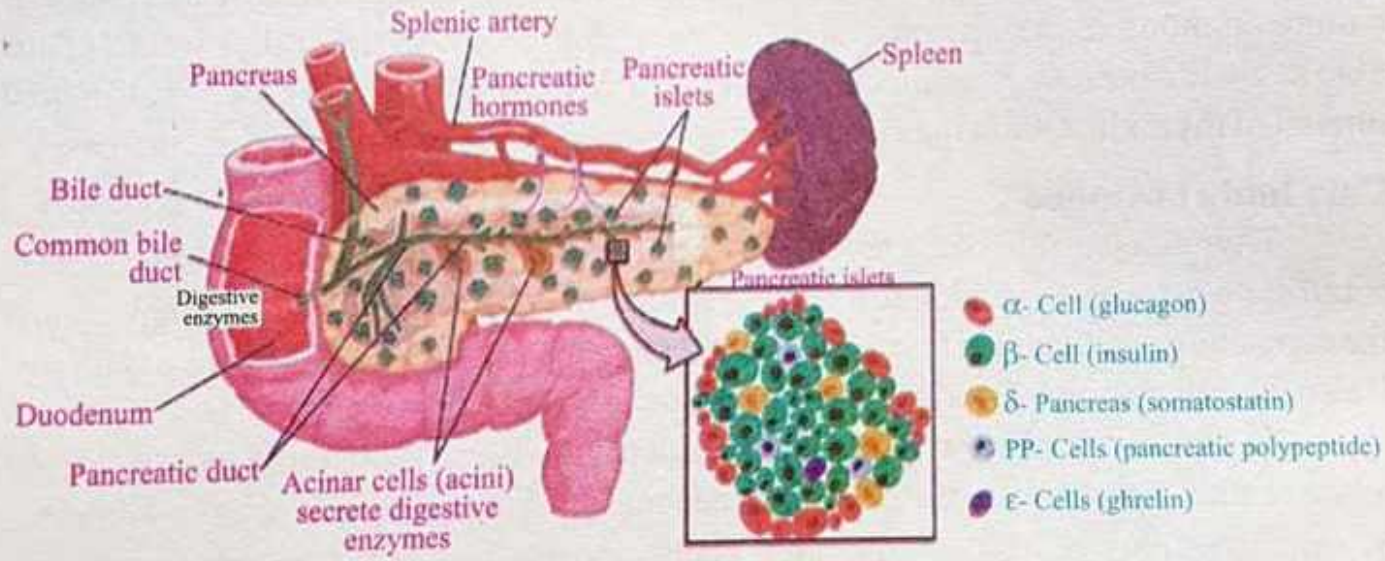


Fig. 18.7: Pancreas (Islet's Langerhans)

Insulin

The beta cells of pancreas secrete a hormone called insulin made of 51 amino acids. It is secreted when blood sugar level rises, such as after meal.

Functions of Insulin

1. It facilitates glucose transport across plasma membrane.
2. It stimulates uptake of glucose by liver, muscles and adipose tissue (fat storing cells).
3. Promotes synthesis of proteins and fats by transferring glucose.

4. Inhibits gluconeogenesis (conversion of amino acids and fats into glucose). Thus lowers blood glucose level.
5. It increases **glycogenesis** (in this process insulin converts glucose into glycogen).

Glucagon

1. **Alpha pancreatic cells** secrete glucagon, made of 29 amino acids.
2. When blood glucose level decreases, glucagon converts glycogen, amino acids and fatty acids into glucose.
3. It is antagonistic to insulin.
4. Sympathetic nervous system stimulates its production.
5. It increases **Glucogenesis,** which is the process of conversion of glycogen into glucose, and, **Gluconeogenesis,** the breakdown of protein, fats and lactic acids into glucose.

Disorders due to insulin deficiency

The deficiency of insulin may lead to a common metabolic disease, called **diabetes mellitus**. It causes hyperglycaemia.

Symptoms of Hyperglycaemia

1. Sugar is excreted in urine.
2. Frequent urine.
3. Abnormal thrust.
4. Rapid weight loss and weakness.
5. Drowsiness and fatigue.
6. Dehydration

Disorders due to excess of Insulin

It causes **hypoglycaemia**.

The glucose utilization increases, in turn blood fat level gets high, which upset nerve/ muscles actions.

Other types of endocrine cells in pancreas

There are three other types of endocrine cells in pancreas (about 15%) which secrete three types of hormones.

i) **Somatostatin:** It inhibits the release of gastrointestinal hormones.

ii) **Pancreatic polypeptide,** self-regulates the pancreatic secretion activities and affects the hepatic glycogen level.

iii) **Glycine act as neurotransmitter**, its deficiency may lead to type-II diabetes, increases insulin receptor in people without diabetes. It is used as supplement by type-II diabetes patients.

18.2.6 Adrenal Gland: (ad; beside, renal; kidney)

These are located on the top of each kidney, thus two in number and each with two distinct regions. **Adrenal cortex** is outer reddish brown portion. **Adrenal medulla** is inner greyish portion. Both are under the control of hypothalamus, which secretes ACTH releasing factor that stimulates anterior pituitary, which in turn stimulates the adrenal cortex. (Fig.18.8)

Hormones of Adrenal Medulla

Adrenal medulla consists of modified ganglionic sympathetic neurons, which secrete two important hormones known as **adrenaline (epinephrine)** and **nor-adrenaline (nor-epinephrine)**. Both prepare the body for stress and emergency situation *i.e.* sympathetic system. These stimulate liver cells to release glucose thus making fuel for cellular energy.

Epinephrine dilates blood vessels in the brain, heart, skeletal muscles, thus increasing alertness to overcome stress and heartbeat, breathing rate and metabolic rate increases.

Nor-epinephrine constricts blood vessels elsewhere i.e., in digestive system and peripheral vasoconstriction. It also sustains blood pressure.

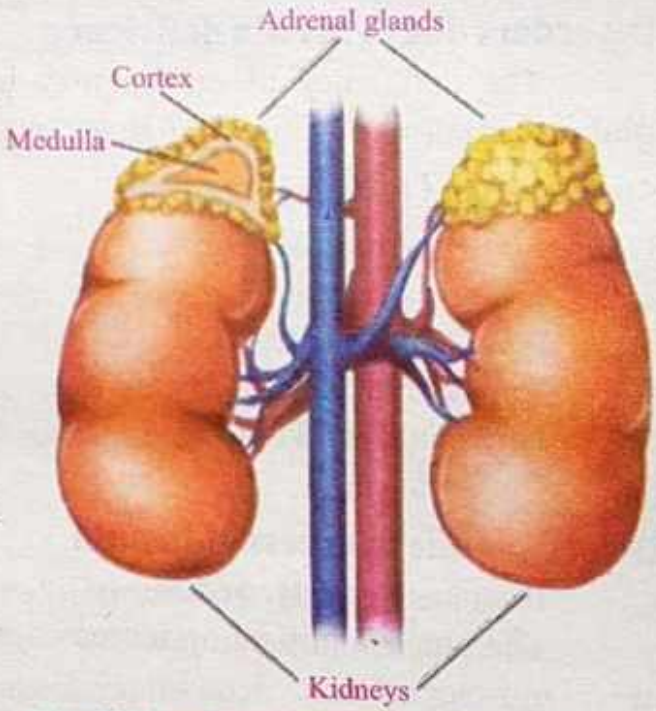


Fig. 18.8: Adrenal Glands on top of Kidneys

Disorders of Medullary Hormones

The over secretion of medullary hormones may cause hypertension and aggressive behavior during routine life while under secretion causes failure to combat with stress situation.

Hormones of Adrenal Cortex

Adrenal cortex remains active all the time, especially after shock or stress situations and infections. It secretes two major hormones.

1. **Glucocorticoids:** It regulates blood glucose level, e.g., cortisone.
2. **Mineralocorticoids:** It regulates the level of minerals in the blood, e.g., aldosterone (Collectively called corticosteroids).

Cortisone

i) The cortisone is involved in glucose metabolism and is produced during anxiety, fever, and disease.

ii) It promotes the hydrolysis of muscle protein to amino acids, then amino acids to glucose.

iii) It also helps to neutralize the inflammatory responses that leads to the pain and swelling joints in arthritis, etc. It favors metabolism of fatty acids rather than glucose, antagonistic to insulin.

Corticosterone is an example of both glucocorticoid and mineralocorticoid; it increases blood glucose level and regulates mineral ion balance.

Aldosterone promotes renal absorption of sodium and renal excretion of potassium, maintains blood volume and blood pressure.

Adrenal cortex mainly produces aldosterone. The adrenal cortex also produces small amount of male sex hormones called **androgen**, both in male and female. Sometimes tumor in adrenal cortex of female causes excess of androgens production and thus the development of certain male characteristics appear.

Disorders of Cortical Hormones

Two important diseases are caused by abnormal cortical hormones.

1. Addison's disease

This disease occurs by **lower secretion of corticosteroids**, which leads to general metabolic disturbances, low blood sugar level, lethargy and weakness in muscle action, loss of salts and the skin has bronze tone, and cannot overcome stress condition such as cold, heat and stress.

Interesting Information

Epinephrine is sometime given through injection as an emergency treat-ment in cardiac arrest (stopping of heart beat), aphylatic shock (sun stroke) and acute asthma.

2. Cushing's disease

This disease occurs due to **over production of cortisol;** characterized by obesity (fat deposition on the back of neck), muscle wasting, hypertension, diabetes and due to excess protein break down muscle and bones become weak.

18.2.7 Gonads (Sex Organs)

The gonads (ovary and testes) besides gametogenesis, also secrete some important hormones.

Hormones of Ovary

The human female contains two ovaries in the abdominal cavities which secrete two important female sex hormones, estrogen and progesterone.

1. Estrogen

There are three types of estrogen which are almost similar in function (oestrone, oestriole and oestradiole). Estrogen is secreted from ripening follicle (in some species from interstitial cell of ovaries) and placenta under the influence of FSH from anterior

pituitary. These are steroid in nature.

Functions: The estrogen performs following functions.

1. At puberty brings about secondary sexual characters (such as rounded appearance in female due to more fat deposition, large pelvic cavity and wide hips, enlargement of accessory sex organs such as vagina, uterus, oviduct, ovary and external reproductive organs) and high pitch of voice.
2. Conception and maintenance of pregnancy.
3. Help in formation and maturation of egg.
4. At the point during estrous (animals) and menstrual cycle (human) exert a positive feedback which results in a sharp rise in LH output by the pituitary.
5. Healing of uterine wall after menstruation.
6. Prepare uterine wall to secrete proteinaceous substance for embryo.

Disorders due to deficiency of estrogen

In young female, it causes failure to mature sexually. In **adult** causes sterility while **in old women** after menopause, it's deficiency causes osteoporosis.

Interesting Information

Estrogen causes softness and smoothness of skin, therefore, female posse-sses softer skin than male. Estrogen is used in making face cream, soaps and shampoos *etc.*

Disorder due to over secretion

The over secretion may lead to development of fibroids (abnormal growth) in uterus and **polycystic ovary syndrome**.

2. Progesterone

This hormone is produced by the ruptured follicle in response of LH from anterior pituitary. The ruptured follicle becomes corpus luteum. Placenta also secretes progesterone during pregnancy.

Extra Information

Polycystic ovary syndrome is disorder of ovaries, numerous small collection of fluid known as follicles, which may disturb regular release of eggs, thus prolonged, frequent irregular menstrual period and level of male sex hormones increases.

Functions

1. Prepares uterus for implantation of fertilized ovum.
2. Promotes the development of mammary glands during pregnancy.
3. Inhibits further secretion of **FSH** (to prevent any more follicles from ripening).
4. Further thickening and vascularization of the uterus wall.
5. Used in birth control pills (to prevent ovulation).
6. Regulates secretion of gonadotropin from anterior pituitary.

Disorder due to under secretion of progesterone

The less secretion of this hormone during menstrual cycle decreases the chances

of pregnancy and may cause early menstruation. It may lead to the still birth or miscarriage.

Testes: (Male Sex Organs)

The testis in the presence of **FSH** and **ISCH** produce male sex hormones known as androgens, from their interstial cells of Leydig. There are many types of androgen, the most important of which are testosterone and 17 beta-hydroxysteroid dehydrogenase. The functions of these hormones are:

1. In fetus, androgen initiates the development of the sex organs.
2. At puberty brings about secondary sexual characters (beard, moustaches, axillary and pubic hair, voice become low pitch and spermatogenesis) and sex derives.
3. They increase secretion of sebaceous glands, sweat glands and increase sub cutaneous fatty tissue.
4. Increase metabolic activities in general.
5. Inhibit formation of female genital organs in fetus.
6. Increase **Red Blood Cells (RBCs)** production and thickness of bones.

Deficiency of androgens

It causes castration (*i.e.* secondary sexual characters do not appear in male and body looks like an immature female), thus causes male sterility.

18.2.8 Thymus Gland

This lobular endocrine gland is situated at upper part of chest behind sternum. It consists of two lobes that join in front of trachea. It is largest and more active in childhood. It is responsible for the development and differentiation of T-lymphocytes before they leave the thymus. The hormone of this gland is called **thymosin** or **thymin**.

18.2.9 Pineal Gland

It is tiny cone shaped body, located deep between the cerebral hemisphere of brain. It produces the hormone, melatonin.

Function

It is involved in a daily cycle called **circadian rhythm** (Regulated by the eyes of mammals). In many mammals, it regulates the seasonal reproductive cycle, sleep and wake cycle in human. It responds to external conditions of light and darkness as sensed through the eyes.

Role of artificially synthesized steroids in sports and their long-term effects on their users.

Steroids are artificial substances which are developed in order to do the job of testosterone. It can be classified as either anabolic or androgenic. Anabolic functions include those that promote formation of muscles, vertical growth and regulation of weight gain or loss. Androgenic refers to masculine attributes such as agility, strength and endurance. By the help of

these drugs, sportsmen can become bigger, stronger, more agile, and hence more competitive. Artificial steroids uses carry many severe health risks. Major medical problems associated with steroids include a weakened immune system, liver disease, kidney disease, high blood pressure, high cholesterol, increased risk for heart disease, blood clots, strokes, tissue damage and cancer.

18.2.10 Other Endocrine Tissues/cells

Many other hormones are also produced by organs or tissues whose function is not primarily an endocrine one, even neurons also secrete hormones.

Hormones of Gut (Gastro-intestinal Tract)

i) **Gastrin:** The hormone **Gastrin**, produced by the stomach wall, travels in the bloodstream but exerts its effect locally, stimulating the production of gastric juice (pepsinogen and hydrochloric acid). The secretion of gastrin depends on proteinaceous food in stomach when it is partially digested.

ii) **Secretin and Cholecytokinin (CCK):** These two hormones control pancreatic and liver secretion. Both are formed in the cells of duodenal wall, in response to acidic chyme, fatty and proteinaceous food.

Placental hormones

Placenta secretes hormones like progesterone, which maintains pregnancy. It also secretes estrogen, chorionic hormones, relaxin and chorionic gonadotrophin hormones. All of these facilitate in pregnancy and birth.

Hormones secreted from Kidneys

Kidneys produce some hormones such as **erythropoietin** which increases **red blood cell production.** The stimuli such as bleeding or moving to high altitudes (where oxygen is scarcer) trigger release of this hormone.

Kidney also secretes **hormone renin** which constricts arteries and monitors blood pressure, takes corrective action if it drops. It is also called **urotensin** and angiotensin.

Calcitriol: It is also secreted from kidneys and acts on the cells of the intestine to promote the absorption of calcium from the diet.

Hormones of Liver: Liver secretes a group of hormone-like compounds called **prostaglandins**. These provide protective response during infection.

Somatomedins hormone is also secreted from liver that stimulate cell growth and development.

Hormones of Brain: Enkephalins and **endorphins** are two related hormones, produced in the brain. Both bind to pain receptors and so block sensation. The enkelphalins found in thalamus and some parts of spinal cord while endorphins found in pituitary gland, in other parts of brain or distributed throughout nervous system.

Hormone of Heart: The heart secretes **atrial natriuretic hormone**, which increases sodium excretion and lowering blood pressure.

Adipose Tissues: Secretes a hormone **leptin**, which reduces appetite.

18.3 Feedback Mechanism (FBM)

It is a type of interaction in which controlling mechanism is itself controlled by the products of reactions, it is controlling. Different hormones act as a system of check and balance for each other in order to keep homeostasis. In this case two opposing systems are required *i.e.* if there is an excitatory system, there must be an inhibitory system.

18.3.1 Negative Feedback Mechanism

The type of FBM in which increase in production decreases the operation so as to stop the production of products. It stabilizes a system.

Example: If our blood glucose level becomes too high then beta cells in the islets of Langerhans respond to secrete more insulin. The insulin lowers blood glucose by converting glucose into glycogen and making body cell membranes more permeable to glucose. Thus glucose is utilized by cell and surplus glucose is stored in the form of glycogen. (Fig.18.9)

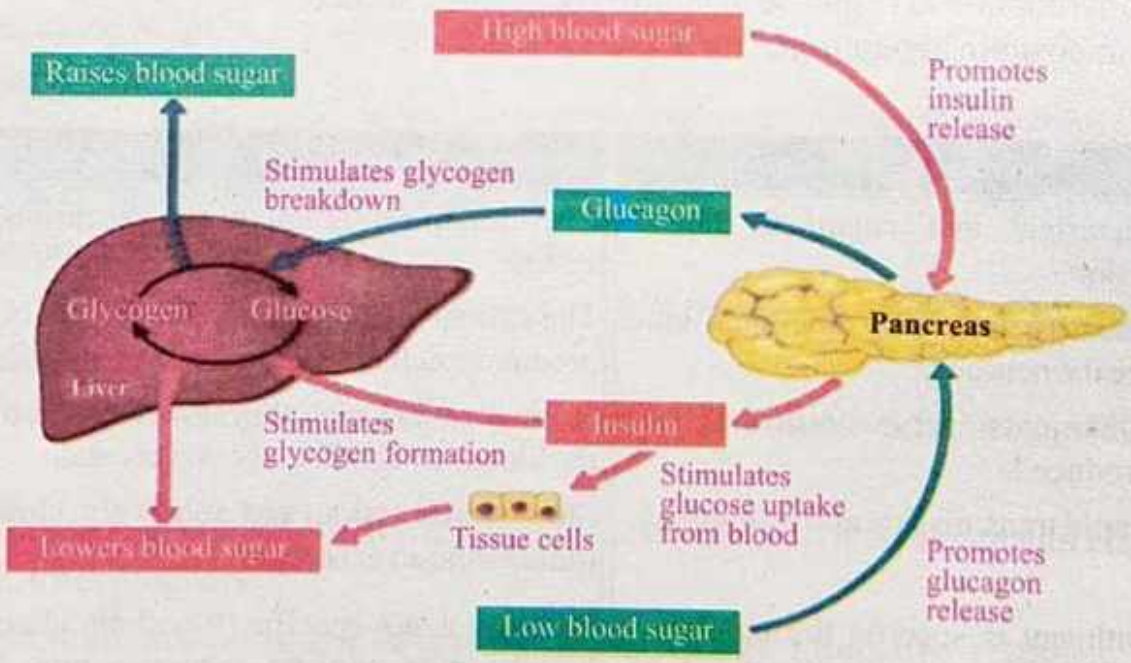


Fig. 18.9: Negative Feedback Mechanism

If the level of blood glucose gets too low, alpha cells in the islets of Langerhans secrete glucagon. It converts glycogen into glucose to raise and maintain blood glucose level. Thus the level of blood glucose is maintained by negative feedback mech-anism.

Negative feedback is most common and self-limiting.

18.3.2 Positive Feedback Mechanism

The type of FBM in which increase in production of a substance increases the operation to produce more products. It speeds up the system rather to stop it, *e.g.* Oxytocin production during labor and suckling by baby. It is rare, explosive and self-reinforcing. (Fig.18.10)

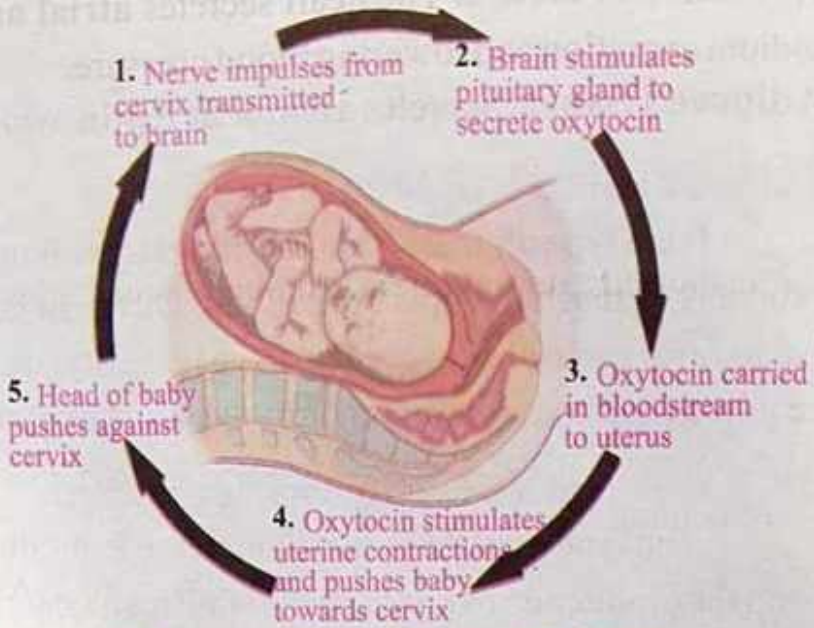


Fig. 18.10: Positive Feedback Mechanism

18.3.3 Similarities between Nervous coordination and chemical co-ordination

i) Both of these synthesize chemical messengers.
ii) Release the chemical messengers in extra cellular spaces of the body.
iii) Help in coordination of the body.
iv) Both function in response to internal or external stimuli.
v) Homeostatic in function.

Table 18.2: Differences between Nervous and Chemical Coordination

S.No.	Nervous Coordination	Chemical Coordination
i)	Electrical and chemical transmission.	Chemical transmission (hormone) through blood system.
ii)	The structural and functional units are the neurons.	The structural and functional units are hormones producing cells and neuron secretary cells.
iii)	Chemicals act where they are produced.	Hormones and neurohormones are poured into the blood which affect the target cells.
iv)	Rapid transmission and response.	Slow transmission and relatively slow acting (adrenaline an exception).
v)	Pathway is specific through nerve cells response is very localized *e.g.* one muscle.	Pathway is not specific (blood circulates whole body) target specific response may be very widespread *e.g.* growth.
vi)	Often short term changes.	Often long term changes.
vii)	The neurohormones are broken down shortly after their release.	Hormones remain active for much longer duration within the blood.

SUMMARY

- Endocrine glands are also known as ductless glands, which make specific chemical compounds known as hormones.
- Hormones are small soluble organic molecules; act as chemical messengers, transported to target cells via blood vascular system.
- Cyclic AMP (cAMP) is second messenger, which carry message of proteinaceous hormone to DNA in the nucleus.
- Hypothalamus produces and secretes a number of releasing and inhibiting hormones or factors.
- Tropic hormones control the secretion of hormone in many of other ductless glands.
- Prolactin hormones (PRL) sometimes inappropriately called Leutotrophic hormone (LTH).
- Antidiuretic Hormone (ADH) is also called vasopressin; its deficiency causes diabetes insipidus.
- Graves' disease is caused by lower secretion of thyroxin.
- Calcitonin is antagonistic to parathormone.
- Parathormone helps in absorption of calcium in the small intestine and reabsorption from kidney tubules.
- Pancreas acts as both endocrine and exocrine glands.
- Cortisone is an example of glucocorticoid.
- Aldosterone is an example of mineral corticoid.
- Follicle Stimulating Hormone (FSH) and Luteinizing Hormones (LH) are gonadotropic hormones.
- Spermatozoa are developed under the influence of Follicle Stimulating Hormone (FSH).
- Progesterone is produced by the ruptured follicle called corpus luteum and also from placenta after pregnancy.
- Prostaglandins are hormone like compound; provide protective response during infection and injuries.
- Positive feedback responses are not homeostatic rather create instability in the body, thus such responses are rare.
- Negative feedback create stability, thus maintains homeostasis.

SECTION-I: OBJECTIVE QUESTIONS

Multiple Choice Questions (MCQs)

A. Choose the correct answer.

1. Excess MSH is secreted in:
   (a) Addison's disease (b) Parkinson's disease
   (c) Grave's disease (d) Alzheimer's disease
2. The smaller number of a cell in pancreas secrete:
   (a) Insulin (b) Gibberellins
   (c) Cytokinins (d) Ethene
3. Between the seminiferous tubules are interstitial cells, which secrete:
   (a) Corticosteroids (b) Testosterone
   (c) Aldosterone (d) Estrogen
4. Hormones are secreted by
   (a) Exocrine glands (b) Endocrine glands
   (c) Only from liver (d) Only from pancreas
5. Insulin hormone is chemically made of
   (a) Steroid (b) Protein
   (c) Carbohydrates (d) Nucleic acid
6. Aldosterone hormone in nature is
   (a) Protein (b) Polypeptide
   (c) Steroid (d) Amino acid
7. Oxytocin and ADH are released by
   (a) Posterior pituitary (b) Hypothalamus
   (c) Anterior pituitary (d) Parathyroid glands
8. Which disease is not related with thyroid
   (a) Exophthalmic goitre (b) Myxoedema
   (c) Diabetes mellitus (d) Cretinism
9. Alpha cells of pancreas secrete a hormone which is known as
   (a) Insulin (b) Glucagon
   (c) Thyroxin (d) Thymosin
10. Reabsorption of sodium and removal of potassium is promoted by
    (a) Aldosterone (b) FSH
    (c) Corticosterone (d) ADH

11. Male sex hormone is

(a) Androgen (b) Progesterone
(c) Estrogen (d) Parathormone

12. Positive feedback causes

(a) Stability (b) Instability
(c) Digestion (d) Respiration

13. Maintenance of level of glucose in the blood is

(a) Negative feedback (b) Sympathetic system
(c) Positive feedback (d) Reflex action

B. Fill in the Blanks.

1. Corticosterone is chemically ..... in nature.
2. Ductless glands are also known as .....
3. Median pituitary lobe secretes the hormone .....
4. Ovulation is induced by .....
5. Graves's disease is an example of .....
6. Lack of insulin causes a disease named .....
7. Reabsorption of water from collecting duct of nephron is promoted by .....
8. Estrogen and progesterone are female ..... hormones.
9. Gastrin is a hormone secreted by .....
10. Labour is an example of ..... feedback mechanism.

SECTION-II: SHORT QUESTIONS

C. Give the short answers of the following questions.

1. Define hormone, write difference between endocrine and exocrine glands.
2. Write role of any three steroid hormones,
3. Illustrate the functions of FSH and LH.
4. Define acromegaly, write its causes.
5. Write short note on oxytocin hormone.
6. Write role of insulin and glucagon.
7. Define feedback mechanism.
8. Write similarities between chemical and nervous coordination.
9. Describe the hormones secreted by kidney.
10. Write a note on thymus.

SECTION-III: EXTENSIVE QUESTIONS

D. Give detailed answers of the following questions.

1. Describe chemical composition of hormones.
2. Define endocrine gland, describe hormones of hypothalamus.
3. Write note on any four hormones of anterior pituitary.
4. Write note on thyroid gland.
5. Write about parathyroid glands.
6. Describe a comprehensive note on pancreas.
7. Describe hormones of adrenal cortex and also disorders of cortical hormones.
8. Write note on female sex hormones.
9. Define testosterone? Describe its function and effects of its deficiency.
10. Define feedback mechanism; explain negative feedback mechanism with an example.

UNIT 19

BEHAVIOR

Major Concept

19.1 The Nature of Behaviour
19.2 Innate Behaviour
19.3 Learning
19.4 Social Behaviour

Learning Outcomes

Students will be able to:

- Define behavior as the series of activities performed by an organism in response to stimuli.
- Explain relationship between stimuli and behavior.
- Describe the relationship between heredity and behavior.
- Explain, through examples, the biological rhythms.
- Define innate (inborn) behavior.
- Describe examples of innate behavior in terms of taxis shown by unicellular organisms and tropism shown by plants.
- Justify reflexes as a type of innate behavior, by giving examples from man and invertebrates.
- Define instincts and justify these as a type of innate behavior.
- Justify the fact that each species displays its own characteristic instinctive behavior through following examples; migration of salmon, dances of bees, construction of hanging nest by birds, construction of intricate web by spider and mating behavior of stickleback fish.
- Define learning and distinguish between learning and innate behavior.
- Define habituation and illustrate it through the example of squirrels' adjustment in a park.
- Explain imprinting by narrating the work of Lorenz.
- Differentiate habituation and imprinting as reversible and irreversible learned behaviors.
- Describe classical conditioning by narrating the work of Pavlov on salivary reflex in dogs.
- Describe instrumental conditioning (trial-and-error learning) by narrating the work of Skinner on rats' learning.
- Describe latent learning, through the example of a rat in a maze with no reward.
- Interpret Kohler's work on chimpanzee's insight learning to justify that reasoning and planning are involved in the insight learning.

- Differentiate between animal aggregations and animal societies.
- Describe social behavior in terms of hostile and helpful interactions between animals belonging to the same species.
- Describe agonistic behavior and relate it with the maintenance of social order in terms of territories and dominance hierarchies.
- Explain territorial behavior by quoting example of the territories of monkeys and gorillas.
- Explain dominance hierarchy by quoting example of the pecking order of chicken.
- Define altruism and illustrate it through the organization of a honeybee society.

Introduction

Animals and humans continually exhibit a range of behaviours. **Behaviors** include the patterns of environment, sounds and body position exhibited by animals. Behaviour is the scientific study of everything that animals do. The study of behaviour of animals in their natural environment is called **ethology,** while the scientists who study the behaviour of animals in their natural environment are designated **ethologists**. In this unit we will study the nature of behaviour, innate behaviour, learning behaviour and social behaviour.

Interesting Information

Physiological factors are things related to your physical body that affect your thinking, include changes to brain structure due to injuries, extended period of inactivity or physical stress.

19.1 The Nature of Behaviour

Behavior refers to coordinate the responses that an animal makes to stimuli. A **stimulus** is a form of energy that activates a specific type of sensory receptor, either a sensory neuron or a specialized cell adjacent to it. Some behaviour is **simple, automatic response** to environmental stimuli. For example, you "behave" when you slam on the brakes to avoid a car accident. Other types of behaviour, such as the eating behaviour of many animals are quite complex. **Complex behavior** is limited to multicellular animals with a neural network that can sense stimuli, process them in central nervous system (Brain), and send out appropriate motor impulses. We exhibit complex behaviour when we walk and talk, drive a vehicle, interact with our family members and do our jobs. Ethologists observe and interpret the behaviour of animals from a **physiological** rather than a **psychological perspective**.

Interesting Information

Psychological theories assume that human beings exist and process informa-tion independently. The reliance of psychological perspective research on S-R (stimulus response) learning models focuses attention on cognitive pro-cessses, attitu-des, beliefs and so on.

19.1.1 Relationship between Stimuli and Behavior

All living organisms possess **sensors** or **senses** which detect forms of energy from their surrounding then transmit the energy into a signal. The signals may either result in a response (either positive or negative) or being ignored (*i.e.* not important). If response, then may be processes in the brain or it becomes reflex. The example of **process response** is salvations in the oral cavity of dog, when it smells or sees food. The signal of food reaches the brain which interprets the smell as a palatable food to eat. Thus responds by salivating, which is its behaviour to the stimulus.

The example of **reflex response** is withdrawal of hand when touching a hot object. This signal does not have to reach the brain for the interpretation rather unconscious response come from spinal cord.

19.1.2 Relationship between Heredity and Behavior

All behaviours depend on nerve impulses, hormones and other physiological mechanisms such as sensory receptors. Therefore, genes play a role in the development of behaviour because they direct the development of the nervous system. In addition, automatic responses depend on specific pathways within the central nervous system of an organism. These pathways are neural programs and genetically determined. **Neural programs** are part of nervous system at the time of birth or developed at an appropriate point in maturation, resulting in behaviour that are called **innate** or **instinctive** or **inborn behavior**. The capacity to learn is inherited. The moodiness, shyness, intelligence and many other psychological characteristics have very important hereditary roles, these are also affected by environment.

19.1.3 Biological Rhythms and their examples

The behavioral activities of living organisms which take place at regular intervals are called biological rhythms. Biological rhythms may be internal or external.

Internal Rhythm is also called endogenous, which is controlled by internal biological clock, *e.g.* body temperature regulation, menstrual cycle etc.

External Rhythm is also called **exogenous** which is controlled by synchronizing internal cycle with external environment e.g. sleep, wakefulness and day/ night cycle.

Biological Rhythms may be:

Circadian Rhythm

It is endogenously generated rhythm with a 24 hours cycle. It includes physiological and behavioural changes such as body temperature, sleep, wakefulness.

Diurnal Rhythm

It is a circadian rhythm which is synchronized

Interesting Information

The circadian rhythm is controlled by the **Supra Chiasmatic Nuclei (SCN)**. It is special area in the hypothalamus of the brain.

with the day/ night cycle. It is termed as diurnal, nocturnal and crepuscular animals.

Interesting Information

Crepuscular animal appearing or active in twilight (i.e., dawn and dusk) while nocturnal in (dim light) night and diurnal in day light.

Ultradian Rhythm

It is much shorter than that of a circadian rhythm (*e.g.* feed cycle).

Infradian Rhythm

It is a biological rhythm, which is more than 24 hours. And can be:

Monthly or Annually Rhythm

Monthly: It includes menstrual cycle in human female.

Annual Rhythm: Annual rhythm is less than or about 365 days *e.g.* hibernation, reproduction in most animals and migration of birds.

Biological Clock

The biological clock is an internal mechanism by which rhythmic phenomenon occurs and is maintained even without intervention of environmental stimuli. It is still not clear how biological clock controls such rhythm.

19.2 Innate Behavior (Inborn or Instinct Behavior)

The **innate behaviors** are preprogramed within nervous system before birth and are demonstrated in a somewhat complete form, the first time they are exhibited. For example a new born baby, will turn to suckle when touched on the cheek near the mouth. The baby performs this without learning or altering its behaviour based on experience. Innate behaviours are important to the survival of an animal because they help animals stay alive in certain situations and provide adaptive advantages that contribute to its fitness or ability to achieve reproductive success. It is especially beneficial for those animals which have short life span and weakly developed nervous system. All plants exhibit innate behaviour. The pathway of innate behavior is simple and automatic i.e., highly developed nervous system is not involved.

19.2.1 Types of Innate Behavior

Innate behavior is genetically transmitted from parent to their offsprings. There are two primary types of innate behaviours, *i.e.* orientation and non-orientation.

The **orientation behaviors** are coordinated movement that occurs in response to an external stimulus and of two main types *i.e.* taxis and tropism. In animals it is called taxis whereas similar behaviour in plants is called tropism.

Taxes

Taxes (singular taxis) is a directional movement, whole animal either moves

toward stimulus or away from stimulus, *i.e.* positive taxis or negative taxis respectively, *e.g.* heat, chemicals (foods) and light. A good example is unicellular protozoan, ***Euglena;*** who shows positive movement towards dim light and negative movement to intense light. Thus *Euglena* during day time moves under the water where intensity of light is less.

Tropism: (mean to turn)

It is directional growth movement in plants *i.e.* towards or away from stimuli. **phototropism**, towards or away from stimulus of light, *e.g.* shoot will grow towards light while roots grows away from light. Root shows positive geotropism or gravitropism (towards soil and gravity) or shoot is negative geotropic and gravitropic. The roots also exhibit positive hydrotropism (towards water). (Fig.19.1)

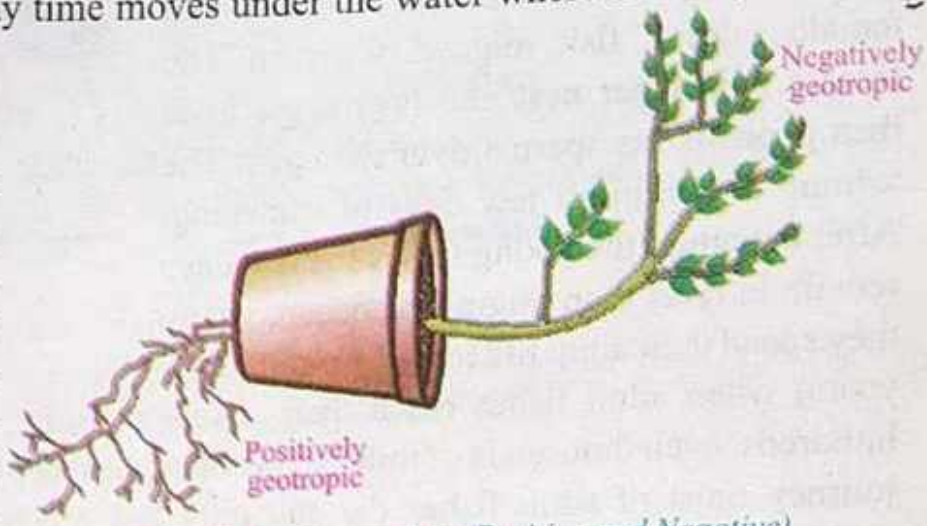


Fig. 19.1: Geotropism (Positive and Negative)

The **non-orientation behaviour** includes reflex and instincts, both do not exhibit particular movement in response to stimuli.

19.2.2 Reflexes or Reflex Action: (L. reflector, to bend back)

It is involuntary, automatic response to changes occurring inside or outside the body. The responses of reflexes may come from unconscious portion of brain such as blinking of our eyes, but most responses come from spinal cord, such as withdrawal of hands when we touch a hot surface.

If a particle of food or a piece of hair enters in your tracheal lining, it will initiate a coughing reflex which cannot be suppressed.

Most insects have simple "startle" reflexes triggered by small disturbances as well as more comprehensive "escape" reflexes triggered by large disturbances.

19.2.3 Instincts: (Fixed action patterns)

This type of innate behaviour is unlearned, inherited fixed action patterns of responses or reactions to certain kinds of stimuli. It is performed without being based upon prior experience *i.e.* in the absence of learning.

In this genetically programmed inflexible behaviour complete body of animal is involved.

Each species displays its own characteristics instinctive behaviour. Some examples of instinctive behaviours are migration of salmon fish, dances of bees,

construction of hanging nest by birds, construction of intricate web by spider and mating behaviour of stickle back fish.

i) Migration of Salmon

For spawning the upriver male and female salmon fish migrate to river. The female builds her nest and lays eggs, male then deposits his sperms over the eggs. The salmon die within a few days of spawning. After hatching, the young fishes for few days remain in river than migrate to ocean, where they spend their adult life (about 6 months to 7 years) when adult fishes reach their sexual maturity, the pacific salmon may swim hundreds, even thousands of miles to get back the river, where they hatched. During this journey most of adult fishes die and only few reach to their breeding ground. The migration for spawning by salmon fish is an example of instinct behaviour. (Fig.19.2)

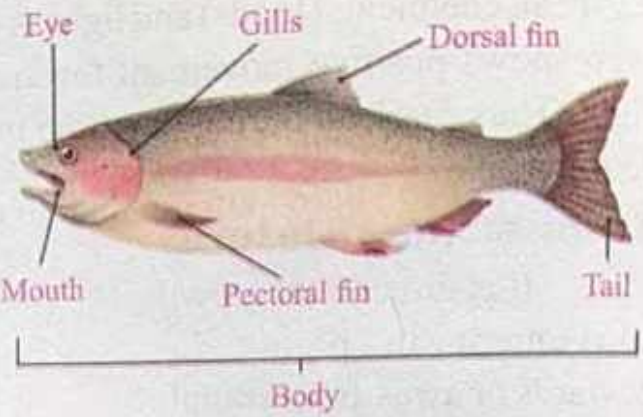


Fig. 19.2: Salmon Fish

ii) Construction and hanging nest by some birds

A bird named **Baya weaver** (Genus *Ploceus*, about 100 species) construct nest during breeding season. They nest in colonies of up to 20-30, close to the source of food, water and nesting material. These nests are made by male who are hanging either between two twigs or leaf. Female selects a nest, then male and female are paired. The descendants of these birds exhibit this behaviour in each generation without learning. Thus it is also an example of instinct behaviour. (Fig.19.3)


Fig. 19.3: Baya Weaver (Bird)

iii) Dances of Bees

The dances of bees is also an example of instinct. When worker bees return to their hives, they do a dance; which is called the **waggle dance.** They can do the waggle dance without learning, thus it is an example of instinct behaviour. They dance to inform and tell other bees of hives, where

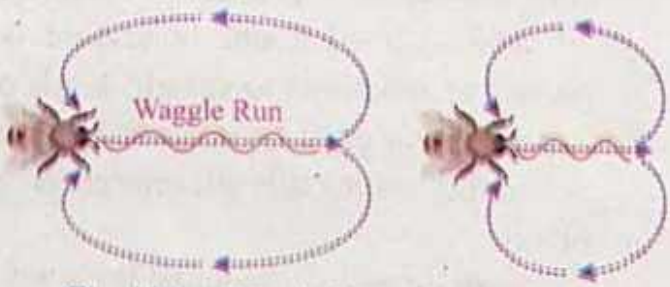


Fig. 19.4: Waggle Dance of Honey Bee

the food is present. (Fig.19.4)

iv) Construction of intricate web by spider

Many species of spiders have instinct to construct intricate web. The web spinning is stereotyped, hard coded instinctive behaviour. Any member of a given species of spider will spin the same web given the same environment, without ever having learned the shape of the web. (Fig.19.5)



Fig. 19.5: Spider Webbing

v) Mating behaviour of Stickleback Fish

There are about eight species of stickleback fishes, who belongs to five genera. Their reproductive behaviour is highly rationalized. They breed during spring, at which time male becomes suffused with color (red to yellow and orange to black depending on species). (Fig.19.6)

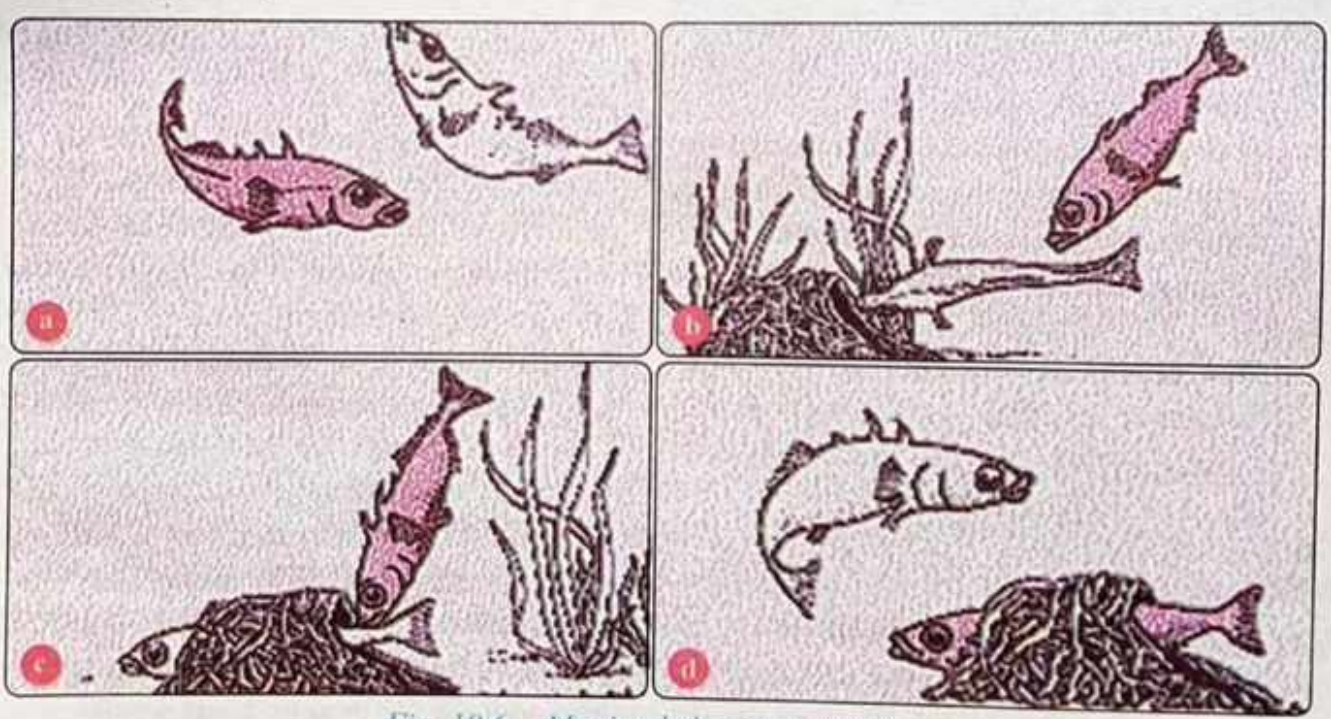


Fig. 19.6: Matting behaviour in Fishes

Male fish after building a nest of plant materials glued together by thread like mucus secretions from his kidneys. After building nest the male coaxes and drives a female into the nest to lay her eggs. He then follows her into the nest to fertilize the eggs. Each female may lay up to 200 eggs, one or more than one female may be chosen by one male. When the nest is full, the male becomes the guard *i.e.* aggressively defends the eggs

from intruders. The male also aerates the eggs, with the help of pectoral fins till hatching, thus parental care is given by the male fish.

19.3 Learning

Learning behaviours; are based on experience, and are not hereditary and inborn. It helps an animal change its behaviour to adapt to changes in environmental conditions. Learning is more prominent in those animals who has comparatively long life span and also have well developed nervous system. It can be grouped into following six categories, i.e., habituation, imprinting, classical conditioning, trial and error learning, latent learning and insight learning. (Table 19.1)

Table 19.1: Differences between Instinctive Behaviour and Learning Behaviour

S.No.	External Respiration	Internal Respiration
i)	It depends on the heredity material which the animal inherits. The animal may be born with the right responses built in the nervous system as part of its inherited structure.	It depends on the environmental influence, but the ability to modify the behaviour depends on the hereditary material.
ii)	Experience has no obvious influence on this type of behaviour.	Experience has an obvious influence on this type of behaviour.
iii)	It depends on the selection mechanism operating during the history of species, so that it helps in the adaptability of the organism in the environment.	It depend on the selection mechanism operating during the history of the individual (during one's life-time) so as to help the organism in its adaptability in the given environment.
iv)	Instinct can equip an animal with a series of responses. This is advantageous for animals with short life spans, and with little or no parental care.	Learning can equip an animal with a set of adaptive responses to its environment. This is advantageous for those animals who has long life spans and have parental care, so that they can modify the behaviour by previous experiences.
v)	Evolves slowly in the species.	Evolves during the life cycle of the individual but the ability of learning depends on the genetic basis of the individual.
	For Example: Honey bees inherit the ability to form wing muscles and wings for flight. They inherit the tendency to fly towards flowers to seek nectar and pollen.	***For Example:*** Conditioned reflex type I, in case of dogs where dogs learn to salivate on ringing of bell alone.

19.3.1 Habituation

In this type of learning, an animal learns by experience not to respond to a situation if the response has neither positive nor negative consequences. For example pigeons and many other birds living in cities learn not to flee from people who pose no threat to them. (This behaviour adaptive and is reversible). Another example of habituation is feeling threatened by **squirrels**, when one in a group feel threatened the other squirrels hear its signal, runs to protective area. If the signal comes from an individual who has caused many false alarms, the signal will be ignored.

19.3.2 Imprinting

It is a time dependent form of learning. It involves exposure to sign stimuli, most often early in development. For instance, in response to moving object and to certain sound. The baby geese imprint on their mother and follow her during a short, sensitive period after hatching. They are **neurally wired** to learn crucial information, identify the individual that would protect them in the months ahead. Normally individual is the mother or father.



Fig. 19.7: K. Lorenz with Geeze (Imprinting)

Imprinting occurs among many animals. **K. Lorenz** explained imprinting stimulus in geese when incubator hatched the **gosling (geese)** spent their first few hours with Lorenz rather than with their parents, they imprint with him and followed "Lorenz" from then on. The goslings do not recognize their parents or other adult geese of their own parent. (Fig.19.7)

19.3.3 Difference between Habituation and Imprinting

Habituation is reversible and imprinting is irreversible learned behaviour. Habituation is an example of simple learning behaviour in which an animal gradually stops responding or no longer react to repeated stimuli. While in imprinting learning behaviour is a specialized form of learning which occurs during brief period in young animals after hatching or birth. They are able to learn from their parents so animals early experiences have a big effect on the way it behaves as an adult.

19.3.4 Classical conditioning (Conditioned reflex Type-I)

Ivan Pavlov's classical experiments with dogs are an example of classical conditioning. Dog will salivate just before eating. **Pavlov's dogs** were conditioned to

salivate, even in the absence of food. The dogs did so in response to the sound of a bell that was initially associated with the presentation of food. In this case, the animals learned to associate an automatic, unconditioned response with a novel stimulus that does not normally trigger the response. (Fig.19.8)

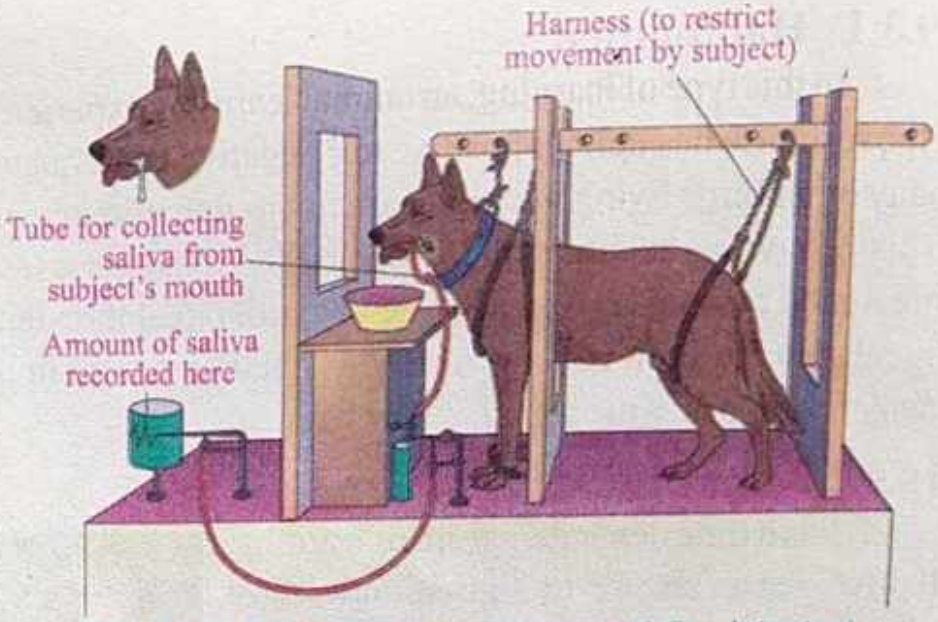


Fig. 19.8: Pavlov Experiment (Classical Conditioning)

19.3.5 Instrumental Learning (Trial and Error or Operant Learning)

In this type of learning behaviour, an animal learns a response to a particular stimulus after many unsuccessful tries.

B. F. Skinner (USA Psychologist) studied operant conditioning in rats by placing them in a specially designed box (also called Skinner box) fitted with levers and experi-mental devices. The rats in the box feverishly, running this way and that, one of them accidently press a lever and a piece of food would appear. At first, rat would ignore the lever and continue to move here and there but soon learned that pressing of lever will give food to him. As the rat learns by chance *i.e.* is trial. Thus type of learning has been named **"Trial and Error Learning"**. (Fig.19.9)

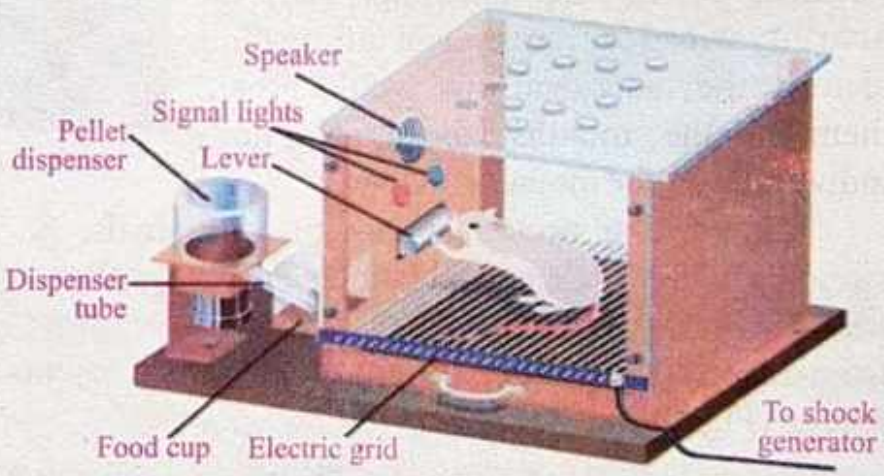


Fig. 19.9: Skinner Box (Instrumental Learning)

19.3.6 Latent Learning (Spatial Learning)

Latent learning is a type of behaviour in which an animal learns a response for a particular stimulus in its routine life without having any reward or punishment. However, sometimes, when the animal is particularly exposed to that stimulus, the animal suddenly response it by quickly recalling the previous experience.

An American physiologist Lashley used a maze. He put a rat in maze and it

wanders about and accidently get food. Did rat learn anything before getting food in the first experience? If we put the rat in the same maze again, it may directly reach the food, without searching food. That means when the rat was wondering, it did learn something without even the incentive of any reward. (Fig.19.10)



Fig. 19.10: Maze (Latent Learning)

19.3.7 Insight Learning

It is complex type of learning because it requires that animal must respond correctly in first attempt to a particular situation, it has never met before. (Unlike trial and error behaviour). **Kohler, German psychologist** performed many experiments on chimpanzee.

A **chimpanzee** is placed in a cage in which some bananas hang from the ceiling. The chimpanzee cannot reach the fruit, but the keeper has placed some boxes of different sizes in the cage. After a short period of head scratching, the chimpanzee moves the largest box and piles other smaller box over it and climb up to reach the bananas. (Fig.19.11)



Fig. 19.11: Kohler Experiment (Insight Learning)

19.4 Social Behaviour

Social behaviour (living in groups) is a set of interaction among individuals of the same species. It increases the efficiency and effectiveness of the species over the individuals of other species.

19.4.1 Animal Societies and Aggregation

A group of individuals of same species who interact and influence each other's behaviour in different ways is called social group or animal society. The key characteristics of a well-organized society include cooperation and division of labor

among animals of different sexes, age groups or casts. For example, in pack of wolves or hives of bees, some individuals of society are given the duties to find food, some reproduce and rearing, some defence. (Fig.19.12)

Aggregation is a group of animals that may be together but don't interact behaviourally *e.g.* a group of buffaloes or zebras and huge flocks of birds.

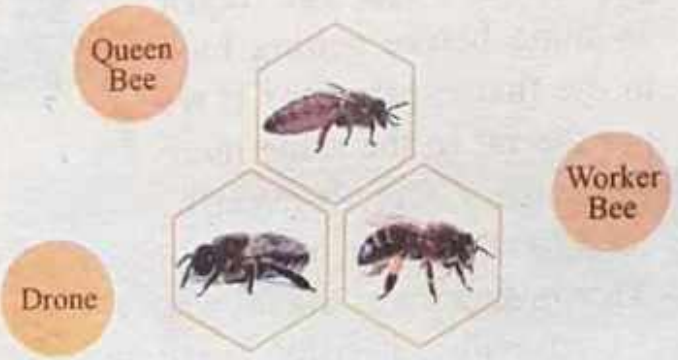


Fig. 19.12: Honey Bee

19.4.2 Hostile and Helpful Intraspecific Interaction

Many species of insects (such as ants, bees, termites) and most vertebrates show a variety of hostile or friendly group behavioural activities associated with number of individuals living together.

A good example of hostile and helpful intraspecific interaction is seen among the worker bees. In the bee hives the old and weak worker bees are killed by other worker bees. While helping interaction is observed among these bees as different bees have specific duties to perform over all functions of the hives. The collection and transformation of honey is done by the worker bees. The queen lays eggs which are fertilized by drone bees.

19.4.3 Agonistic Behaviour (Gk, agon, struggle)

This type of social behaviour occurs in **competitive situation**, includes a variety of threats or actual combat that settles disputes between individuals in a population. During these acts animals use enormous energy and cause injury to each other.

Agonistic behaviour is displayed to maintain social order such as territoriality and dominance hierarchy. (Fig.19.13)



Fig. 19.13: Gibbon Monkey

a) Territorial Behaviour

The methods by which an animal or group of animals protect their territory from intrusions of other species. Territorial boundaries may be marked by sounds such as bird songs, or scent such as **pheromones**

secreted by the skin glands of many mammals. A good example of territorial behaviour is recorded in mountain gorillas.

i) Territorial behaviour in mountain gorillas

Gorillas are highly social, relatively non-territorial and live in groups called troops. The oldest and strongest adult male called the **Silverback**, is usually the dominant one of the troop. Thus silverback gorilla enjoys exclusive breeding rights with the females. (Fig.19.14)



Fig. 19.14: Mountain Gorilla

Adolescent females, are transferred to a different troop once they reach about 8 years of age.

Adolescent males, on the other hand, usually remain in the troop until they can leave and establish a new troop on their own as the silverback gorilla.

Although gorillas typically aren't aggressive, they do exhibit territorial behaviour by standing upright on their two legs and **pounding their chests** in order to intimate whatever threat they have been given. These gestures, however, are more for show and aren't usually violent.

Skill Analysing and Interpreting

Give examples to interpret that hormones and brain control instincts.

Ans. Hormones can function as a feedback system in reproduction. A good example of a reproductive feedback loop can be seen in ringdoves. Gonadotropins stimulate the gonads of both males and females to produce steroids. Courtship and nest building follow, this increase in gonadal steroids. Rising levels of female progesterone stimulate egg laying and incubation. At this stage, gonadotropins decrease, as do female courtship displays. Males, however, remain responsive to females at this point. After approximately one week of incubation, levels of prolactin increase in both sexes, allowing both males and females to produce a milk-like substance; gonadotropin and steroid levels decrease. When the eggs hatch and the chicks mature, prolactin levels decrease, gonadotropins increase, and the cycle begins again.

Extra Information

Pheromones are chemical messengers like hormones but act outside the body of secreting organism. Pheromone helps for searching of food and also affect many behavioural and sexual responses.

Innate behaviour or instinct is usually in the form of simple reflexes such as removing one hand from a hot stove. The human suckling reflex is a good example of a complex unlearned behaviour.

So we observed from above examples that hormones and brain control instincts.

ii) Gibbon Monkeys

Another example of territorial behaviour is seen in **gibbon monkeys**. These monkeys defend their territories with vigorous visual and vocal displays. The voice of mating pair can be heard up to one kilometre distance. In most species males, and in some also females, sing solos that attract mates as well as advertise their territory. The song can be used to identify not only which species of gibbon is singing but the area it is from.

b) Dominance Hierarchy

It is a social structure within a group of animals in which certain individuals are dominant over others. The dominant individual able to claim access to better resources in the form of mates, shelter, food and other desirable commodities.

Example: Pecking order in chicken

The pecking order is, literally determined by pecking (bite or strike something with its beaks) when referring to this ordered social structure in chickens, and sometimes other bird species, it is called pecking order. It is a natural process that chickens have to work out among themselves. This order of social dynamics determines the status of individual bird of a flock and their role. (Fig.19.15)



Fig. 19.15: Pecking order in Chicken

19.4.4 Altruism (Altruistic Behaviour)

Altruism means acting in the best interest of others rather than in one's own self-interest (some people believe altruism constitutes the essence of morality).

In social insects, *e.g.* in **honeybees** ***(Apis)*** female workers are sterile, never produce offsprings, instead they spend their whole lives to look after their siblings (brother / sisters). Especially by helping their sister, queen bee, to reproduce.

Thus they are aiding in the production of new workers, drones and queen.

Science, Technology and Society (STS)

Rationalize why the marine snail, *Aplysia*, has proved very helpful in the studies of neurobiology and the behaviour pattern.

Learning and Memory in *Aplysia*: It is a marine snail and given common name of sea hare by the Ancient Greeks because of their supposed resemblance to the European hare. Juvenile *Aplysia* is attractive for neurobiologists because it has large brain cells (neurons). The cell body of one neuron can measure up to 1mm in diameter, which makes it relatively easy to study the physiology of these cells to find out how they accomplish learning.

For operant conditioning, one needs a spontaneous behaviour that can be modified by reinforcement, so a reflex is not suitable. Well, about the only thing these animals do in their natural environment is to eat and reproduce. Naturally, their feeding behaviour has received some attention from neurobiologists interested in operant conditioning.

State the role of research in neurobiology in the understanding of behaviour.

Ans. Behavioural Neuroscience, also known as biopsychology, or psychobiology is the application of the principles of biology (in particular neurobiology), to the study of physiological, genetic, and developmental mechanisms of behaviour in humans and animals. It typically investigates at the level of neurons, neurotransmitters, brain circuitry and the basic biological processes that underlie normal and abnormal behaviour. Often, experiments in behavioural neuroscience involve non-human animal models (such as rats and mice, and non-human primates) who has implications for better understanding of human pathology and therefore, contribute to evidence-based practice.

SUMMARY

- Behaviour is the sum of everything that animals do.
- There are two main types of behaviour that is innate behaviour and learned behaviour.
- Withdrawal of hand touching hot object is an example of reflexes.
- Biological clock is an internal mechanism by which biorhythm occurs and maintained even in the absence of the environmental stimuli.
- Circadian rhythms can be classified into diurnal/ nocturnal and crepuscular circadian rhythm.
- Exogenous stimuli are due to changes in the external stimuli while endogenous due to

internal stimuli.

- All plant behaviours is innate in nature.
- Tropisms are growth movements related to directional stimuli.
- Habituation is simplest form of learning and an animal learns to ignore a repeated, irrelevant stimulus.
- The trial and error learning occurs through experience.
- In society, organisms live together in organized groups.
- Altruism means the principle of living for the interest of others.
- The queen bee controls the bees with a chemical known as pheromone.
- Skinner box was designed by B.F. skinner an American psychologist.

EXERCISE

SECTION-I: OBJECTIVE QUESTIONS

Multiple Choice Questions (MCQs)

A. Choose the correct answer.

1. The scientific study of everything animals do, is called:
   (a) Pharmacology (b) Behaviour
   (c) Reflexes (d) Society
2. The biorhythm, due to internal stimuli is
   (a) Exogenous (b) Diurnal
   (c) Endogenous (d) Crepuscular
3. The movement of Euglena towards dim light is
   (a) Positive Taxis (b) Negative Taxis
   (c) Positive Kinesis (d) Negative Kinesis
4. The useful behaviour for animal with short life span is
   (a) Instinct (b) Learning
   (c) Reflex action (d) Taxis
5. The strongest and oldest adult male gorilla is called
   (a) Silverback (b) King
   (c) Golden back (d) Beta
6. To solve a mathematical problem is an example of
   (a) Instinct behaviour (b) Insight learning
   (c) Reflex action (d) Involuntary act
7. A hormone like chemical acting outside the body is called
   (a) Pheromone (b) Corticoid
   (c) Protein (d) Fatty acid

8. Trial and error learning is also called
   (a) Conditional reflex type I (b) Classical conditioning
   (c) Conditional reflex type II (d) Insight learning
9. Organisms living together in organized groups are said to live in
   (a) Colony (b) Society
   (c) Solitary (d) Dependant
10. The animals having short life cycle depend on
   (a) Learned behaviour (b) Innate behaviour
   (c) Social behaviour (d) Agonistic behaviour

B. Fill in the blanks.

1. A ..... is a form of energy that activates a specific type sensory receptor.
2. The behavioural activities of living organisms which take place at regular intervals are called .....
3. Hibernation is an example of ..... rhythm.
4. There are two primary types of innate behaviour that is orientation and .....
5. The movement of plant towards or away from stimulus of light is called .....
6. The time dependant form of learning involves. Exposure to sign stimuli, most often early in development is known as .....
7. Kohler, German psychologist performed many experiment on .....
8. A group of individuals of same species which interact and influence each other behaviour is called .....
9. Adolescent females are transferred to a different troop once they reach about ..... years of age.
10. *Aplysia,* is marine snail were given the common name of ..... by ancient Greeks.

SECTION-II: SHORT QUESTIONS

C. Give the short answers of the following questions.

1. Define behaviour, ethology and ethologist.
2. Differentiate between internal and external rhythm.
3. Define diurnal and annual rhythm.
4. Write short note on taxes.
5. Write three differences about instinctive and learning behaviour.

6. Describe the dances of bees.
7. Describe construction of intricate web by spider.
8. Write note on habituation.
9. Illustrate altruism.
10. Define territorial behaviour.

SECTION-III: EXTENSIVE QUESTIONS

D. Give detailed answers of the following questions.

1. Discuss in detail biological rhythms.
2. Define innate behaviour. Describe any two types of innate behaviour.
3. Describe migration of salmon and construction of hanging nest by some birds.
4. Explain mating behaviour of stickleback fish.
5. Define learning behaviour. Explain imprinting.
6. Describe trial and error and spatial learning.
7. Explain insight learning and habituation.
8. Define social behaviour, explain agonistic behaviour with example.
9. Describe dominance hierarchy and altruistic behaviour.

UNIT 20

REPRODUCTION

Major Concept

20.1 Reproductive system of Man
20.2 Disorders of Reproductive System
20.3 Sexually Transmitted Diseases

Learning Outcomes

Students will be able to:

- Describe the structures of male reproductive system and identifying their functions.
- Explain the principal reproductive hormones of human male and explain their role in the maintenance and functioning of reproductive system.
- Explain the structures of female reproductive system and describe their functions.
- Describe the menstrual cycle emphasizing the role of hormones.
- Describe the causes of female and male infertility.
- Explain that *in vitro* fertilization (test tube babies) is one of the methods to solve the problem of infertility.
- Define miscarriage and state its causes.
- Relate miscarriage with abortion.
- Describe the causes, symptoms and treatment of gonorrhoea and syphilis.
- Explain AIDS as a worldwide sexually transmitted disease.

Introduction

Reproduction is the biological process by which organisms give birth or give rise to new organisms which may or may not be like their parents. It helps to continue their race. This is a fundamental process and seen in all organisms. Reproduction is important for survival and maintenance of all organisms. Without this process life would come to an end. A living organism does not need reproduction to survive, but as a species, they need this mechanism for continuity and to ensure that they are not extinct.

20.1 Reproductive System of Human

The reproductive system of human is different from all other systems of body in two ways.

i) It becomes functional at the age of puberty while other systems are functional at birth or shortly after birth.

ii) The other systems are almost similar but reproductive system is quite different in male and female human.

20.1.1 Male Reproductive System

The male reproductive system performs following main functions:

i) To produce, maintain and transport semen (sperms + fluids).

ii) To discharge semen within the female reproductive tract during **sexual intercourse**.

iii) To produce and secrete male **sex hormones,** responsible for maintaining the male reproductive system.

Unlike the female reproductive system, most part of male reproductive system is located outside of the body *i.e.* **penis**, **scrotum**, and **testicles** (testes) while some parts *i.e.* vas deferens and associated glands like seminal vesicles, prostate gland and Cowper's gland are located inside the body. (Fig.20.1)

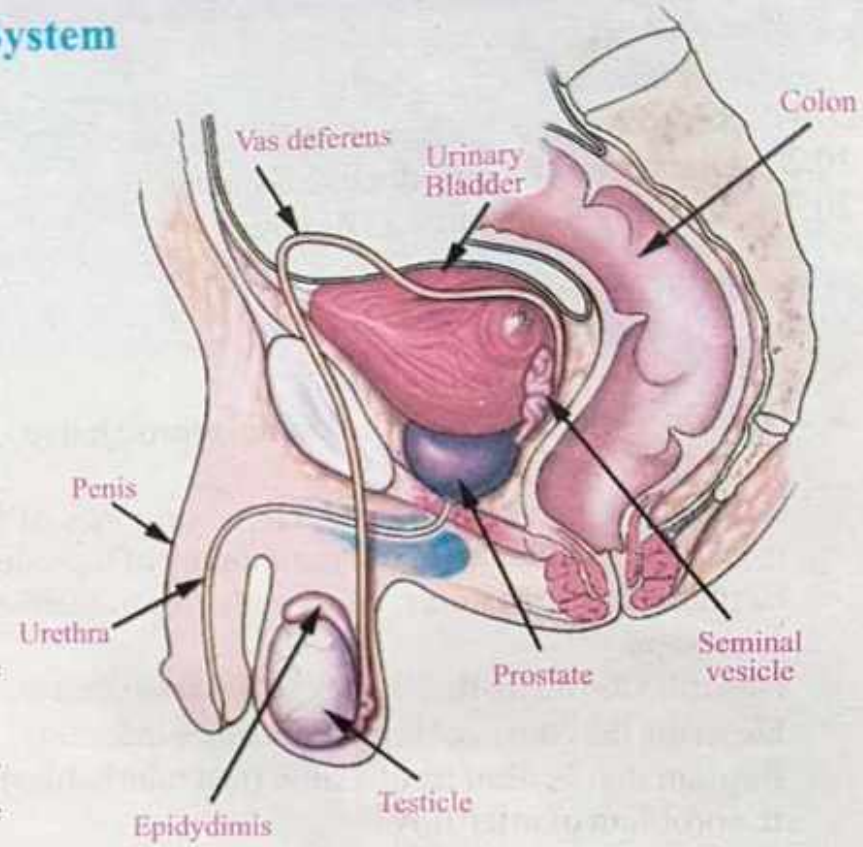


Fig. 20.1: Human Male Reproductive System

Testes

The testes (singular testis) are the male gonads. These are oval-shaped organs about the size of large olive seeds. These are located outside of body in scrotum. The scrotum is a large

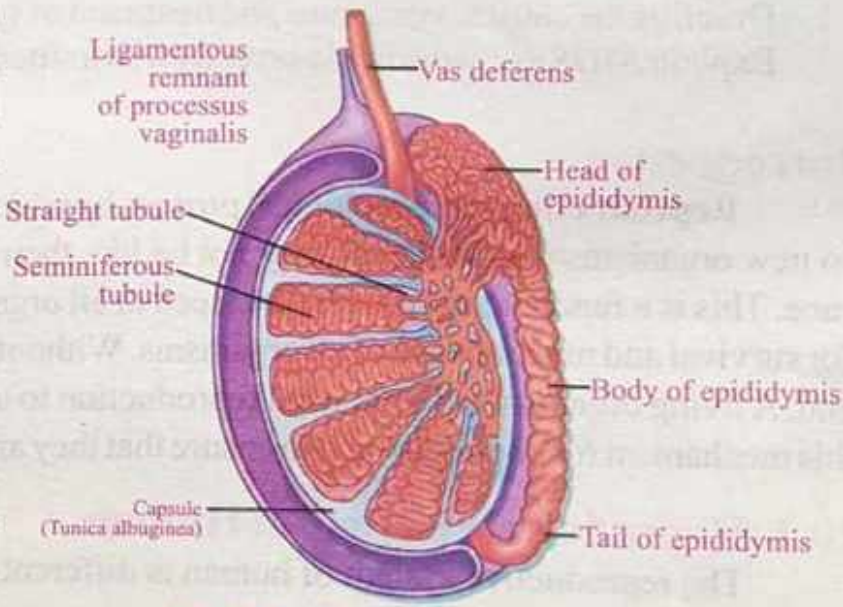


Fig. 20.2: Internal Structure of Testis

pouch like sac of skin that hangs behind and below the penis. The scrotum acts as climate control system for the testes, because for the normal sperm development, the testes must be at a temperature slightly cooler than the body temperature. The testes are usually two in number. In the testes there are coiled masses of tubules called **seminiferous tubules**. The sperms are produced in these tubules. The testes also produce male sex hormone called **testosterone** by leydig cells (interstial cells). (Fig.20.2)

Accessory Ducts

These include the following:

Epididymis:- It is a long coiled tube that rests on the back side of each testis. It stores and transports sperms. Here sperms also get mature.

Vas deferens:- It is a long muscular tube that travels from epididymis into the pelvic cavity to just behind the bladder.

Ejaculatory ducts:- The two vas deferens and two **seminal vesicles** join to form ejaculatory duct. The ejaculatory ducts empty into urethra.

Urethra:- The urethra is the tube that carries urine from bladder to outside of the body. In male, it has the additional function of ejaculating semen during sexual excitement. Therefore, urethra is also called **urinogenital duct**.

Copulatory Organ (Penis)

It is the male organ used in sexual intercourse. The skin of penis is loose and elastic to accommodate changes in penis size during an erection. The penis consists mainly of tissues that can fill with blood to cause an erection.

Accessory Glands:- Following three types of glands are associated with male reproductive system.

Extra Information

About 100 million sperms are released into the vagina during intercourse, only one of these will fertilize the egg.

Human Sperm

The human sperm has a head with a diameter of about 2.5um. It contains a large nucleus with little cytoplasm and acrosome. The nucleus carries a haploid set of chromosomes. The middle piece containing mitochondria which provide energy for sperm activity. The tail of sperm is a flagellum which enables the sperm to swim towards the egg.

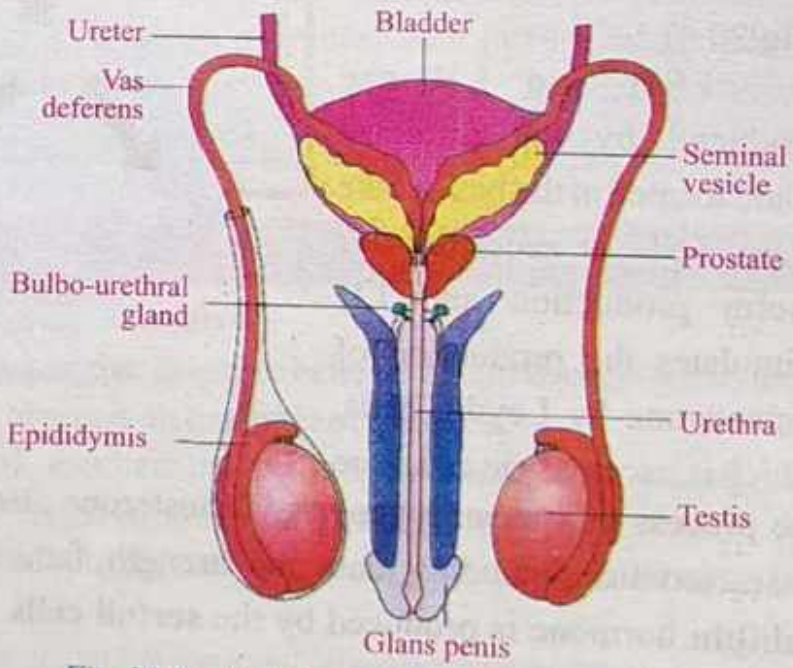


Fig. 20.3: Male Reproductive Organs (Front View)

Seminal Vesicle:- These are sac like pouches that attached to vas deferens near the base of the bladder. It produces a sugar rich fluid that provides sperms with a source of energy to help them move. (Fig.20.3)

Prostate glands

These are walnut size structure that are located below the urinary bladder at both side of urethra. The prostate gland contributes additional fluid to ejaculate, to nourish and protect the sperms.

Bulbourethral glands (Cowper's gland)

These are pea sized structures located on the side of urethra, just below the prostate glands. These glands produce a clear, slippery fluid which serves to lubricate and neutralize any acidity in urethra.

Hormonal Control of Male Reproductive Function

The entire male reproductive system is dependent on hormones. The primary hormones which involved in the functioning of the male reproductive system are: Follicle Stimulating Hormone (FSH), Luteinizing Hormone (LH) and testost-erone. (Fig.20.4)

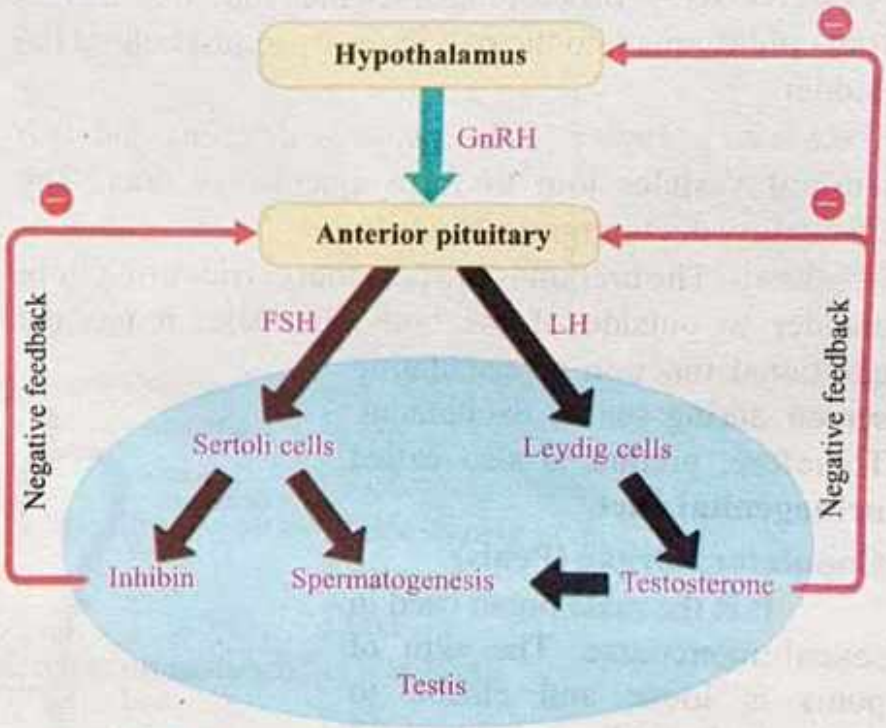


Fig.20.4: Hormonal Control of Male Reproductive System

FSH and LH are produced by the pituitary gland located at the base of the brain. FSH is necessary for sperm production and LH stimulates the production of testosterone by Leydig cells, which is necessary to continue the process of **spermatogenesis**. Testosterone also helps in the development of male characteristics, including mass and strength, fat distribution, bone mass and sex drive. **Inhibin** hormone is produced by the **sertoli cells** and controls the spermatogenesis at normal rate.

20.1.2 Female Reproductive System

The female reproductive system is more complex than the male reproductive system, because the male needs only to produce and deliver gametes. However, female reproductive system besides producing gametes also gestates, gives birth and nourishes the new born. The female reproductive system is also under the influence of menstrual cycle.

Structure of Female Reproductive System

The female reproductive system consists of following parts.

i) Ovaries ii) Ducts iii) External genitalia

i) Ovaries

There is a pair of **ovaries**, which are oval-shaped and attached to the dorsal body wall just below the kidneys. Eggs or ova develop inside the ovaries of mature female. There are approximately **4,000,00 potential (follicles) cells** are already present at birth, only about 500 will ever become mature within two ovaries and they are released from puberty to menopause. Usually, only one egg is released every month. The ovaries take turn alternate to release an egg.

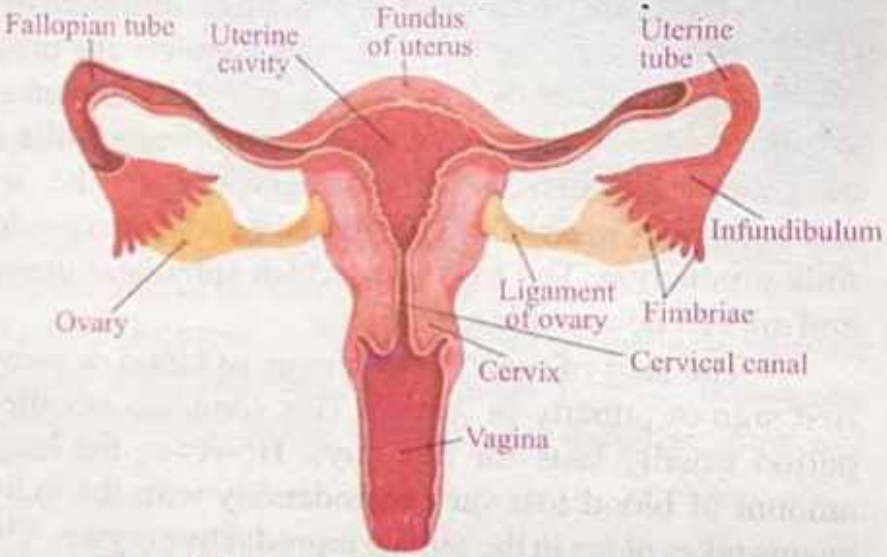


Fig. 20.5: Human Female Reproductive System

The egg is spherical in shape and about **120μm** in diameter, containing a large nucleus with haploid number of chromosomes. (Fig.20.5)

ii) Oviduct (Fallopian tube or uterine tube)

The ovary releases mature egg into oviduct which is a narrow muscular tube. It leads from ovary to the uterus. The egg is fertilized in the oviduct.

Uterus

Uterus is a pear shape elastic sac about 7.5cm long. It is the site for development of **fetus**. During pregnancy, the wall of the uterus consists of three layers. The outer layer is called perimetrium, middle layer is myometrium which is thick and muscular. The inner layer is known as endometrium which is spongy lining of

Extra Information

Reproductive system contains the largest cell of the body: the egg, which is about **120mμ** in diameter and smallest human cell: the sperm, about **5mμ** in diameter.

uterus. At the lower narrow end of the uterus is a circular ring of muscle known as cervix.

iii) External Genitalia (Vagina)

Leading from the cervix to the outside is the birth canal or vagina. It is thin walled 8-10cm long tube. The opening of the vagina is the **vulva**. Semen is deposited in the vagina during intercourse.

Extra Information

A female uterus is normally about 3 inches long and 2 inches wide which can expend up to 20 times during pregnancy. Uterus contains one of the strongest muscles in the female body.

20.1.3 Female Reproductive Cycle and its Hormonal Regulation

The female reproductive system is controlled by the follicle stimulating hormone (FSH) and luteinizing hormone (LH) which are produced by pituitary gland. Their release is controlled by hypothalamus. FSH stimulates the ovarian follicles to produce estrogen, which helps in the maturation of egg while LH stimulates the production of progesterone in ovaries. The estrogen triggers the development of secondary sexual characteristics in female. The pituitary gland also produces **prolactin**, which stimulates milk production. The **oxytocin**, which stimulates uterine contraction during child birth and milk let down during sucking.

The start of monthly discharge of blood or menses from uterus via vagina is the first sign of puberty in female. This condition is called **menstruation**. The menstrual period usually lasts for five days. However, the length of the menstrual period and amount of blood lost vary considerably with the individual. Every month, a cycle of events takes place in the female reproductive organs. This is called **menstrual cycle**. The average menstrual cycle for an adult female is 28 days. However, the menstrual cycle ranging from 21-33 days, are not abnormal. The effects of emotional disturbances, stress, mental fatigue and illness may alter or stop the menstrual cycle. An unbalance diet or malnutrition may cause the periods to be very irregular or to stop completely. A young girl may take about three years before her periods become regular.

The menstrual cycle has 4 phase:

Menstrual Phase

Menstruation is the elimination of the thickened lining of the uterus (endometrium) and blood from the body through the vagina. Menstrual fluid contains blood, cells from the lining of the uterus and mucus. The average length of this phase is 5 days.

Follicular Phase

The follicular phase starts on the stoppage of menstruation and ends with ovulation. The pituitary gland releases follicle stimulating hormone (FSH), which stimulates the ovary to produce about **5-20 follicles**. Each follicle houses an immature egg. Usually only one follicle will mature into an egg while the others die. The growth of

the follicles stimulates the lining of the uterus to thicken in preparation for possible pregnancy.

Extra Information

Fallopian tubes are about 12cm long and wide as a sewing needle.

Ovulation Stage

Ovulation is the release of mature egg from the surface of the ovary. This usually occurs mid of the cycle, about 14th day of the cycle.

During the follicular phase, the development of follicle causes a rise in the level of estrogen. The hypothalamus in the brain recognizing these rising levels and releases a chemical called **gonadotropin releasing hormone (GnRH)**. This hormone stimulates the pituitary gland to produce raised levels of luteinizing hormone (LH) and FSH within two days, ovulation is triggered by the high level of LH. The egg is funneled into the fallopian tube and toward the uterus by waves of small hair like projections. The life span of the typical egg is only around 24 hours.

Luteal Phase

During ovulation, the egg bursts out from its follicle, but the ruptured follicle stays on the surface of the ovary. For the next two weeks or so, the follicle transforms into the

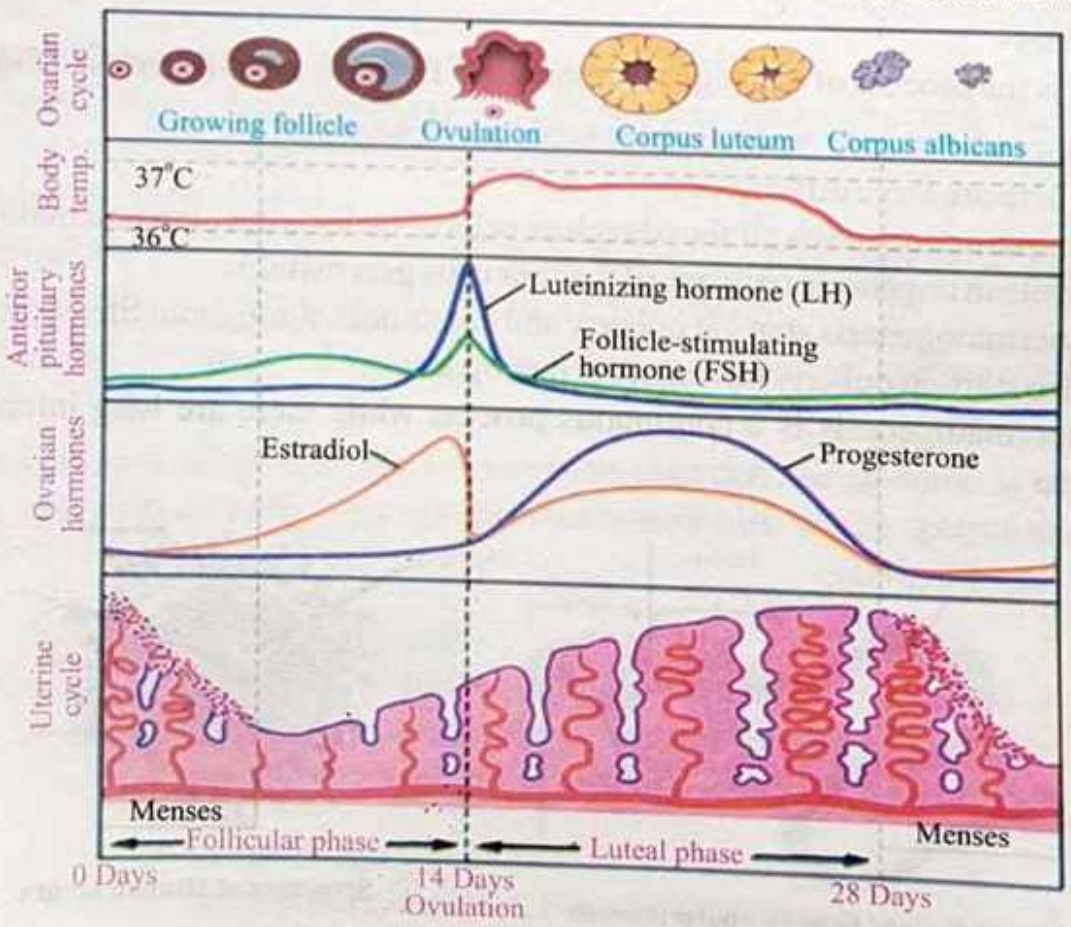


Fig.20.6: Menstrual Cycle in Human

structure called **corpus luteum**. This structure starts releasing progesterone along with small amount of estrogen. The combination of hormone maintains the thickened lining of the uterus of fertilized egg implants in the lining of the uterus. It produces the hormones that are necessary to maintain the corpus luteum. It induces the **human chorionic gonadotropin (hCG)**, the hormone that is detected in urine test for pregnancy. If pregnancy does not occur, the corpus luteum degenerates usually during day 22 after menstruation. The drop in progesterone level causes the lining of the uterus to fall away. This is known as menstruation. The cycle repeats. (Fig.20.6)

Extra Reading

Gametogenesis

- The production of gametes is known as gametogenesis.
- The process of gametogenesis occurs in gonads.
- The process of gametogenesis starts at puberty.
- There are two types of gametogenesis i.e. spermatogenesis and oogenesis.

Spermatogenesis

It is the process of sperm formation in male gonads (testes).

Oogenesis

It is the process of ova (eggs) formation in female gonads (overies). (Fig.20.7)

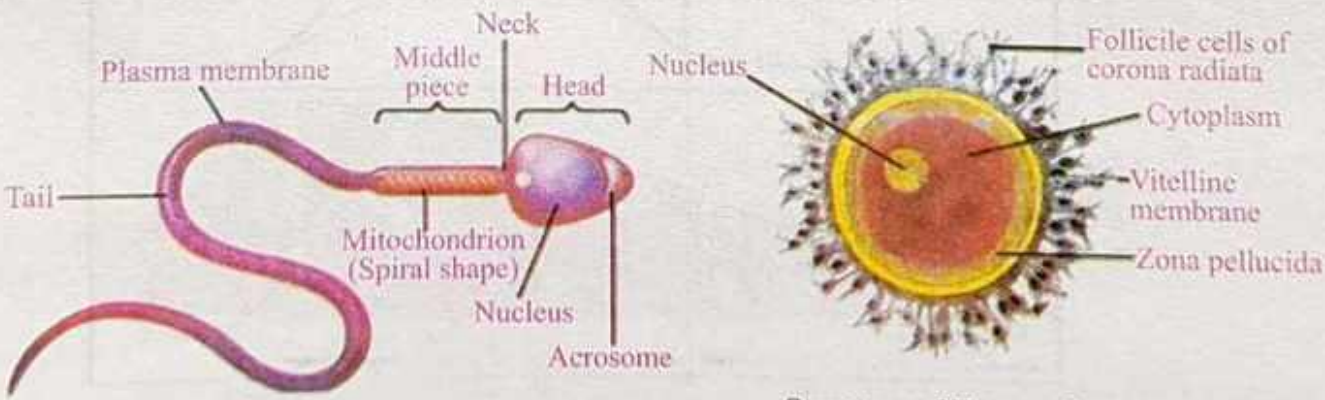
Differences between Spermatogenesis and Oogenesis

There are three differences

i) In spermatogenesis all four daughter cells of meiosis develop into mature gametes while in oogenesis only one of the four cells gets mature.

ii) Spermatogenesis starts at puberty and continuous throughout life while oogenesis also starts at puberty but ceases at menopause.

Spermatogenesis is a continuous process while there are long interruptions in oogenesis.



Structure of Mature Human Spermatozoan **Structure of Human Ovum**

Fig. 20.7: Structure of Sperm and Egg

Terms use for Human Ovum

Zona pellucida is thick transparent membrane surrounding a mammalian ovum before implantation.

Corona radiata is many layers' thick follicle cells adhering to oocyte which supply vital proteins to the cell.

Corpus albicans is regressed form of the corpusluteum.

20.2 Disorders of Reproductive System

The reproductive disorder is a disease or a condition when there is a problem in reproductive system of male or female. The main disorders of reproductive system include abnormal puberty, infertility in male and female and miscarriage in female. Here infertility and miscarriage will be discussed.

Infertility

In general, **infertility** is defined as not being able to get pregnant after one year (or longer of unprotected sexual intercourse between partners). This infertility may be in male or female.

20.2.1 Causes of Male Infertility

Some common causes of male infertility are as under:

a. Azoospermia:- A condition in which there are no sperm in semen when a man ejaculates. This may be because the man does not make sperm or because the sperms are blocked from entering the semen.

b. Oligospermia:- In this type of male infertility, less amount of sperms is produced due to increase in temperature of testes, infections, *etc.*

c. Sperm deformities:- The change in shape or structure of sperms may also be the cause of male infertility.

d. Autoimmune disorder:- In autoimmune disorder, the immune system start fighting its own parts of body. This autoimmunity may also attack sperms and cause infertility.

20.2.2 Causes of Female Infertility

The most common causes of female infertility include problems with ovulation, damage to fallopian tube or uterus or problems with cervix. Age also contributes to infertility because as a woman ages, her fertility naturally tend to decrease.

20.2.3 Treatment of Infertility

Some forms of infertility are treatable. Hormone therapy can sometimes increase sperm and egg production. Surgery can often correct ducts that formed improperly or

blocked. However, a commonly used technique to treat infertility is ***invitro*** **fertilization (IVF)** commonly known as **test tube baby**.

In Vitro Fertilization (IVF)

It means fertilization outside of female body in glass wares. In this process egg and sperm of couples are taken outside of body in laboratory and fertilized in test tube. Fertilized eggs are incubated until they have formed at least eight cells and are then transferred to the women uterus for implantation. If mature sperms are defective or low in number, a whole sperm or its nucleus is injected directly into the egg. (Fig.20.8)



Fig.20.8: In Vitro Fertilization

Although it is a costly procedure but this has enabled more than a million couples to conceive children.

20.2.4 Miscarriage

It is a term used for a pregnancy that ends on its own, within the first 20 weeks of gestation.

Causes of Miscarriage

There are many reasons why a miscarriage may happen, although the cause is often not identified.

Most miscarriages happen when unborn baby has fatal genetic problems like abnormalities in chromosomal number and structure. The other causes include infection, medical conditions in mother, such as diabetes or thyroid disease, hormonal problems, immune system response, uterine abnormalities, weakness in cervix (cervical insufficiency), *etc.*

Extra Information

A pregnancy that ends before 37 weeks of gestation, resulting in a live born infant is known as premature birth.

Miscarriages versus Abortion

A miscarriage is a natural spontaneous termination of a pregnancy. An abortion occurs when a procedure is done with the purpose of ending a pregnancy.

20.3 Sexually Transmitted Diseases (STDs)

Sexually transmitted diseases are infections that are commonly spread by sexual activity. More than 30 different types of bacteria, viruses and parasites can be transmitted through sexual activity. Some examples of sexually transmitted diseases are chlamydia, gonorrhoea, syphilis, genital herpes, AIDS, *etc.* Here only gonorrhea, syphilis and AIDS will be discussed.

Gonorrhea

It is caused by the gram positive bacterium *Neisseria gonorrhaeae*. There is no blood test to diagnose gonorrhoea. In male, typical symptoms are pain upon urination and a thick greenish yellow urethral discharge. If a baby is exposed during birth, an eye infection leading to blindness can result. Gonorrhoea can spread to internal parts of the body, causing heart damage or arthritis. It is transmitted through direct contract or sexual contact. It is treated using antibiotics penicillin or tetracycline.

Syphilis

It is caused by a spirochete bacterium *Treponema palladium*. It has three stages, which are typically separated by latent periods. In the primary stage, a hard chancre (ulcerated sore with hard edges) appears. In the secondary stage, rash appears all over the body.

During the tertiary stage, syphilis may affect the cardiovascular and nervous system. It damages reproductive organs, eyes, bones joints, central nervous system, heart and skin. Sexual contact is the major source of its dissemination. Syphilis is a very devastating disease. Control depends on prompt and adequate treatment of all cases be treated with antibiotic therapy.

AIDS-A worldwide sexually transmitted disease

AIDS is caused by a virus called HIV (Human Immunodeficiency Virus). HIV destroys the body immune system. That is why this disease is called AIDS (Human Immune Deficiency Syndrome). The HIV attacks on specific type of white blood cells called T-cells. HIV may transmit through blood transfusion, contaminated syringes, surgical instruments, *etc.* However, the most prominent cause is sexual transmission. AIDS is a major global public health issue. There are approximately 38 million people living with HIV at the end of 2019. Over two thirds of all people with HIV infection live in African region (26 million). HIV can be diagnosed through rapid diagnostic tests. However, still there is no cure for AIDS.

List the measures that can help to prevent transmission of HIV.

The HIV is transmitted from one person to another by exchanging fluids of body. Therefore, following measures should be taken to prevent transmission because prevention is so for only cure for AIDS.

- Follow the Islamic teaching and refrain from immoral sexual activities.
- Avoid sharing instruments that are likely to break the skin and be contaminated with blood e.g. razors and tooth brushes.
- If you require acupuncture, ear, piercing, nose piercing, *etc.* You should go to reliable operators and make sure that needles used are sterilized or insist on using disposable instruments.
- Blood of donor must be screened before transfusion.
- Use disposable syringes and sterilized operation tools for surgery.
- Affected mothers must avoid breast feeding to their infants.

Science, Technology and Society (STS)

Become aware of the ethical implications of abortion.

Abortion is one of the most controversial issues associated with reproduction. It raises ethical issues. Some people think that abortion is always wrong. The others think that abortion is right at some circumstances. The commonly raised ethical issues are: (i)It is considered as murder. (ii) It can increase sexual corruptions. However, abortion should be allowed in following cases.

- When mother life is at risk.
- When there is a risk of injury or mother physical or mental health is at risk.
- When prenatal testing predicts the abnormal are handicapped fetus.

SUMMARY

- Reproduction is the biological process by which organisms give birth to new organism of their own kinds to continue their race.
- The reproductive system is different from other systems of body.
- Unlike female, male reproductive system is mostly located outside of body.
- The male reproductive system consists of testes, ducts, associated glands and external genitalia.
- The female reproductive system consists of ovaries, ducts and external genitalia.
- The female reproductive system is more complex because it has to perform number of functions *i.e.* to produce gametes, gestate the fetus, give birth and nourish the new born.
- The male reproductive system is controlled by gonadotropins and testosterone.
- The female reproductive system is controlled by follicle stimulating hormone (FSH), Luteinizing hormone (LH), progesterone and estrogen hormone.

- Menstruation is the elimination of the thickened lining of the uterus and bleeding through the vagina.
- Ovulation is the release of mature egg from the surface of ovary.
- The production of gametes is called gametogenesis. In male it is called spermatogenesis while in female it is called oogenesis.
- The reproductive disorder is a disease or a condition where there is a problem in reproductive system of the male or female.
- Infertility is defined as not being able to get pregnant after one year or longer of unprotected sexual intercourse between partners.
- *In Vitro* Fertilization is a common way of treating infertility.
- Miscarriage is a term used to describe the end of pregnancy of its own.
- Sexually transmitted diseases are infections that are commonly spread by sexual activity.
- There are about 38 million people living with HIV infection at the end of 2019.

EXERCISE

SECTION-I: OBJECTIVE QUESTIONS

Multiple Choice Questions (MCQs)

A. Select the correct answer.

1. The first convoluted part of vas deferens is:
   (a) Vas deference (b) Epididymis
   (c) Sertoli (d) Placenta
2. Decrease of FSH and increase of estrogen, causes pituitary to secrete:
   (a) Luteotropic hormone (LTH) (b) Luteinizing hormone (LH)
   (c) Vasopressin (ADH) (d) Oxytocin
3. Uterus opens into the vagina through:
   (a) Cervix (b) External genitalia
   (c) Fallopian tube (d) Vulva
4. Pregnancy is maintained by the:
   (a) Luteotropic hormone (LTH) (b) Corticosteroids
   (c) Progesterone (d) LH and FSH
5. Syphilis is a sexually transmitted disease which is caused by:
   (a) *Neisseria gonorrhoeae* (b) *Treponema pallidum*
   (c) *E. coli* (d) *Myobacterium ovium*
6. Reproductive system is different from other systems of body due to the fact that
   (a) Functional at birth (b) Non-functional at birth

(c) Functional at puberty (d) Become functional in fetus

7. Fertilization occurs in
   (a) Ovary (b) Fallopian tube
   (c) Uterus (d) Vagina
8. The sperms are produced in the
   (a) Epididymis (b) Vas deferens
   (c) Seminiferous tubules (c) Prostate gland
9. The cervix is the opening of
   (a) Ovary (b) Vagina
   (c) Fallopian tube (d) Uterus
10. Sperms are stored in
   (a) Epididymis (b) Urethra
   (c) Prostate gland (d) Vas deferens
11. FSH is a hormone produced by
   (a) Pituitary gland (b) Adrenal gland
   (c) Ovary (d) Testes
12. Uterus is a pear-shaped elastic sac about
   (a) 4cm long (b) 5cm long
   (c) 7.5cm long (d) 10.5cm long
13. The average menstrual cycle of an adult human female is about
   (a) 5 days (b) 8 days
   (c) 28 days (d) 14 days
14. Oligospermia is a condition in male in which
   (a) Abnormal sperms are produced
   (b) More sperms are produced
   (c) No sperms are produced
   (d) Less sperms are produced
15. The number of AIDS patients in world are in 2019
   (a) More than 1 billion (b) Over 38 million
   (c) Less than 3 million (d) Less than 2 million

B. Fill the blank.

1. Most part of male reproductive system located ..... of body.
2. The scrotum acts as climate control for the .....
3. Female reproductive system is more ..... than male.
4. There are ..... potential follicle cells already present at birth in ovary.
5. The egg is spherical in shape and about ..... µm in diameter.

6. Ovulation is the release of mature ..... from the surface of the ovary.
7. Chorionic gonadotropin hormone in urine is checked for ..... test.
8. IVF is commonly used technique to treat .....
9. The natural or spontaneous termination of pregnancy is called .....
10. The wilful ending of pregnancy is called .....

SECTION-II: SHORT QUESTIONS

C. Give the short answers of the following questions.

1. Illustrate that reproductive system is different from all other system.
2. Write the functions of male reproductive system.
3. Describe that female reproductive system is more complex than male reproductive system.
4. Write the causes of male infertility.
5. Write the causes of female infertility.
6. Write some measures to prevent AIDS.
7. Differentiate miscarriage and abortion.
8. Write the main causes of miscarriage.
9. Briefly describe AIDS.
10. Describe the role of hormone to control the male reproductive function.

SECTION-III: EXTENSIVE QUESTIONS

D. Give detailed answers of the following questions.

1. Describe the structure and function of human male reproductive system.
2. Explain structure of female reproductive system.
3. Describe the hormonal control of female reproductive system.
4. Describe the menstrual cycle and also explain its phases.
5. Define infertility and explain in vitro fertilization procedure to treat infertility.

UNIT 21

DEVELOPMENT AND AGEING

Major Concept

21.1 Embryonic Development
21.2 Control of Development
21.3 Human Embryonic Development
21.4 Birth and Nursing
21.5 Disorders During Embryonic Development
21.6 Postnatal Development
21.7 Ageing

Learning Outcomes

Students will be able to:

- Describe cleavage and relate it with the amount of yolk.
- Explain the events of gastrulation.
- List the tissues and organs formed from the three germ layers.
- State the events of neurilation.
- Describe the formation of neural crest and list the structures that are derived from neural crest cells.
- Define organogenesis.
- Through experimental narration, describe the role of the nucleus and cytoplasm in controlling.
- Give a brief overview of the work done by Hans Spemann in the discovery of induction.
- Define organizers and differentiate between primary and secondary induction.
- Describe the events of development in human in terms of first, second and third trimesters.
- Describe in brief the development of twins and quadruplets.
- Describe the structural details of placenta and umbilical cord.
- Differentiate the term gestation and pregnancy.
- Describe the role of fetal and maternal hormones in initiating labor pains and culminating in the birth of baby.
- Define the term premature birth and correlate it with the growth phases in the second and third trimesters.
- Define afterbirth and describe how umbilical cord is detached from the baby.
- Define colostrum and describe the role of prolactin in the production and oxytocin in the secretion of milk.

- State the hormonal regulation in the end of milk production.
- Compare breast-feeding and bottle-feeding, in terms of advantages and disadvantages.
- Describe the maternal derived abnormalities (rubella, abnormal neural tube, thyroid gland and limb development).
- Relate the major genetic abnormalities in embryos with spontaneous abortion.
- Describe how fetal surgery helps to correct the detected fetal developmental problems.
- Define the term allometric growth and correlate it with the postnatal development in human.
- Define the term ageing.
- Rationalize ageing as a part of normal development.
- List the genetic and extrinsic factors responsible of ageing.
- State the changes (graying, thinning hair, pigmented patches of skin, slowed movements, fading vision, impaired hearing, reduced ability to adapt to stress and decreased resistance to infections) as primary ageing.
- State the changes that are the result of environmental, lifestyle factors such as disease, disuse (lack of exercise), and abuse (smoking, obesity, malnutrition and exposure to ultra-violet light) as secondary ageing.
- List some changes that occur at the system and those that occur at cellular level during ageing.

Introduction

What happens after the birth of an infant is crucial to its survival? However, what happens before birth may be even more crucial. In fact, if an infant does not develop properly before birth, normal growth after birth becomes difficult and sometimes impossible.

This chapter focuses on life before birth, the gradual growth and progressive changes in a developing human from conception until the time the fetus leaves the mother's womb.

21.1 Embryonic Development

Embryo is a class of transitional forms on the path from a fertilized egg to an adult. The study of animal and plant development from fertilized egg to formation of all major organs is called **embryology**. The early stage of young one up to formation of organs is called **embryo.**

The first stage of development begins with **formation of gametes** (eggs and sperms), which develop inside the reproductive organs of parent's body.

Fertilization, the second stage, starts when the plasma membrane of sperm fuses with the plasma membrane of an egg. It is over when the egg nucleus and sperm nucleus fuse, thus forming a **zygote.**

The process of embryonic development after zygote formation comprises of following four stages:

i) Cleavage ii) Gastrulation
iii) Organogenesis iv) Growth

Extra Information

Each daughter cell of developing zygote up to blastulation is called blastomere.

21.1.1 Cleavage

Cleavage is a program of mitotic cell division that divides the volume of zygote (fertilized egg) cytoplasm into number of smaller, nucleated cells called **blastomeres** (Thus, in cleavage, number of cells increases but size of cells hardly increases). (Fig.21.1)

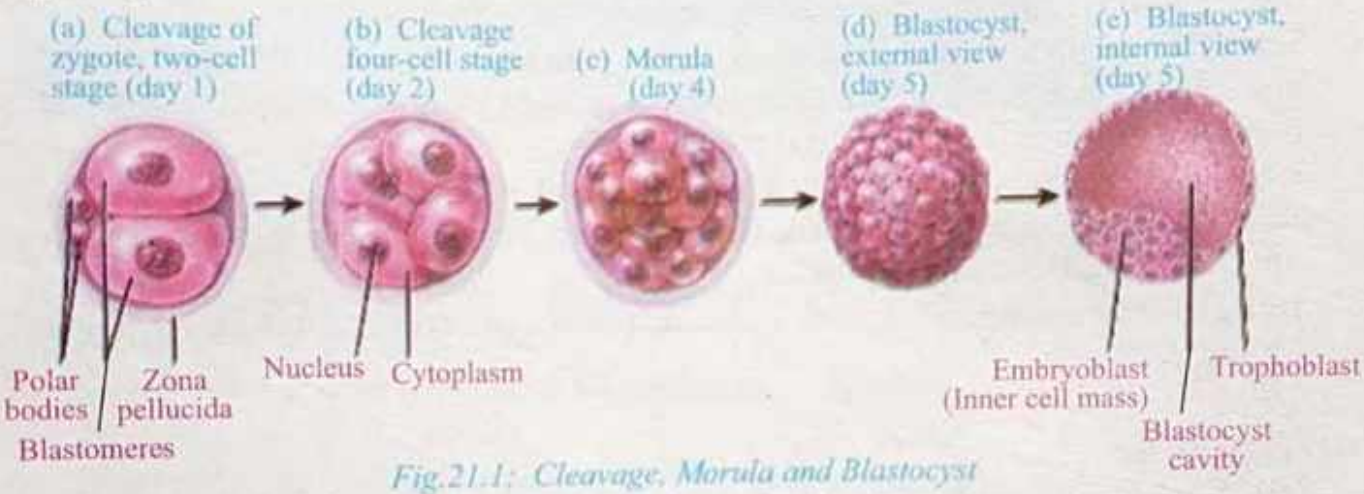


Fig.21.1: Cleavage, Morula and Blastocyst

Morulation: After many cleavages (repeated cell divisions), the zygote is transformed into a solid or compact ball of cells known as **morula.**

Blastulation: The cleavage in morula continues and cells arrange themselves to form blastula. The **blastula** is hollow ball of cells, which contains a fluid filled cavity known as **blastocoel**. This embryonic stage in mammals is called **blastocyst**.

The **blastocyst** contains fluid-filled hollow sphere made of a single layer of large, flattened cells known as **trophoblast** and also 20-30 small rounded cells called **inner cell mass** which are located at one side of embryo.

21.1.2 Different Patterns of Cleavage Based on the Amount of Yolk

Most animal eggs contain varied amount of **yolk**, which is mixture of proteins, fats, phospholipids, calcium and some other minerals. **Yolk** serves as food for developing embryo.

The amount and distribution of yolk varies among different animal groups, for example, the eggs of most invertebrates and simple chordates are **isolecithal** *i.e.* contains small amounts of yolk which is uniformly distributed through the cytoplasm. Many higher chordates such as birds and reptiles possess large amount of yolk which is concentrated at one side of egg known as **(vegetal pole)** such eggs are called **telolecitha**l.

The pole of egg where embryo is placed called **animal pole**.

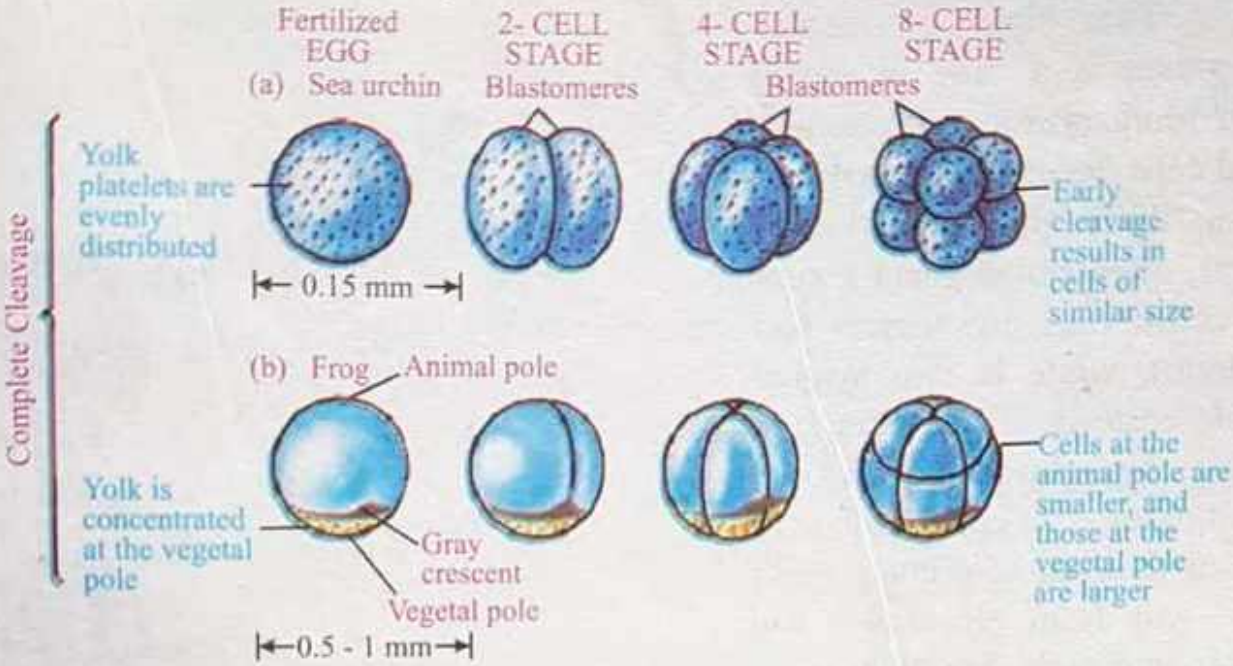


Fig. 21.2: Different Patterns of Cleavage

The amount of yolk in egg also effects on the pattern of cleavage. If egg is isolecithal than entire egg divides and redivides, producing equal size of daughter cells. This type of cleavage is called **holoblastic** *e.g.* in eggs of bony fish and amphibians. While in the telolecithal egg, the cleavage is **meroblastic** *i.e.* cell division occurs only in the **blastodisc** (the small disc of cytoplasm at the animal pole) *e.g.* eggs of reptiles, birds and some fish. This type of cleavage is also known as **discoidal** or **partial cleavage**.

Difference between Radial cleavage and Spiral cleavage. (Fig.21.2)

The holoblastic cleavage may be radial or spiral.

- **Radial cleavage** is present in deuterostomes while **spiral cleavage** is present in protostomes.
- In spiral cleavage cell divisions are diagonal to the vertical axis of embryo while in radial cleavage the plane of cell division is parallel to vertical axis of the embryo.

Table 21.1: Comparison between Radial and Spiral Cleavage

S.No.	Spiral cleavage	Radial cleavage
i)	Spiral cleavage occurs in most protostomes.	Radial cleavage is found in most deuterostomes.
ii)	Some ecdysozoans (Arthropods, Nematods) show radial or superficial (insects) cleavage. 	Tunicates and mammals have specialized cleavage patterns. 

21.1.3 Gastrulation

This stage of animal development is a time of major cellular reorganization. The newly formed cells become arranged into two or three **primary tissues (layers),** often called **germ layers** (*i.e.* ectoderm, mesoderm and endoderm), while in two layered animals instead of mesoderm, a jelly like **mesogloea** is present) *e.g.* coelenterates. The cellular descendants of these three primary germ layers will form all tissues and organs of the adult. (Fig.21.3)

The Ectoderm / Outer layer

It is the outermost primary tissue layer, the one that forms first in the embryos of every animal. These cells form the integument (outer layer of skin, hair, nail, feathers and scales), nervous system and parts of sense organs, inner layer of mouth, rectum, anus and teeth.

The Mesoderm / Middle layer

This intermediate primary tissue layer gives rise to the skeleton, muscles, blood and blood vessels, reproductive organs, connective tissues, excretory organs, lymphatic tissue and inner most layer of the skin.

The Endoderm / inner layer

This is the inner most primary tissue layer. These cells give rise to the lining of the

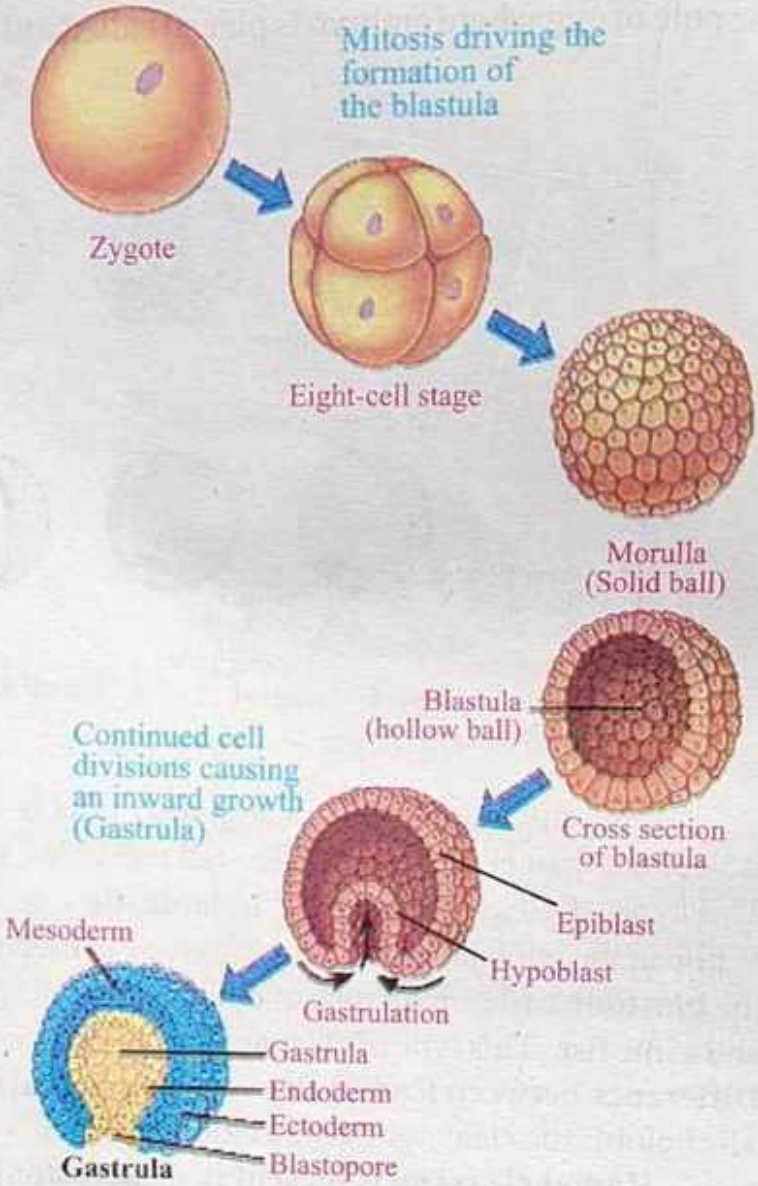


Fig.21.3: Formation of Gastrula

Extra Information

Mesogloea refers to the tissue found in coelenterates between ectoderm and endoderm that function as a hydrostatic skeleton. It is related to but distinct from mesohyl, which generally refers to the tissue found in sponges.

digestive tract, digestive organs, and associated gland, respiratory tract, lungs, urinary bladder and the urethra.

The formation of mesoderm was a pivotal (very important) step in the evolution of nearly all large complex animals.

Gastrulation in Human

In human embryo during 3rd week of pregnancy, gastrulation initiates. The **trophoblast** in this stage thicken at one point to form a mass of cells known as **inner mass cells**, which after implantation break into two fluid filled sacs. These sacs are separated by a double layer of cells called the **embryonic disc**. One of these sacs is known as **amniotic sac (amnion),** filled by amniotic fluid. The other sac is yolk sac. In human this sac does not contain yolk because human embryo gets nutrients from the mother, first from uterus lining, later by placenta from mother. Gastrulation begins when a groove with raised edges called the **primitive streak,** appears on the dorsal surface of the embryonic disc and establishes the longitudinal axis of the embryo. The surface cells called **epiblast**, migrate across other cell and enter the primitive streak. This lower layer is called **hypoblast**, which is future endoderm. The epiblast gives rise to ectoderm. The cells of the ectoderm migrate through the primitive streak into the interior of the embryo, forming the mesoderm. (Fig.21.4)

Spina bifida

Occurs due to defect in the protective covering which does not close around an unborn baby's spinal cord, leaving gap. This can lead to permanent nerve damage and sometime paralysis.

Blastocyst

It is the structure formed in the early development of mammals (human). It possesses an inner cell mass which subsequently forms embryo. The outer layer of it consists of cell, collectively called the **trophoblast**, which gives rise to the placenta.

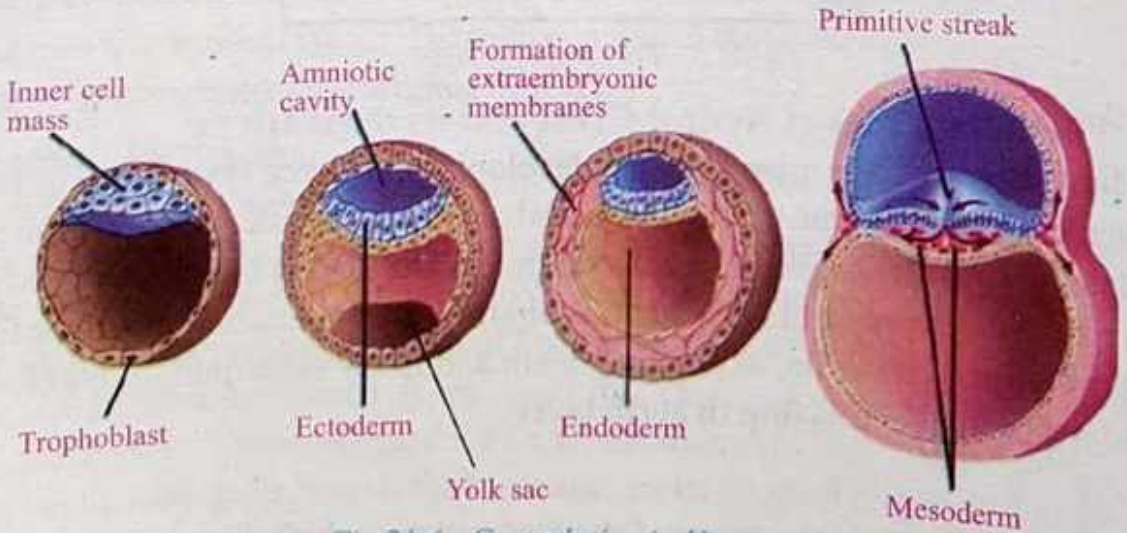


Fig.21.4: Gastrulation in Human

21.1.4 Neurilation in Human Embryo

The process of neurulation begins during fourth week of pregnancy. The mesodermal cells immediately beneath the early primitive streak aggregate, forming a rod of mesodermal cell called the **notochord**, the first axial support of the embryo. These developing notochordal cells induce the overlying ectoderm to thicken, forming **neural plate**. The central region of the neural plate pushes downward to form a depression called **neural groove,** then **neural fold**. The cells in neural fold continuously move to upper margin and ultimately fuse to form neural tube, which soon pinches off and becomes covered by surface ectoderm. At this point the embryo is designated as **neurula.**

The **neural tube** of neurula grows and differentiates in brain and spinal cord. At the end of fourth week, the vesicles of fore, mid and hind brain is formed while at the end of eight to nine week, all flexures are evident. (Fig.21.5)

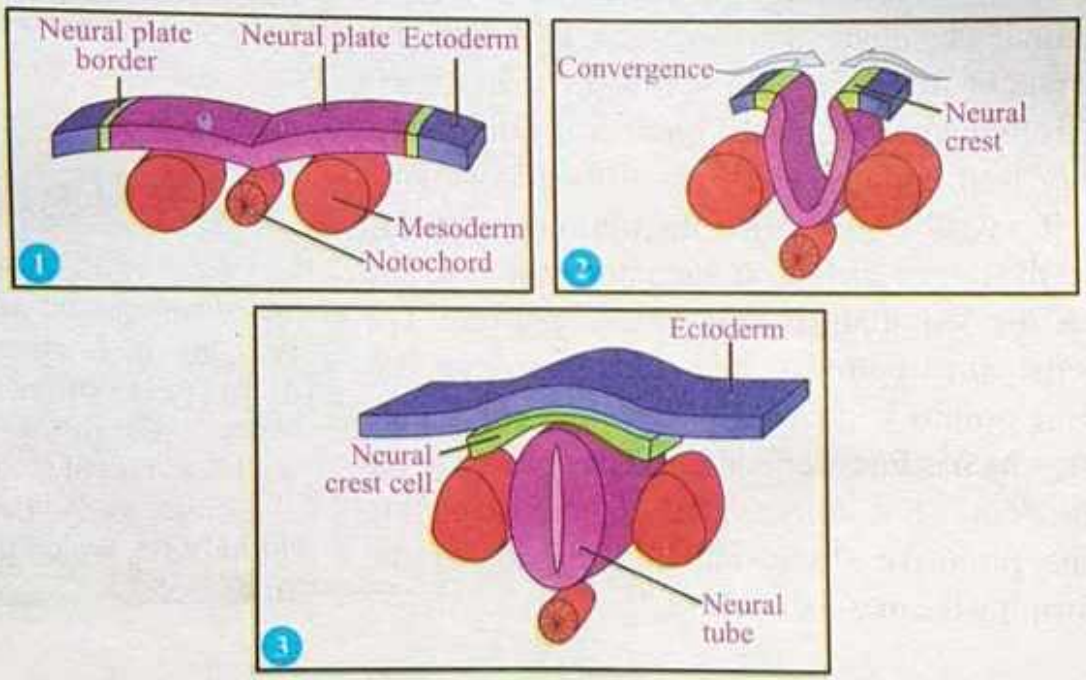


Fig.21.5: Formation of Neural Tube

21.1.5 The Formation of Neural Crest and its derivatives

Many motor nerves arise from the developing brain and spinal cord of fetus. The sensory nerves have separate origin, the neural crest, which is developed in the region of neural plate border. The neural crest cells migrate widely to the lateral side of neural tube and give rise to the nerves and sympathetic ganglia. These cells also help in the formation of cortical region of medulla, skull bone, teeth and many other parts. Therefore, many embryologists consider it as **fourth germ layer**.

21.1.6 Organogenesis

Organogenesis is the stage of development in which formation of organs and

organ systems take place during embryonic development. The first major step in organogenesis is **neurulation** (differentiation of ectoderm that produces brain/spinal cord).

21.1.7 Growth

Growth is last step of development which begins by the start of third month (in case of human embryo) and ends long after birth. It is characterized by increase in size and mass of an organism.

From third month till birth, human embryo is called as fetus. The rest of developmental period comprises only growth and maturation of organs and organ systems.

21.2 Control of Development

Each and every body cell of multicellular organism contains complete set of chromosomes which contain all bodily genes. These chromosomes came due to mitosis of the zygote. As the development proceeds further, different cells differentiate along different lines and perform different functions. Later studied confirm that nucleus determines the characteristics of the individual, while the cytoplasm selectively turns on some genes and switches off others.

Here we will discuss the role of nucleus and cytoplasm in development.

21.2.1 Role of Nucleus in Development

The experiment of **Dietrich** and **Spemann** revealed the importance of nucleus and cytoplasm during development of an embryo.

Experiment of Hans Adolf Edward Dietrich (1891)

Dietrich took sea urchin zygote after one division then separated the two daughter cells. Each daughter cell was allowed to divide grow into a complete larva. Both daughter cells developed into normal larvae: Dietrich concluded that both of these cells contained all the genetic information of the original zygote.

Experiment of Spemann

1st Experiment of Spemann

In first experiment, Spemann took **salamander's zygote (an amphibian)** and then divided the zygote into two equal halves with the help of minute ligature of human hair. The nucleus was present in one half but the other half had no nucleus. When the developmental process continued, it was seen that cleavage was completed in the half containing nucleus but the enucleated half was not seen dividing. When nucleated side had reached at 16-cell stage, one of the cleavage nuclei crossed the narrow cytoplasmic bridge to the enucleated side, immediately this side started dividing. Thus both sides

complete cleavage and formed two complete embryos.

2nd Experiment of Spemann

In another experiment, Spemann separated the two halves of embryo; both of them contained nuclei. Both these halves developed into complete embryos. He also observed that from a 16-cell embryo, even if a single cell is separated, it contains a complete set of genes and form a complete embryo. Through series of experiments, Spemann also observed that sometimes it may happen that the nucleated half can develop into abnormal ball of cells. Later studies revealed that development depends on the position of gray crescent. **Gray crescent** is the pigment free area that appears at the time of fertilization. So in the half lacking grey crescent, no further development can take place. (Fig.21.6)

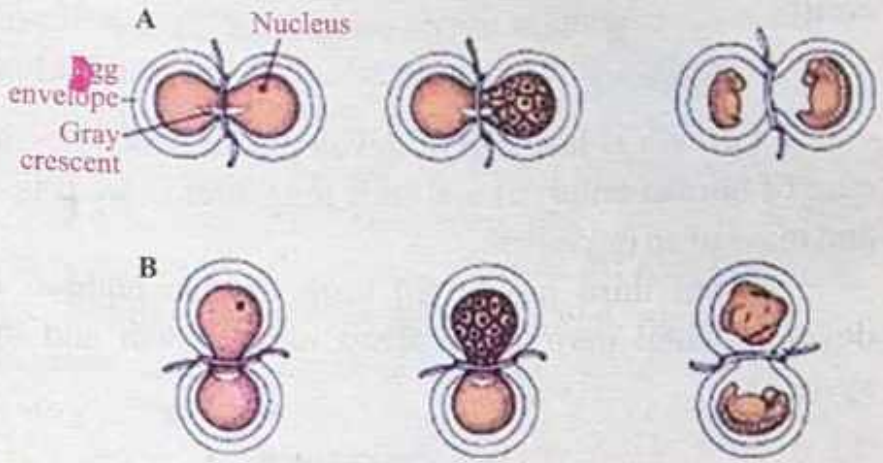


Fig. 21.6: Spemann Experiment

Conclusions made by Spemann

Two conclusions were made by Spemann:

i) The nuclear information is same in each daughter cell.

ii) The grey crescent area in the cytoplasm contains information essential for proper development.

To know causes of differentiation

After completion of two experiments, questions arose in the mind of Spemann that if all the cells contain same nuclear material, what causes the cells to differentiate. There are two ways by which cells undergo differentiation and become committed to particular determinative (serving to define, qualify or direct) molecules.

i) During cleavage, cytoplasmic segregation of determinants takes place.

ii) Induction or interaction with the neighbouring cells takes place.

Role of Cytoplasm in Development

It is known that different cytoplasmic components contain different morphogenetic determinants that are responsible for cell differentiation. These determinants are present in blastomeres. In the zygote of an ascidian (Urocordate), four different colors are observed in cytoplasm which are segregated into different blastomeres.

Clear cytoplasm; produces larval epidermis.

Yellow cytoplasm; gives rise to muscle cells.
Grey vegetal cytoplasm; gives rise to gut.
Grey equatorial cytoplasm; produces notochord and neural tube.

Role of Nucleus in Development

Most gene controlled substances, which can easily be identified, are found in the cytoplasm, and are probably produced in it. Through experiment it is found that production of developmentally active substances by the nucleus itself or its immediate neighbourhood, is however, available in some cases:

Experiment on Acetabularia to observe Nuclear Role

Acetabularia is a unicellular alga, consists of a foot, stalk with an umbrella shaped cap at its top. On the basis of structure and shape of the cap, two species of ***Acetabularia*** have been identified. (***Acetabularia mediterranea***, which has regular shaped cap and ***Acetabularia crenulata***, which has irregular shaped cap). (Fig.21.7)

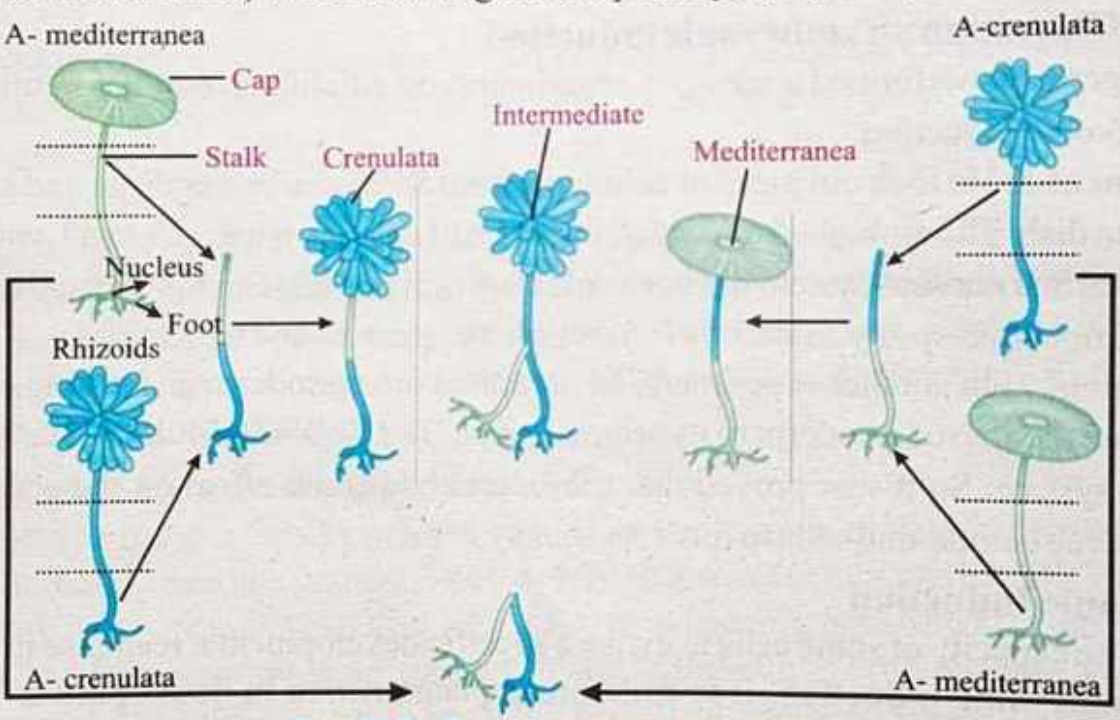


Fig. 21.7: Experiment on Acetabularia

There is only a single nucleus in foot, although the alga may attain the size of several centimetres or more. **Hammerling** showed that if the cap of this alga is removed, a new one is regenerated. He cut off the nucleus containing base (foot) from an alga of one species (***A. mediterranea***) and grafted a similar piece containing the nucleus of another species (***A. crenulata***). When the cap was removed, it was seen that the new regenerated one had the characters of ***A. crenulata***. So nucleus lying at the base of the alga and not the stalk to which the regenerate was attached determined the structure of cap. It means that irrespective of the fact to which species the cytoplasm belonged, the genes were able to

express according to the type of nucleus.

Conclusion of above Experiments

From all these experiments, it was concluded that both gene and cytoplasm play important role in development. Nucleus contains all the genes, which determine the characteristics of the individual, while cytoplasm plays the role that genes, transcribe at their proper time.

21.2.2 Differentiation and Embryonic Induction

A zygote contains cytoplasmic components which are not distributed equally within the egg. These different cytoplasmic components are believed to have morphogenetic **determinants** that control the functioning of a specific cell type. This is now called differentiation. So zygote contains complete information for the development of an individual but it is difficult to see how these cells differentiate.

Work of Spemann on embryonic induction

Spemann performed a series of experiments on amphibian embryo to understand the embryonic induction.

Experiment 1: He took out piece of ectoderm from *Salamander's* embryo and grew it in a separate dish. The embryo, from which the piece of ectoderm was removed, was unable to form normal nervous system but has a defective nervous system. Similarly, the isolated piece did not develop any structure even though it was active and healthy.

Experiment 2: In another experiment, he separated the mesoderm underlying ectoderm and folded the flap of ectoderm to its original piece. The *Salamander* did not develop any nervous system. So it was proved that mesoderm had some effect on the ectoderm to stimulate the ectodermal cells to form nervous system.

Embryonic Induction

The capacity of some cells to evoke a specific developmental response in others is called **embryonic induction**. It is widespread phenomenon in development. Work on embryonic induction was reported by **Hans Spemann** and **Hilde Mangold in 1924**. They took two embryos of salamander at the gastrula stage and removed a piece of dorsal lip of blastopore from one embryo then transplanted it into a ventral or lateral position of another salamander gastrula. It invaginated (put in sheath or turn inside out) and developed a notochord and **somites**. It also induced the second embryo to form neural tube and a complete nervous system was formed where the dorsal blastopore lip was placed.

Later on, it was seen that only cells from the dorsal lip of blastopore were capable of inducing a complete embryo. This area corres-ponds to the presumptive areas of

notochord, **somites** and **prechordal plate**. Spemann designated the dorsal lip area, the **primary organizer** because it was the only tissue capable of inducing development of secondary embryo in the host. This was called **primary induction**. Subsequentstudies revealed that many other cell types originate by inductive interactions, a process called **secondary induction**. *e.g.* cells of the neural plate induce neural crest in the embryo. (Fig.21.8)

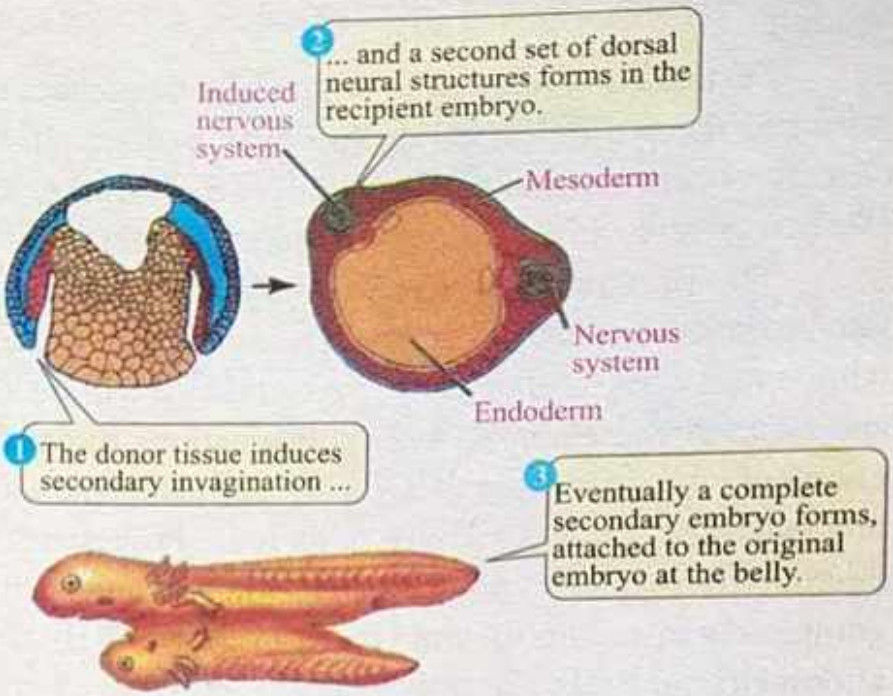


Fig. 21.8: Experiment of Primary Organizer

21.3 Human Embryonic Development

Soon after syngamy, the fertilization occurs and one celled **zygote** is formed. The zygote undergoes changes that leads to the formation of embryo, fetus and ultimately to

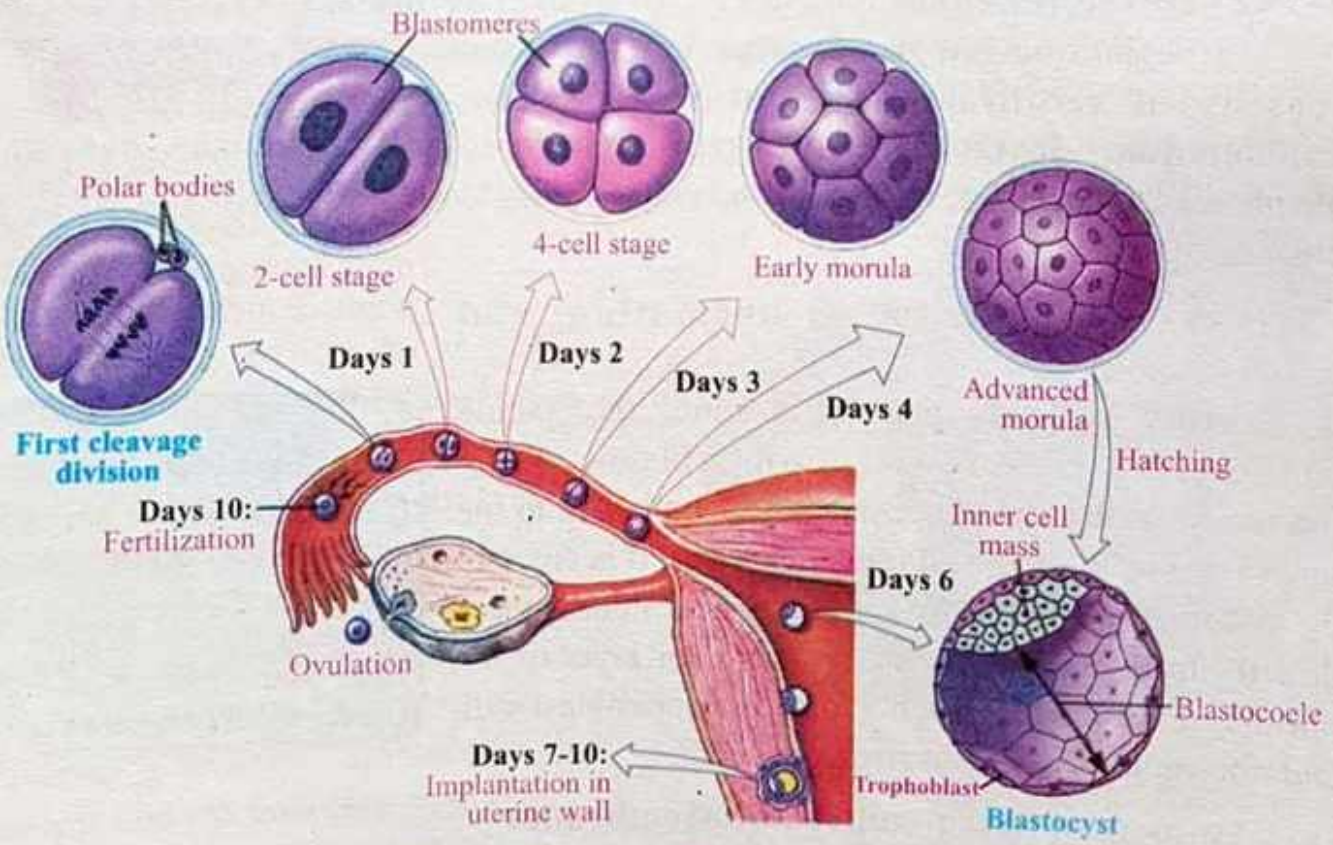


Fig. 21.9: Cleavage and Blastocyst Formation

an adult.

Fertilization (conception) normally takes place in proximal portion of **fallopian tube** and the zygote travels down towards uterus. In the fallopian tube, it undergoes cleavage which leads to the formation of blastocyst (a cluster of cells resembling a tiny raspberry) by the time it reaches the uterus. (Fig.21.9)

The **pregnancy is** usually established when blastocyst implanted (embedded) into the **endometrium of uterus**. The inner cells of blastocyst will become the embryo while outer cells (extra embryonic ectoderm) will become the membranes that protect and nourish the embryo. After implantations the embryo begins to secrete **human chorionic gonadotropin (HCG)** which retains the **corpus luteum,** thus secretion of progesterone continues (FSH inhibited). Progesterone maintains and develops the endometrium. The outer protective membrane of embryo, the **chorion** grows and completely surrounds the embryo. It develops **villi** (fibrous projections) and burrows into endometrium. Later placenta begins to form, which nourishes the fetus throughout the pregnancy. A normal human pregnancy or gestation period lasts nine months (280 days) from the time of the last mensuration or 266 days after fertilization.

Human gestation period can be divided roughly into three **trimesters** (three months period).

21.3.1 Development of Human Fetus in first Trimester

It begins from **last menstrual period (LMP)** and consists of fertilization, blastocyst formation, implantation, development of extra-embryonic membranes, placental development and major events of organogenesis.

Interesting Information

HCG (human chorionic gonadotropin) is known as pregnancy hormone, because during pregnancy test, this hormone is recorded.

Fertilization, Blastocyst formation and implantation

After syngamy and fertilization, the zygote undergoes to a series of cleavage to form blastocyst. The blastocyst, at the end of second week, implanted to the inner layer of uterine wall (endometrium). It is covered by endometrial cells. Now embryo gets nourishment directly from the endometrium. The outer layer of the blastocyst is known as trophoblast. The trophoblast with endometrium slowly gives rise to placenta.

Extra Information

Conception is the time when sperm travels up through the vagina in to the uterus and fallopian tube to fertilize the egg. Thus female becomes conceived or pregnant a child.

Development of Extra-embryonic Membranes

All those membranes which protect and nourish the embryo are collectively

known as extra embryonic membranes. These are amnion, allantois, chorion and yolk sac.

Amnion is first protective coat, which is personal pond of embryo and fetus. It is filled with fluid and gives watery medium which protects fetus from physical trauma. The second protective coat is **allantois,** contributes to the circulatory system. Its blood vessels become umbilical cord (blood vessels of fetus), that transport blood to and from the placenta. The third protective coat is **chorion**, covers all other membrane and becomes the part of placenta. The **yolk sac** contains little or no yolk in case of human. It is first site of RBC formation and also become a part of **umbilical cord**. (Fig.21.10)

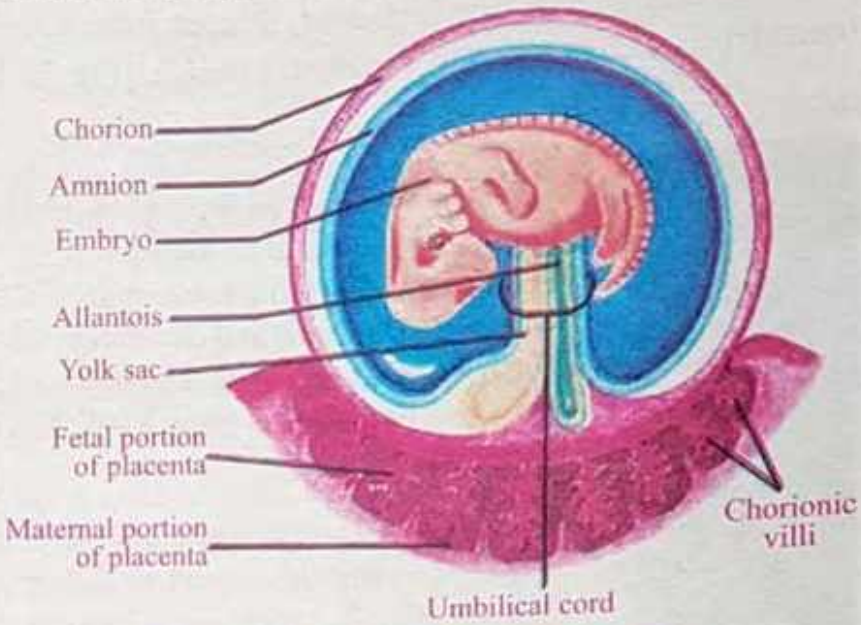


Fig.21.10: Extraembryonic Membranes

Placental Development

Some cells of the embryo grow into a disk like structure known as **placenta,** which closely attaches the embryo to umbilical cord and mother blood vascular system. It helps in the exchange of glucose, amino acid, salts, CO_2 and urea between mother and fetus. It also produces some hormones like estrogen and progesterone to maintain pregnancy.

The placenta grows throughout pregnancy; however, development of the mother blood supply to the placenta is completed by the end of the first trimester (about 12-13 weeks). The corpus luteum slowly degenerates due to decline of human chorionic gonadotropin and placenta take over the production of progeste-

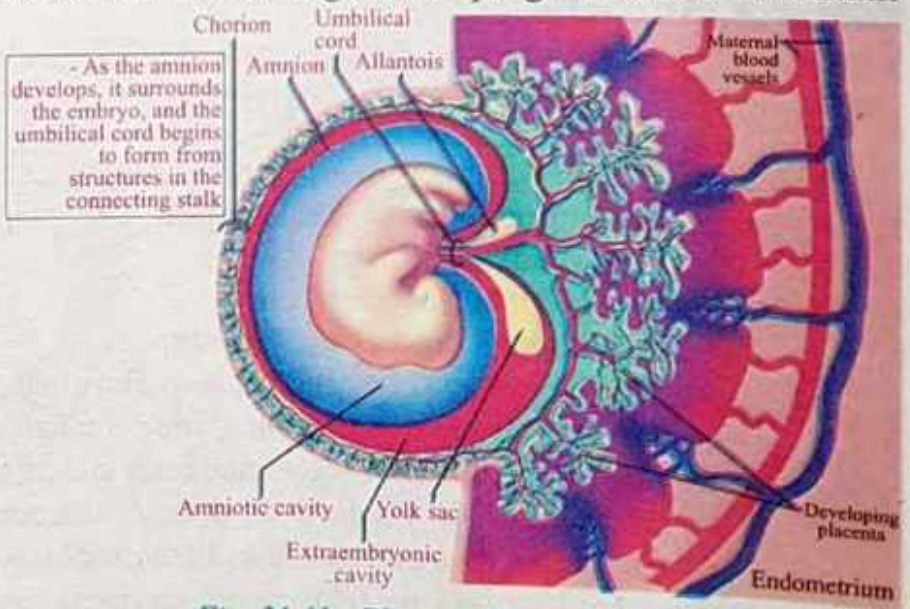


Fig. 21.11: Placentral Development

rone to maintain pregnancy.

At the end of first trimester, fetus is fully formed, weighing about one ounce and measuring, an average 3 to 4 inches in length. (Fig.21.11)

Table 21.1: Major Events During First Trimester

By the end of four weeks	1. All major systems and organs begin to form 2. The embryo looks like a tadpole 3. The neural tube (which becomes the brain and spinal cord), the digestive system and the heart and circulatory system begin to form. 4. The beginnings of the development of eyes and ears. 5. Tiny limb buds appear (which will develop into arms and legs) 6. The heart is beating.
By the end of eight weeks	1. All major body systems continue to develop and function, including the circulatory, nervous, digestive and urinary systems. 2. The embryo is taking on a human shape, although the head is large in proportion to the rest of the body. 3. The mouth is developing, tooth buds (which will become baby teeth). 4. The eyes, nose, mouth and ears are becoming more distinct. 5. The arms and legs are clearly visible. 6. The fingers and toes are still webbed but can be clearly distinguished. 7. The main organs continue to develop and the babies' heartbeat can be heard with ultra sound examination using an instrument called a fetal Doppler. 8. The bones begin to develop, the nose and jaws are rapidly developing. 9. The embryo is in constant motion but cannot be felt by the mother.
From embryo to fetus	1. After eight weeks, the embryo is now referred to as a fetus (which means offspring). 2. Although the fetus is only 1 to 1 ½ inches long at this point, all major organs and systems have been formed.
During weeks 9 to 12	1. The external genital organs are developed. 2. Finger nails and toe nails appear. 3. Eyelids are formed. 4. Fetal movement increases. 5. The arms and legs are fully formed. 6. The voice box (larynx) begins to form in the trachea. The fetus is most vulnerable during the first 12 weeks. During this period of time, all of the major organs and body systems are forming and can be damaged if the fetus is exposed to drugs, radiation, tobacco and chemical toxic substances. Even though, the organs and body systems are fully formed by the end of 12 weeks, the fetus cannot survive independently.

Second Trimester

During second trimester, fetus looks quite human, sexes becomes apparent and can be determined with the help of **ultrasound**. In girls uterus and ovaries are going to develop while in males testes begin to descend. During this trimester, the baby grows to about 0.6kg and 0.3-meter long. The sensory organs are almost completely developed; fetus can hear, eyelids and lashes are quite apparent. The heartbeat of fetus can be felt through **stethoscope**. The head is about half of the overall body size. Mother can feel movements of fetus and fetus moves around, finger prints beginning to develop (finger prints are unique to every individual; even identical twins have different finger prints).

Third Trimester

The third trimester is rapid growth period. During this stage, body weight increases about 28 grams per day *i.e.* double several times. Eyes are open, subcutaneous fat begins to be deposited. At the end of this trimester, the fetal head descends towards the cervix. After 9 months of pregnancy or normal delivery, baby might be about 18-20 ½ inches and weigh 6 to 9 pounds or about 3400 grams.

21.3.2 Twins and Quadruplets

Two or more fetuses in one pregnancy are called multiple fetuses, which may be either identical or non-identical (fraternal).

Identical twins or **quadruplets** come from **monozygote** *i.e.* a single ovum which has been fertilized by one sperm. During first or second or third cleavage, the cells of zygote separate and two, four or eight embryos are formed. All are of same sex, blood type and most other features. They do not always look exactly alike, such as different

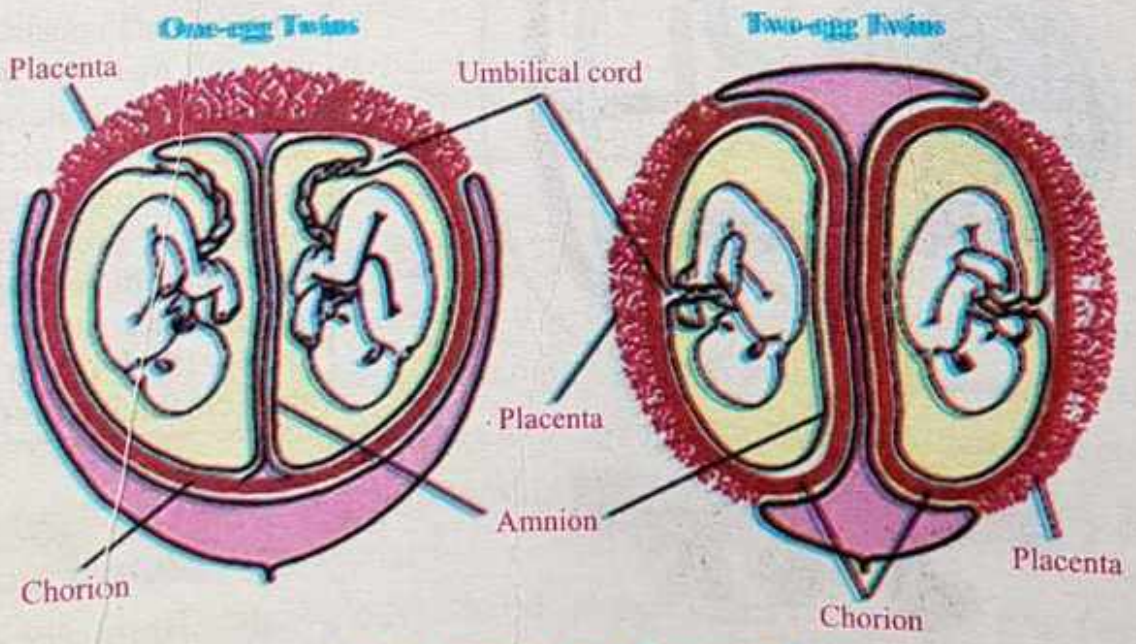


Fig. 21.12: Identical and Fraternal Twins

finger prints or one may be right handed while other left handed. Identical twins mostly share the **same placenta** and **chorion** but usually grow in separate amniotic sacs in uterus.

Fraternal twins or **non-identical twins** come from multiple fertilized eggs *i.e.* **dizygotic** or **multiple zygotic.** They may be of same sex or different sex. Their placenta and amniotic sacs are also separated. These differ from each other in many features. (Fig.21.12)

21.3.3 The Placenta and Umbilical Cord

It is the physiological adjustment of the new-born with mother till birth. The placenta was the source of nutrients and oxygen for the fetus. It was the site for the removal of waste products from fetal circulation because the lungs were not functional as organs of gas exchange. The fetal body had two major adaptations to limit the flow of blood to the lungs. First a hole between two atria known as **foramen ovale** shunted most atrial blood directly into the left atrium, thus avoiding the right ventricle and pulmonary circulations. In addition, the right ventricular blood, that is pumped into the aorta rather through the lungs by **ductus arteriosus** (connection between pulmonary

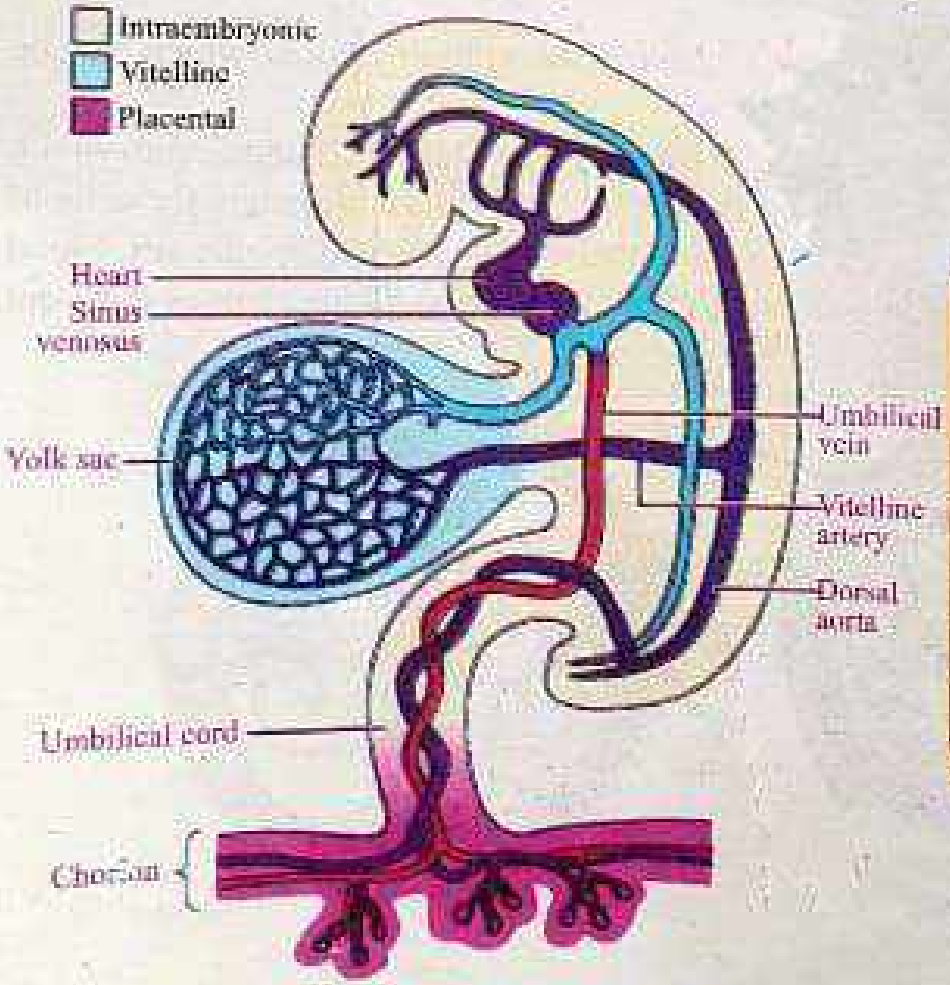


Fig. 21.13: Umbilical Cord

Interesting Information

The placenta consists of fetal part and maternal part. Fetal part consists of chorionic villi, which increase surface area for absorption. Maternal part consists of projections from endometrium. Average weight of placenta is about 600 grams, 15-20 cm in diameter and 3 cm thick at the centre.

artery and aorta). At birth, the foramen ovale is closed by two flaps of heart tissue that fold together and fuse.

The ductus arteriosus is shut off by contractions of muscles in its walls. Complete closure may take several months. The two umbilical arteries and one vein also must close off.

The **umbilical cord**, also called **naval string** develops and connects the embryo to the placenta. In human, the umbilical cord normally contains one umbilical vein, supply oxygenated blood, nutrient rich from the placenta. It also contains two umbilical arteries which brings back deoxygenated blood, nutrient depleted blood to placenta. Thus fetal heart pump only deoxygenated blood to placenta. (Fig.21.13)

21.3.4 Difference between Gestation and Pregnancy

The **gestation** is the period of time between **conception** and **parturition** (birth). During this period the young one grows and develops inside the mother's uterus. Gestational age is the common term used during **pregnancy** to describe how far along the pregnancy is, that is normal pregnancy can range from **38 to 40 weeks or 9 months**.

21.4 Birth and Nursing

Birth is also called **parturition** or **labor,** normally towards the end of pregnancy, the uterus becomes progressively more excitable. It develops such strong rhythmical contractions that baby is expelled. Many types of hormones aid in parturition such as estrogen, progesterone, many fetal and maternal hormones.

21.4.1 Role of Fetal and Maternal Hormones in Controlling Birth

The birth of baby is controlled by many fetal and maternal hormones. Two things must happen for normal birth, the muscles in the **womb** and abdominal wall have to contract and the cervix needs to soften or increase in diameter.

The estrogen and progesterone are secreted during pregnancy but from seventh month onward, estrogen secretion becomes greater than progesterone secretion. It stimulates the **myometrial cells** of the uterus to form abundant **oxytocin receptors**. Due to these receptors myometrium becomes more irritable and weak, thus irregular uterine contraction initiated. These uterine contractions are known as **Braxton Hick contractions** or **false labor pains**. The **false labor pains** convert into **real labor pains** with the help of two other chemical signals, which are:

i) Oxytocin

It is secreted from fetal pituitary gland which might play a role in exciting the uterus.

ii) Fetal pituitary gland

also secretes **Adrenocorticotropic Hormone (ACTH)** which stimulates the adrenal gland to release **corticosteroids**. It affects two regions, firstly the placenta and causes a decrease in the production of progesterone. Secondly it also stimulates the fetal membrane to produce an increased secretion of **prostaglandins**. The hormone oxytocin causes contractions of uterine myometrium and prostaglandin increase the power of the contraction. Now these powerful contractions stimulate mother's

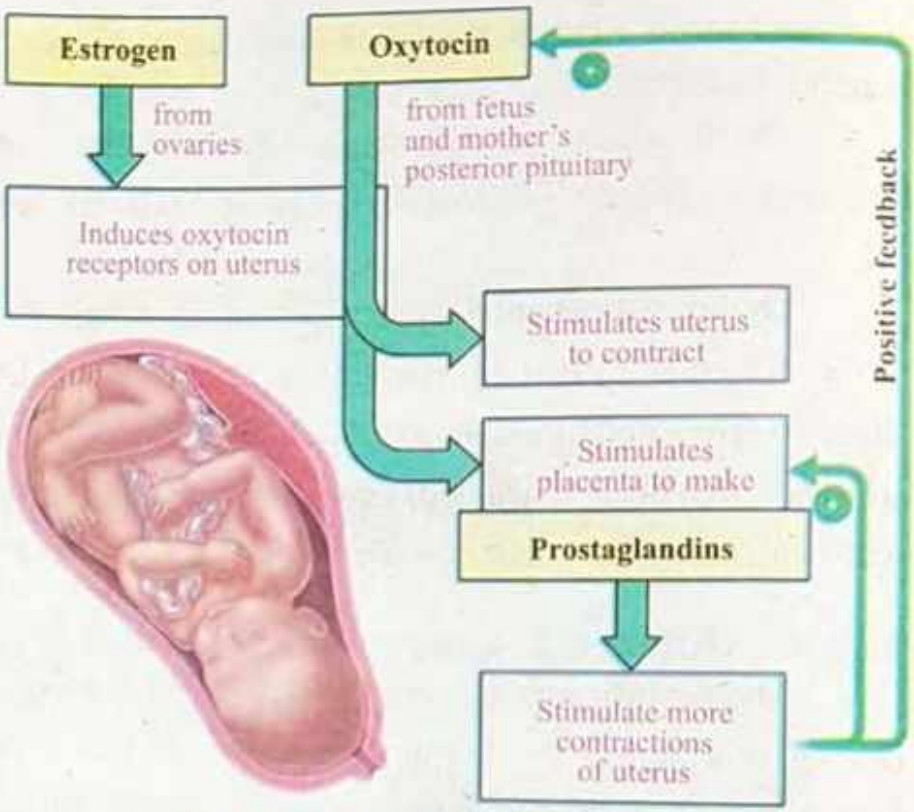
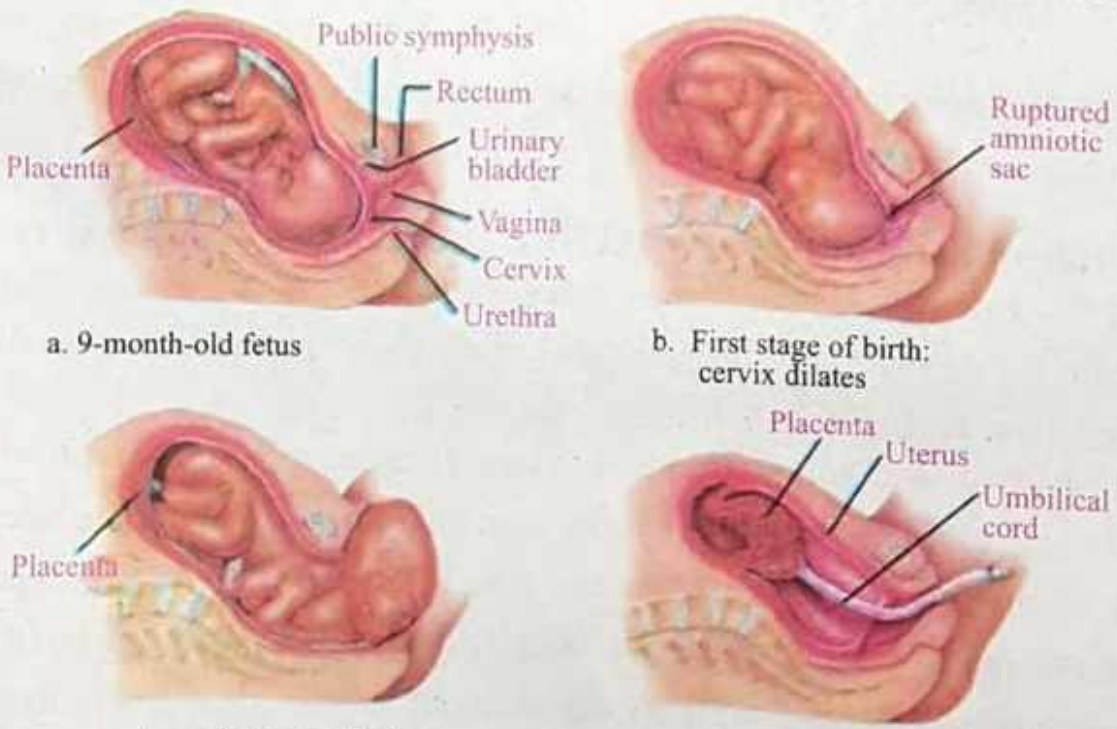


Fig. 21.14: Hormonal Control of Birth (Positive Feedback Mechanism)



a. 9-month-old fetus

b. First stage of birth: cervix dilates

c. Second stage of birth: baby emerges

d. Third stage of birth: expelling afterbirth

Fig.21.15: Process of Birth

hypothalamus, which signals for oxytocin release by the mother's posterior pituitary gland. Thus true labor begins *i.e.* positive feedback mechanism helps the release of more and more oxytocin, which causes greater contractile force and so on. The release of oxytocin occurs in waves during labor.

The process of labor (birth) has three steps *i.e.* cervix dilation, expulsion and placental removal.

- The **cervix dilation** is first step that is opening up and thinning of the cervix.
- The **expulsion** of the baby is second step *i.e.* strong continuous contractions force the fetus down and out of the uterus and vagina.
- Soon after birth the **expulsion of placenta** takes place. (Fig.21.15)

Clamping and Cutting of Umbilical Cord

After the delivery of the baby (second stage of the birth) the umbilical cord is still attached to the baby. The umbilical cord is clamped artificially as early as 1 to 5 minute after the birth of the child. Clamping is followed by cutting of the cord, which is painless due to the lack of any nerves.

After Birth

Following the birth of the foetus, usually within 10-15 minutes, the placenta separates from the uterine wall and is expelled by uterine contractions through the birth canal. This expulsion is termed the afterbirth.

21.4.2 The Premature Birth

The premature or preterm birth of baby means less than 27 weeks (6 months) of gestational or pregnancy period, which is caused by many factors during **second and third trimester**. These factors include:

1. Smoking and not getting good prenatal care.
2. Being overweight or underweight during pregnancy.
3. High blood pressure, blood clotting disorders, diabetes mellitus.
4. Getting pregnant too soon after having a baby.
5. Multiple births and a baby that has certain defects.

The premature baby faces many complications such as:

1. Increased risk of infections.
2. Difficulty in maintaining body temperature.
3. Feeding problem and may cause jaundice.
4. Breathing difficulty because lungs are not fully developed.
5. Some high terms complications like blindness, disturbance in hearing capacity.

21.4.3 Colostrum, Lactation or Nursing

The secretion and yielding of milk by mother after giving birth is called **lactation**.

The new born baby is supplied with maternal milk soon after birth. Initially mammary glands of mother produce special yellow color lymph like fluid known as **colostrum**. It is quite rich in antibodies (particularly IgA), little fat and less lactose and globulin protein than milk.

Later after 2 or 3 days of birth, milk production begins by prolactin, secreted from anterior pituitary (under the influence prolactin releasing hormone). This hormone also prepares and enlarges the mammary glands for milk production and storage. Once the mammary glands filled with milk, it synthesizes **serotonin neurotransmitter**, which slows down prolactin production. In majority of cases as soon as breast feeding stops by mother, her reproductive cycle begins again. However, sometimes the reproductive cycle can initiate even when mother is breast feeding.

Role of Oxytocin in the Secretion of Milk

The sensory receptor around nipples is stimulated by sucking of baby on breast that creates nerve impulses. These impulses pass from receptors to the hypothalamus which also stimulates posterior pituitary to release oxytocin.

Oxytocin causes dilation of milk ducts within mammary glands and thus promotes ejaculation of milk. The nursing of milk is also helpful for mother because this is also responsible for the contraction. Thus it returns uterus to its pre-pregnant size.

Table 21.2: Comparison of Breast Feeding and Bottle-Feeding

Breast Feeding Nutrition	*Bottle-Feeding Nutrition*
It contains perfect balance of nutrients.	It is not efficiently utilized as breast milk.
Having high level of nutrients.	Nutritional contents depend on proper preparation.
It is digested and absorbed easily, always at perfect temperature.	Some babies have difficulty in tolerating certain elements.

Breast Feeding		*Bottle-Feeding*	
Advantages	**Disadvantages**	**Advantages**	**Disadvantages**
Baby gets immunity and readily available at any time and any place.	Baby early breastfeeding may be uncomfortable.	Baby does not get immunity but presence of mother is not necessary.	Preparation time varies, can be unhygienic.
Creates affections of mother and child due to prolactin.	Certain medication can interrupt breastfeeding.	No or less affection due to absence of prolactin.	Baby may not tolerate formula well. Always have to carry bottles, formula/mixing items with you.

21.5 Disorders during Embryonic Development

Fetus faces many disorders at birth, which are collectively known as embryonic development disorders or birth defects.

21.5.1 Maternal derived abnormalities

The abnormalities or disorders are transmitted from mother to fetus during pregnancy or just after birth, such as rubella, neural tube defect, thyroid gland and development defects, *etc.*

Rubella

It is caused by the rubella virus and also called as German measles. Rubella virus can be extremely dangerous if the mother is infected within the first twenty weeks of pregnancy, the baby may be born with **Congenital Rubella Syndrome (CRS).**

The CRS syndrome follows intrauterine infection by Rubella virus and comprise cardiac (Patent Ductus Arteriosus), cerebral, ophthalmic (cataract) and deafness.

It may also cause prematurity, low birth weight, anaemia and hepatitis.

Neural Tube Defects (NTDs)

These are serious birth defects with symptoms that range from mild to severe impairment, occur due to abnormal closure of neural fold. They are caused by incomplete development of the brain, spinal cord and meninges.

The fetus spine fails to close properly during the early stages of pregnancy. (Fig. 21.16)

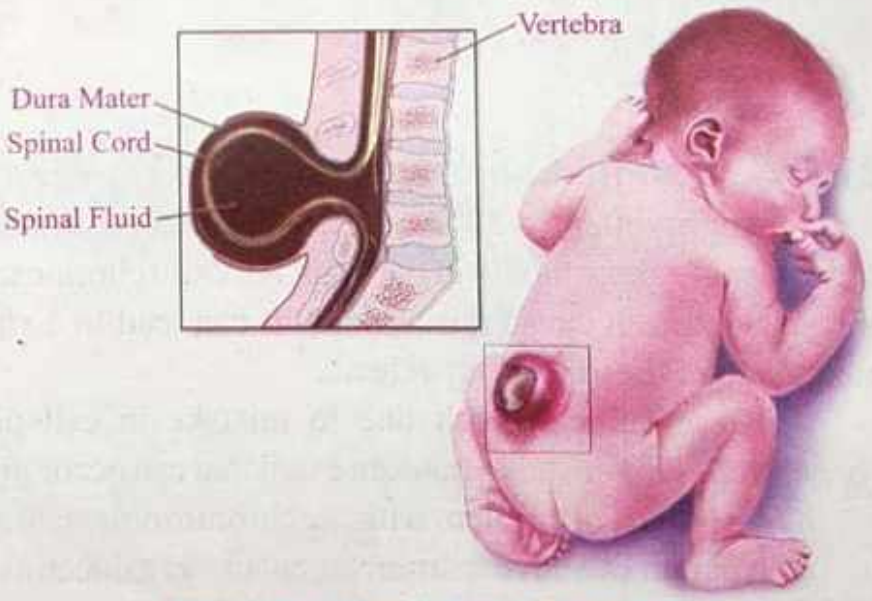


Fig. 21.16: Neural Tube Defects (NTDs)

Thyroid gland disorder

It is congenital hypothyroidism of new born baby. The baby frequently has **hyperbilirubinemia**, and delayed skeletal maturation, reflecting immaturity of liver and bone respectively. They are at risk of permanent mental retardation if thyroid hormone therapy is delayed or inadequate. Their size at birth, however, is normal.

Developmental Defects

The upper and lower limbs have a large number of different genetic and environment derived abnormalities, some of which can be surgically repaired. Among

them partial or complete absence of limbs or digits are common. (Fig.21.17)

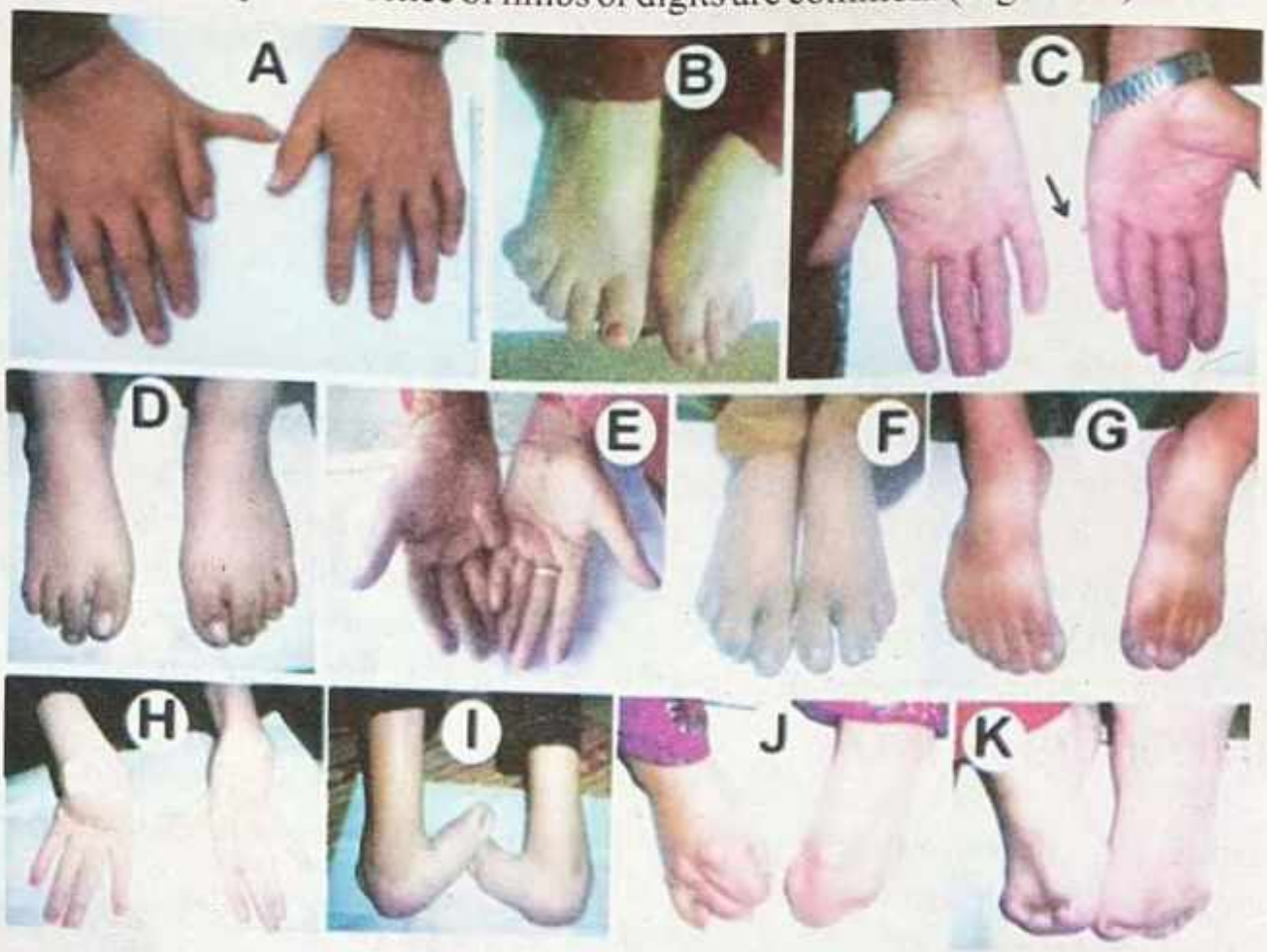


Fig.21.17: Limbs Development Defects

21.5.2 Genetic Abnormalities related to Spontaneous Abortions

Approximately 50% of first and second trimester miscarriages are due to a chromosome abnormality in the fetus. An extra chromosome (2n+1) or a missing (2n–1) chromosome can cause miscarriage. It can lead to a child with learning difficulties or mental retardation and birth defects.

These defects result due to mistake in cell division soon after the time of conception. This error is a random event that can occur in anyone's pregnancy.

An inherited problem with the chromosomes can also cause miscarriage.

A parent can have rearrangement (a "translocation") of his or her chromosomes, in which the chromosomes are structured differently.

Another genetic cause of miscarriage is a change in a single gene or several genes on the chromosomes. This can cause specific genetic diseases or birth defects.

21.5.3 Fetal Surgery and defected fetal Development Problems

The surgery of fetus within maternal uterus to treat parental defect is called **fetal surgery**.

Open Fetal Surgery

During open fetal surgery, uterus is completely opened to operate the fetus. This surgery is done to treat or close the neural tube defects. It is also used for congenital disease like **diaphragmatic hernia**.

Extra Information

Diaphragmatic hernia is an abnormal opening in diaphragm, thus organs move from belly to chest cavity near lungs.

Minimally Invasive Foetoscopic Surgery or Fotendo

This surgery uses small incisions and is guided by foetoscopy and sonograpy. It is used for:

- Fetal bladder outlet obstructions (FOO), it is blockage of the bladder.
- Pulmonary/Aortic valvuloplasty
- Atrial Septostomy (a small hole is created between the atria of heart).

Interesting Information

Valvuloplasty is the widening of a stenotic aortic valve using a balloon catheter inside the valve.

21.6 Postnatal Development

There are five stages of postnatal development, which are neonatal, infancy, childhood, puberty (adolescence) and adulthood (maturity).

- The stage from birth to one month is called **neonatal**.
- The stage from one month to two-year age is called **infancy**.
- **Childhood** from third year to 12-14 years.
- **Adolescence** begins at around 12 to 13 years of age till adult hood.
- **Adulthood** includes the year between 18 to 25 years of age.
- The process of ageing is called **senescence**.

21.6.1 Allometeric Growth

The term **allometeric growth** means differential growth *i.e.* varying rates of growth for different parts of the body during development of baby. For example, head of human baby is larger than to the rest of body. Similarly, tarsus of foot, hands and legs grow more rapidly than head. The reproductive organs grow more slowly than other organs till childhood. Some systems like lymphatic system develops more rapidly in early age and after puberty become decrease. The skull and brain reach to its maximum size well before adulthood *i.e.* about 90% of adult size soon after age of 06 years.

21.7 Ageing

Ageing is negative physiological changes in our body or we can say it is the phenomenon of getting old. Ageing is inevitable process, it cannot stop or prevented. The study of ageing is called **gerontology**. Development continues throughout stages of life

but after growth and differentiation, cells begin to deteriorate. The average human life is between 70 to 80 years (maximum 110-115).

21.7.1 Genetic and extrinsic factors responsible for ageing

Genetic or Intrinsic Factor

Several evidences have been discovered that exhibit ageing has a genetic basis. Many experiments have shown that human cells will divide less than 100 times outside the body. The reason behind it is **telomeres**. The end of each chromosome contains specific nucleotide sequence, which is called **telomeres**. This is at maximum length during fetal stage, later becomes the nucleotide sequence telomeres decreased after each mitosis. When these nucleotide sequences are shortened to a critical length, the cell is no longer able to divide thus damaged tissues cannot regenerate and we begin to wear out.

Extrinsic Factor

Many extrinsic factors lead to ageing, mostly due to poor health, osteoporosis and cardiovascular diseases are important factors.

Osteoporosis

It is the progressive decline in bone density which results to bone fracture. There is no denying that osteoporosis occurs as a result of ageing. The causes of osteoporosis are **menopause**, cigarette smoking, drinking heavy alcohol and deficiency of Ca^{+} and vitamins.

Cardiovascular diseases

Cardiovascular diseases are leading cause of ageing and death. It can be prevented with balance diet including vegetables, fruits and regular exercise.

21.7.2 Signs and Symptoms

There are many different signs and symptoms of ageing. Most of these develop gradually and are very diverse, but it should be remembered that it is not possible to diagnose ageing based on isolated signs and symptoms alone. Different people possess widely varying degrees of these signs and symptoms.

Primary Ageing

- An overall decrease in energy and vigour.
- Changes in sleeping patterns.
- Decreased memory.
- Skin and hair changes such as **wrinkles, brown spots on the skin, loss of skin elasticity, hair become thin and loss affecting the limb**.
- Muscles weakened therefore movement becomes slow.
- A loss or decrease in vision and hearing.
- Susceptible to infection and stress.

- Sexual dysfunction and urinary problems such as inconsistence, dribbling and change in frequency of urination.
- Changes in menstrual cycle.
- Abdominal obesity and inability to lose weight.

Secondary Ageing

This process results from diseases and poor health practices (*e.g.* no or less exercise, smoking, malnutrition, excess fat, exposure to ultra violet light and other forms of self-damage). It is often preventable whether through lifestyle choice or modern medicines.

21.7.3 Cell Level Changes in Ageing

Teratology

It is the study of abnormal development.

All cells change as they age. Cells become larger; their capacity to divide and reproduce tends to decrease. Normal cells have built-in mechanisms to repair minor damage but the ability to repair declines in ageing cells.

DNA is damaged through the ageing process and changes occur in:

- Cellular membrane;
- Enzymes;
- The transport of ions and nutrients;
- The nucleus chromosomes undergo such changes as clumping, shrinkage, and fragmentation.

Other changes occur in organelles like mitochondria and lysosomes where numbers are reduced, causing cells to function less efficiently. This effect also ties in with a decrease in hormonal secretions. A decrease in metabolism has several effects:

- Toleration of cold is less;
- A tendency to gain weight increases;
- There is a decreased efficiency in the body's use of glucose

21.7.4 System Level Changes in Ageing

Mostly gastro-intestinal tract maintains its functional level well into old age. The areas which are defected in old age are alteration in taste, decrease stomach acidity and decreases blood flow to the liver. The secretion of saliva from salivary glands become less than normal thus affects chewing and swallowing. It also affects the taste of food.

Usually ageing is accompanied by a lower product of neurotransmitters, but only when a drop approaches 50% will ensure **dementia** (15% old age have severe dementia). Due to malnutrition, the heart becomes smaller than normal while some time larger than normal due to severe high blood pressure or unchanged in size. Fat will accumulate in the heart muscle, as a response an increase in total body fat take place.

Infections occur more frequently in the elderly and are more often severe due to

low degree working of immune system.

Fertility in man gradually declines with age while in women it ends with menopauses.

Science, Technology and Society (STS)

1. List some diseases due to ageing and what medical science is doing to treat those diseases.

Osteoarthritis: Anti-inflammatory drugs and painkillers are given in the early stages. Later a joint replacement may be necessary.

Osteoporosis: Calcium intake is recommended in the form of medicine or food. Hormone therapy is recommended for most women after menopause if they wish to avoid problem (ERT).

Arteriosclerosis: Lifestyle changes, such as eating a healthy diet and exercising, are often the best treatment for arteriosclerosis. But sometimes, medication or surgical procedures may be recommended as well.

2. Describe how a blastula is divided into two (by using micros manipulator) to produce twins of the animals for biological research.

Micromanipulator is a device used to manipulate small material and specimen under a microscope. The best example of micromanipulation is the division of blastula in order to produce twin embryos for the purpose of biological research.

SUMMARY

- Embryonic development is the progressive changes which are undergone before an organism acquires its adult form.
- Zygote leads to a multicellular stage known as embryo.
- The study of embryo is called embryology.
- Cleavage is the division of zygote where number of cells increase but size of cell does not increase.
- A solid ball of small cells during cleavage is called morula.
- Blastula is a hollow ball of cells.
- Each daughter cell up to blastula is known as blastomere.
- Holoblastic and meroblastic are two type of cleavage on the basis of amount and distribution of yolk.
- Gastrulation is the phase of embryonic development which is characterized by differentiation of embryonic germ layer.
- The three germ layers are ectoderm, mesoderm and endoderm.

- The first major phase in organogenesis is neurilation.
- By the start of third month, the embryo is called fetus.
- Grey crescent is the area, which is important for proper development.
- Pregnancy is established when blastocyst is implanted into the endometrium.
- The human gestation period is 266 days after last menstrual period.
- Human pregnancy can be divided into three trimesters.
- Lactation is secretion and yielding of milk by mother after giving birth.
- Rubella is commonly known as German measles.
- The five life stage of postnatal development are neonate, infant, childhood, adolescence and adulthood.
- The study of ageing is called gerontology.
- Fertility in man gradually decline with age while in female it ends with menopause.

EXERCISE

SECTION-I: OBJECTIVE QUESTIONS

Multiple Choice Questions (MCQs)

A. Select the correct answer.

1. The hypoblast is mainly presumptive.
   (a) Endoderm (b) Mesoderm
   (c) Ectoderm (d) Blastoderm
2. At the cephalic end of primitive streak, closely packed cells from local thickening are known as:
   (a) Primitive gut (b) Primitive ridges
   (c) Splanchnic mesoderm (d) Hansen's node
3. The cavity formed between somatic and splanchnic mesoderm is:
   (a) Archenteron (b) Henson's node
   (c) Coelom (d) Neurocoel
4. The morula is still about the same size of:
   (a) Sperm (b) Zygote
   (c) Mulberry (d) Blastocyst
5. New mothers experience cramps in uterus while nursing because of:
   (a) Prolactin (b) Oxytocin
   (c) Both a and b (d) hCG

6. Cleavage begins from zygote and end into
(a) Morula (b) Gastrulla
(c) Blastula (d) Neurula

7. During cleavage, mulberry like compact ball is
(a) Morula (b) Blastulla
(c) Gastrula (d) Blastoderm

8. Blastomeres are formed during
(a) Gastrulation (b) Neurilation
(c) Cleavage (d) Growth

9. The umbilical cord in human contains
(a) One artery. two vein (b) Two arteries one vein
(c) Only one vein (d) Only two vein

10. Study of ageing is called
(a) Teratology (b) Paleozoology
(c) Gerontology (d) Biotechnology

11. Neurula tube is formed from
(a) Ectoderm (b) Endoderm
(c) Mesoderm (d) Hypoblast

12. Average gestation period in human female is
(a) 280 days (b) 250 days
(c) 320 days (d) 350 days

13. The fluid which surrounds embryo is called
(a) Amniontic fluid (b) Chorionic fluid
(c) Yolk (d) Uterus fluid

14. Prolactin prepare the mammary glands for the production of
(a) Sweat (b) Sebum
(c) Milk (d) Mucus

B. Fill in the blanks.

1. ..... beings at around 12 or 13 years.
2. Blastomeres are formed during .....
3. Neural plate is formed from .....
4. The negative physiological changes in our body are said to be .....
5. Ectoderm, mesoderm and endoderm are three ..... layers.
6. Rubella, commonly known as German .....
7. The cleavage, in which entire egg divides into daughters' cells is called .....

8. The pigment free area that appears at the time of fertilization is known as grey .....
9. The upper layer of cells of blastoderm is called .....
10. The lower layer of cells of blastoderm is called .....

SECTION-II: SHORT QUESTIONS

C. Give the short answers of the following questions.

1. Define morula, blastula and gastrula.
2. Write signs/symptoms of ageing.
3. Differentiate between meroblastic and holoblastic cleavage.
4. Write fate of three embryonic germ layers.
5. Describe changes in fetus during third trimester.
6. Differences between identical twins and non-identical twins.
7. Write note on umbilical cord.
8. Describe briefly about Rubella.
9. Illustrate the postnatal development.
10. Write changes that occur at cellular level during ageing.

SECTION-III: EXTENSIVE QUESTIONS

D. Give detailed answers of the following questions.

1. Explain gastrulation in human.
2. Describe human embryonic development.
3. Write role of hormones in controlling birth.
4. Define ageing and describe factors of ageing.
5. Describe the experiments of Spemann on the development of neural tube.

UNIT 22

INHERITANCE

Major Concept

22.1 Mendelian Inheritance (Mendelian Laws)
22.2 Exceptions to Mendelian Inheritance
22.3 ABO Blood Group System
22.4 Rh Blood Group and Erythroblastosis Foetalis
22.5 Polygenic Inheritance and Epistasis
22.6 Gene Linkage and Crossing Over
22.7 Sex Determination
22.8 Sex Linkage

Learning Outcomes

Students will be able to:

- Associate inheritance with the laws of Mendel.
- Explain the law of independent assortment, using a suitable example.
- Express limitations in the law and its usefulness.
- State the scope of independent assortment in variation.
- Evaluate that inheritance of genes and their mixing during fertilization is based on mathematical probabilities.
- Describe the exceptions to the Mendel's laws of inheritance.
- Explain incomplete dominance and exemplify it through the inheritance of flower color in 4 O' clock plant.
- Differentiate between incomplete dominance and co-dominance.
- Describe multiple alleles and state the alleles responsible for the trait of ABO blood groups.
- Explain the case where two alleles have equal dominance and through the genetics of human blood group of AB.
- Name the various human blood group systems.
- Associate multiple alleles with the ABO blood group system.
- Investigate the reasons for O-ve individual as the Universal donor and AB +ve as the Universal recipient.
- Describe the occurrence of some other blood group systems.
- Associate the positive and negative blood groups with the presence and absence of Rh factor.
- Justify why Rh incompatibility could be a danger to the developing foetus and mother.
- Explain *Erythroblastosis foetalis* in the light of antigen-antibody reaction.
- Suggest measures to counter the problem of *Erythroblastosis foetalis* before it occurs.
- Explain the terms: polygenic and epistasis.

- Describe polygenic inheritance, using suitable examples from plants (grain color in wheat) and animals (skin color in man).
- List at least five polygenic traits discovered in humans.
- Relate polygenic inheritance with epistasis.
- Give one example of epistasis from mammals (coat color inheritance in Labrador retrievers) and one from plants (pigment phenotype in foxgloves) and justify modified Mendelian ratios.
- Describe the terms gene linkage and crossing over.
- Explain how gene linkage counters independent assortment and crossing-over modifies the progeny.
- Exemplify the concept of gene linkage by quoting the example of wing length and width of abdomen in *Drosophila melanogaster*.
- Suggest why linkage could be observed / evaluated only if the number of progeny is quite large.
- Explain the XX-XY mechanism of sex determination in *Drosophila* and mammals.
- Describe the XX-XO and ZZ-ZW sex determination systems and evaluate by studying the karyotype.
- Identify the difference between homogametic and heterogametic conditions in the karyotype of male and female humans.
- Identify male and female individuals from the karyotype of Drosophila and man.
- Solve the genetic problems related to XX-XY, XX-XO and ZZ-ZW sex determination.
- Describe the concept of sex-linkage.
- Explain the inheritance of sex-linked traits (eye color) in *Drosophila*.
- Describe the sex-linked inheritance of male characters due to Y-chromosome and the effect of Holandric genes.
- Describe the X-linked disorders with reference to the patterns of inheritance.
- Describe sex influenced and sex limited traits with common examples from human genetics.
- Name some of the sex-linked disorders of man and Drosophila.
- Critically analyze the inheritance of Haemophilia, colour blindness and muscular dystrophy.

Introduction

Inheritance is the process by which genetic information is passed from parents to child. This is why member of the same family tend to have similar characteristics. We actually have two genomes. We get one copy of our genome from each parents. Inheritance describes how genetic material is passed on from parent to offspring. The simplest form of inheritance was uncovered from the work of Gregor Mendel in 1865. From years of experiments using the common pea plant, Mendel was able to describe the way in which genetic characteristics are passed down from generation to generation. This passing of characters from parents to offsprings is known as **Heredity**. The difference that are shown by the individuals of a species and also by the offsprings of same parents are referred as **variations**. Variations may be harmful or useful or useless. This study of

heredity and variations is called **genetics**.

In this unit we will study Mendelian inheritance, dominance relations, multiple alleles, with example of blood groups, polygenic inheritance, epistasis, gene linkage, crossing over, sex determination and sex linkage.

22.1 Mendelian Inheritance

Mendelian inheritance refers to the patterns of inheritance that are characteristics of organisms which reproduce sexually.

Gregor John Mendel was an Austrian monk who formulated some of the fundamental principles regarding the inheritance of traits. Between 1856 – 1865, he performed number of experiments in which he cross-bred pea plants (*Pisum sativun*) with 7 pairs of contrasting characteristics Mendel explained his results by describing two laws of inheritance that introduced the idea of dominant and recessive genes. (Fig.22.1)

Character				F$_2$ Generation Ratio
Dominant Form	×	Recessive Form		
Purple flowers	×	White flowers		(3/4:1/4)
Yellow seeds	×	Green seeds		(3/4:1/4)
Round seeds	×	Wrinkled seeds		(3/4:1/4)
Green pods	×	Yellow pods		(3/4:1/4)
Inflated pods	×	Constricted pods		(3/4:1/4)
Axial flowers	×	Terminal flowers		(3/4:1/4)
Tall plants	×	Dwarf plants		(3/4:1/4)

Fig.22.1 Mendel's Seven Contrasting Pairs of Characters

22.1.1 Association of Inheritance with Laws of Mendel

Gregor John Mendel, through his work on pea plants, discovered the fundamental laws of inheritance. He deduced that factors (genes) come in pairs and inherited as distinct units, one from each parent. Mendel tracked the segregation of parental genes and their appearance in the offspring as dominant and recessive traits. He recognized the mathematical patterns of inheritance from one generation to the next. On the basis of his series of experiments on pea plants he formulated following laws:

> **Extra Information**
> On genetic level all humans are more than 99% identical.

1. The Law of Segregation

The law of segregation states that the two alleles of a single trait will separate randomly. Each inherited trait is called factor (gene) pair. Parental factors (genes) are randomly separated to the sex cells so that sex cells contain only one member of the factor (gene) pair. Offspring, therefore, inherits one allele from each parent when sex cells unite in fertilization.

2. The Law of Independent Assortment

The law of independent assortment states that the allele of one gene separate independently of another allele. Genes for different traits are sorted separately from one another so that the inheritance of one trait is not dependent on the inheritance of another.

> **Extra Information**
> The term Mendalian inheritance refers to a set of rules that revolve around the passing down of hereditary traits from parents to offsprings.

Inheritance of Single Trait (Monohybrid Cross)

The Law of Segregation

Mendel carefully selected 7 pairs of contrasting characters for his experiments. First he experimented plants with one pair of contrasting characters such as tallness and shortness of the plants. This type of cross which involves only one pair of contrasting characters is called monohybrid cross.

Procedure and Observations

In one of his experiments, Mendel crossed tall pea plants (about 2 meters high) with dwarf pea plants (about 20 – 50 cm). He used pure breeding varieties *i.e.* plants which when self-fertilized produced offsprings that resembled their parents. He crossed pollinated tall plants with pollen from dwarf plants and vice versa. He planted the seeds from these plants and observed the resulting hybrid which he called the **first filial generation** or **F_1 generation.** In F_1 generation all plants were tall. He then allowed F_1 plant to self-pollinate and produced seeds which gave rise to **F_2 (second filial)**

generation. In F_2 he got 1064 plants. Out of these 1064 plant 787 were tall plants and 277 dwarf plants *i.e.* in the ratio of about three tall one dwarf (3:1).

Mendel also made crosses using 6 other contrasting characters of pea plants and got almost similar results.

In all his experiments, Mendel observed that one trait or character appeared in F_1 generation while other disappeared. However, this character reappeared in F_2 generation but only in about $1/4^{th}$ of the total number of offspring. The character which appeared in F_1 generation is called **dominant** while the character which could not express itself in F_1 generation is called **recessive** trait.

Interpretation of the Results

On the basis of these experimental results Mendel was able to suggest a mechanism to explain the observations, he had made about pea plants. Infact, he suggested a model of how the inheritance of traits could be explained. Mendel concluded that:

- Hereditary characters are responsible for transmission of characteristics.
- Each characteristics is controlled by a pair of factors (genes) in the cell of an organism *e.g.* colour of flower, colour of seed, shape of seed, height of plant, *etc.*, are controlled by a pair of factor.
- If the two factors differ then only the dominant one will show its effect *e.g.* if a pea plant contains one factor for tallness and one for dwarfness, only the tall (dominant) will show the effects.
- The two factors in each pair separate or segregate during gamete formation and each gamete will contain only one factor. This statement is known as Mendel's law of segregation.

Hence when a pea plant containing a factor for tallness and a factor for shortness produces gametes. A particular gamete will either have tall factor or the dwarf factor but not both. Thus the gametes are always pure.

- The fusion of haploid gametes at fertilization restores the diploid condition in the zygote.
- Gametes unite at random so that a predictable ratio of characteristics occur among the offsprings.

Dominant Gene

It is able to express itself even in the presence of its recessive allele and does not require similar allele to produce its effect.

Recessive Gene

It is unable to express its effect in the presence of dominant allele so it produces phonotypic effect only in presence of similar allele.

Extra Information

The term dominant and recessive do not mean that an organism possessing a dominant trait is healthier or more vigorous than an organism with the recessive trait. Both dominant and recessive alleles can be disease carrier.

Inheritance of Two Traits (Dihybrid Crosses)

Mendel's Law of Independent Assortment

Mendel suggested his second law of inheritance by following two characters at the same time, such as seed color and seed shape. Pea seeds shape may be either round (smooth) or wrinkled. From single character crosses, Mendel knew that allele for yellow seed is dominant (Y), while allele of green seed is recessive (y). He also knew that allele from round seed is dominant (R), and allele for wrinkled is recessive (r).

Procedure and Observations

Mendel crossed pure **round-yellow seeded plant (RRYY)** with **wrinkled green seeded plant (rryy)** and got F_1 generation. In F_1 generation, he got all round-yellow seeded plants. However, these plants will be dihybrids *i.e.* RrYy. The key step in the experiment is to see what happens when F_1 plants self-pollinate and produce F_2 generation. If the hybrids transmit their allele in the same combinations in which the alleles were inherited from parental generation, then the F_1 hybrid will produce only two classes of gametes: RY and ry. This dependent assortment hypothesis predicts that the phenotype ratio of F_2 generation will be 3:1, just as in monohybrid cross.

Interesting Information

Pure bred means that if you let the plant self-fertilize, the offsprings will always look exactly like their parents *i.e.* if the tall plants were crossed then the offspring will always be tall.

The alternative hypothesis is that the two pairs of allele segregate independently of each other. In this example the F_1 plant will produce 4 types of gametes in equal quantities *i.e.* RY, rY, Ry, ry. If sperm of the 4 classes fertilize eggs of the 4 classes, there will be 16(4×4) equally probable ways in which the alleles can combine in F_2 generation. These combinations result in 4 phenotype categories with a ratio of 9:3:3:1. Nine will be round-yellow, three will be wrinkled yellow, three will be round-green and one will be wrinkled green. When Mendel did the experiment and obtained F_2 generation, his results were close to the predicted 9:3:3:1 phenotypic ratio. These results were supporting the hypothesis that the allele for one gene-supporting seed colour and seed shape are sorted into gametes independently of the alleles of other genes.

Interpretation of the Results

Mendel tested all seven pairs of contrasting characters in various dihybrid combinations and always observed a 9:3:3:1 phenotypic ratio in F_2 generation. Is this consistent with the 3:1 phenotypic ratio observed for the monohybrid crosses? To investigate this question, let's consider one of the two dihybrid characters by itself. Looking only in pea color we see that there are 416 yellow and 140 green peas, a 2.97:1 ratio, or roughly 3:1 ratio. In this dihybrid cross, the pea color alleles segregate as this were a monohybrid cross. The result of Mendel's dihybrid cross is the basis for what is

called **law of independent assortment**. This law states that the alleles of two (or more) different genes get sorted into gametes independently of one another. In other words, the allele a gamete received for one gene does not influence the allele received from another gene.

Limitations of the Law of Independent Assortment

This law applies only to those genes (allele pairs) located on different chromosomes (non-homologous chromosomes) or alternatively to genes that are very far apart on the same chromosome. All the pea characters Mendel chose for analysis were controlled by genes on different chromosome. This situation greatly simplified interpretation of his multi-character pea crosses.

Usefulness of Law of Independent Assortment

This law explains that desired characters of two parents can be expressed in single parents and undesired characters can be prevented from expression. Can you guess how?

Scope of Independent Assortment in Variation

The independent assortment genes also contribute in mutation because it results in the shuffling of chromosomes into various gametes. Crossing over occurs when homologous chromosomes exchange genetic information. Thus, chromosomes are formed that contain genes from both parents. (Fig.22.2)

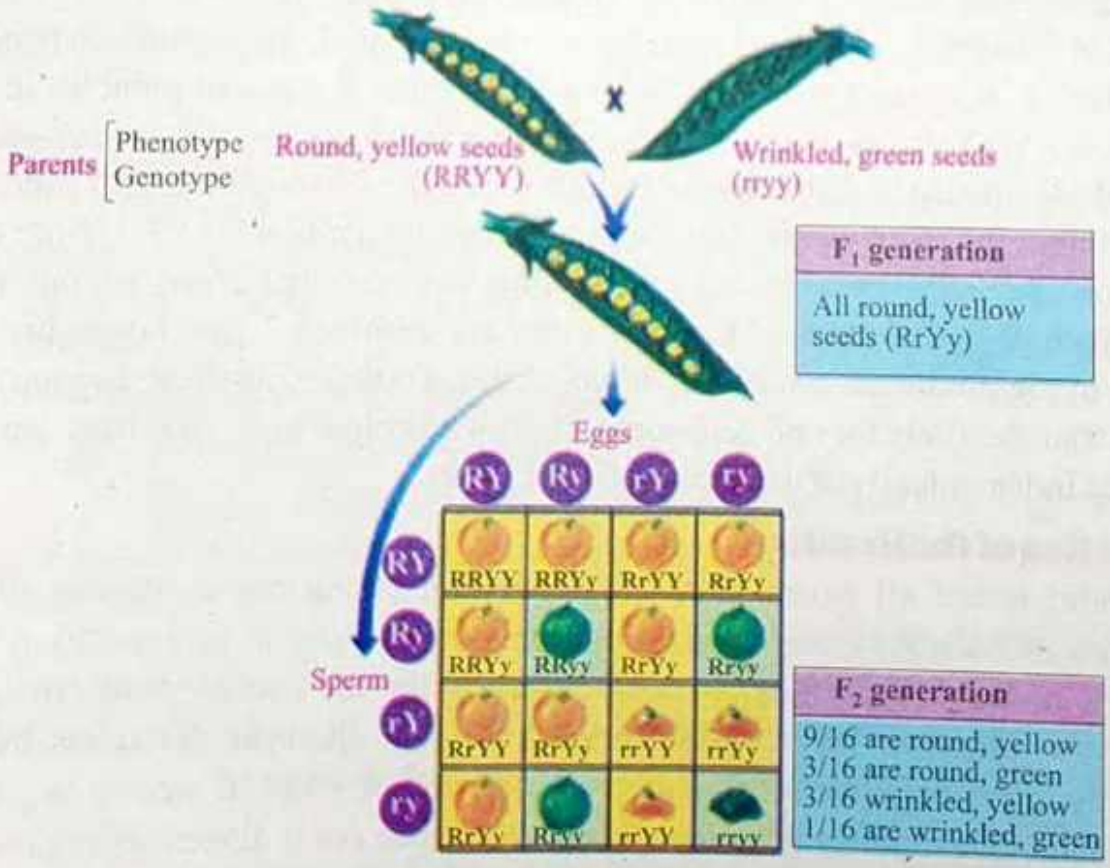


Fig.22.2 Dihybrid Cross

22.1.2 Inheritance and Mathematical Probabilities

Probability is a chance of occurring of an event. Mendel laws reflect the same rules of probability that apply to tossing coins, rolling dice and drawing cards from a deck. The probability scale range from 0 to 1. An event that is certain to occur has a probability of 1, while an event that is certain not to occur has a probability of 0 with a normal coin, the chance of tossing tails is 1/2 and chance of tossing heads is 1/2.

Tossing a coin illustrates an important lesson about probability. For every toss, the probability of head is 1/2. The out-come of any particular toss is unaffected by what has happened on previous trials.

The phenomena such as coin tosses are referred as independent events. Each toss of a coin whether done sequentially with one coin or simultaneously with many is independent of every other toss. And like two separate coin tosses, the alleles of the one gene segregate into gamete independently of another gene's alleles (the law of independent assortment). The combined probability of two or more independent events can be calculated by product rule.

Product Rule

This rule states that probability of two or more independent event occurring together can be calculated by multiplying the individual probability. This rule is useful in genetics. The product rule is used to predict frequencies of fertilization events.

According to this rule the probability of round yellow phenotype in F_2 generation of a dihybrid cross is equal to the product of individual probabilities of round (3/4) and yellow (3/4) phenotype *i.e.* P=3/4×3/4= 9/16.

22.2 Exceptions to Mendelian Inheritance

We know today that there are many exceptions to Mendel's laws. It means that not every gene has alleles that are strictly dominant or recessive. Does this mean that Mendel was wrong? No it means that we know more today about genetics, diseases and inheritance than 150 years ago, when Mendel formulated his laws. Some of the most common exceptions of Mendelian inheritance will be discussed here.

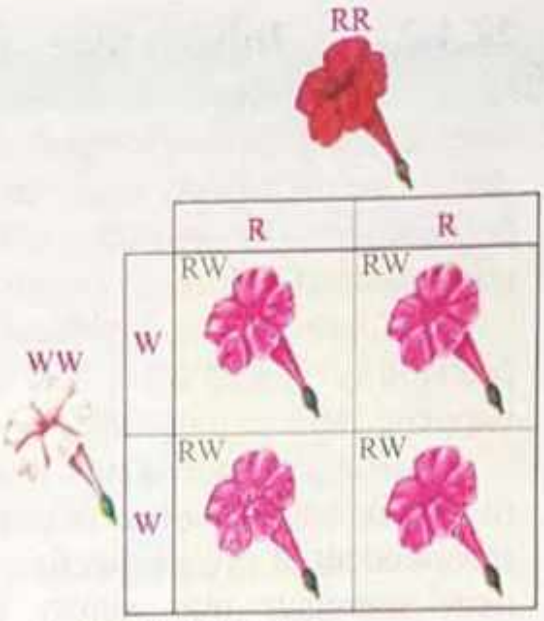
22.2.1 Incomplete Dominance

When two contrasting characters are crossed, and if in F_1 generation none of the characters is fully expressed then this phenomenon is called incomplete dominance. It was first described by Carl Correns.

Example: When red (RR) Japanese 4 o'clock flower plant (*Mirabilus Jalapa*) is crossed with white (WW) 4 o'clock flower plant, in F_1 generation hybrid plant have pink (RW) flowers. This third intermediate phenotype results from the flowers of heterozygotes having less red colour than the red homozygotes. This is unlike the case of Mendel's pea plant. (Fig.22.3)

At first glance incomplete dominance of either allele seems to provide evidence for the blending hypothesis of inheritance which would predict that red or white traits

could never reappear among offsprings from pink hybrid. In fact, inbreeding F_1 hybrids produce F_2 offsprings with a phenotypic ratio of one red to two pink to one white *i.e.* 1:2:1 ratio. Thus genotype and phenotype ratio is same (RR, 2RW, WW). The segregation of the red flower and white flower alleles in the gametes produced by the pink flowered plants confirms that the allele for flower colour are heritable factors that maintain their identity in the hybrids; that is; inheritance is particulate.



F_1 all (100%) pink
F_2 one red (25%), two pink (50%), one white (25%)

Fig. 22.3: Incomplete Dominance

22.2.2 Co-dominance

The dominance relation when two contrasting characters are crossed and in F_1 generation both of them fully express themselves is called co-dominance.

For example, the human MN blood group is determined by co-dominant alleles for two specific molecules located on the surface of red blood cells, the M and N antigen molecules. A single gene locus at which two allelic variations are possible, determines the phenotype of this blood group. Individual homozygous for the M allele MM have red blood cells with only M molecules; individual homozygous for the N allele NN have RBCs with only N molecules. But both M and N molecules are present on the red blood cells of individuals heterozygous for the M and N alleles (MN). The MN phenotype is not intermediate between the M and N phenotypes, which distinguishes co-dominance from incomplete dominance. Rather, both M and N phenotypes are by heterozygotes, since both molecules are present. (Table 22.1-22.2)

Genetic Problem

What would be expected offspring when red four O'clock plant is crossed with pink one.

Solution:

Red	X	Pink	
RR	X	RW	
RR	RW	RR	RW
Red	Pink	Red	Pink

Ratio = 2:2

Skill

What will be the result of cross between red bulls to white cow? What will be genotype and phenotype of offspring?

Table 22.1: MN Blood Group Showing Co-dominance

Genotype	Phenotype	Antigen Present on red BC
$L^M L^M$	M	M
$L^M L^N$	MN	M and N
$L^N L^N$	N	N

Table 22.2: Difference between Incomplete Dominance and Co-dominance

S.No.	Incomplete dominance	Co-dominance
i)	Intermediate trait appear.	Has independent effect. Both traits simultaneously appears.
ii)	Both alleles are expressed itself partially.	Both alleles are equally conspicuous.
iii)	None of the parental characteristics express in offspring.	Both parental characteristics express in offspring.

Multiple Allele

Any one of a series of three or more alternative or allelic forms of a gene, only two of which can exist in any normal diploid individual is known as multiple allele.

The ABO blood group is an example of multiple allele. It is also an example of exception to Mendelian inheritance.

The 4 blood groups A, B, AB and O are all determined by a single gene. Three alleles of this gene exist. I^A, I^B and i. I^A and I^B are dominant while i is recessive to both I^A and I^B.

22.3 Blood Group System

Although the ABO and Rh-groups are most important for blood transfusions, there are 36 other known blood group that usually do not complicate the blood transfusion are called **rare types**.

Each blood group has a combination of sugars and protein called antigens that are found on the surface of RBCs. There are about 600 antigens so there is potential for a lot of variation between different people.

22.3.1 ABO Blood Group System

ABO blood group is an example of multiple allele which is an exception to Mendelian inheritance. In 1900 **Karl Landsteiner** reported a series of test, which identified the ABO blood group system. He got noble prize in 1910 for his discovery. The ABO blood group is also found in other **primates** like apes, chimpanzees, gorillas.

Extra Information

There is no crossing over between the members of multiple allele. Crossing over takes place between two different genes only and does not occur within gene.

Antigen of ABO Blood Group

ABO antigens are glycolipid in nature, attached on the surface of red blood cells. These antigens stick out from cell membrane and there are many antigen sites per red blood cell. Besides their presence on red blood cells, soluble antigens can be present in plasma, saliva and other secretions. These antigens are also expressed on tissues other

than red blood cells. There are two types of antigens *i.e.* antigen A and B. The presence or absence of these antigens makes 4 types of blood groups *i.e.* blood group A when antigen A is present, blood group B when antigen B is present, blood group AB when both antigens A and B are present and blood group O when both antigens A and B are absent.

Genetic Basis of ABO System

Blood groups are inherited from both parents. The ABO blood group is controlled by a single gene with three types of alleles *i.e.* I^A, I^B and i. The I stands for isoagglutinogen. The I^A and I^B both are dominant alleles, while 'i' is recessive. The gene is located on long arm of chromosome no 9. The individual with genotype I^AI^A and I^Ai have type A blood group and individual with I^BI^B and I^Bi have type B blood group.

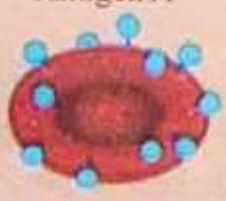
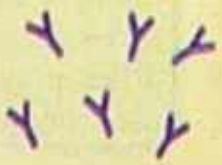
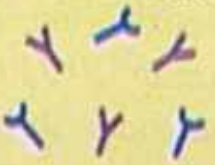
Problem

A man of blood group B and women of blood group A have three children. One is group A, one group B and one group O. What are the genotype of five people?

The genotype I^AI^B have blood group AB because both I^A and I^B alleles are dominant. An individual having genotype ii has blood group O.

Codominance: Another example of codominance is human blood type AB, in which two types of protein ("A" and "B" appear together on the surface of blood cells. (Table:22.3)

Table 22.3: ABO Blood Group Antibodies and Antigens

ABO Blood Groups				
Antigen (on RBC)	Antigen A 	Antigen B 	Antigen A + B 	Neither Antigen A nor B 
Antibody (in plasma)	Anti-B Antibody 	Anti-A Antibody 	Neither Antibody	Both Antibodies 
Blood Type	**Type A** Cannot have B or AB Blood. Can have A or O Blood	**Type B** Cannot have A or AB Blood. Can have B or O Blood	**Type AB** Can have any type of blood. Is the universal recipient	**Type O** Can only have O blood. Is the universal donor

Antibodies of ABO Blood System

Two types of antibodies are present in blood plasma. The antibodies present together with the antigens in opposite way *i.e.* **Antigen A** with anti-body B, **antigen B** with antibody A, **antigen AB** has no antibodies, none of the antigen with both antibodies A and B. There is an agglutination reaction between similar antigen and antibody. Antigen "A" agglutinates the antibody A and antigen "B" agglutinates the antibody B.

Transfusion Principle

Blood transfusion is the process of transferring blood into one's circulation intravenously. Transfusions are used for various medical conditions such as deficiency of blood, blood lost during pregnancy or any surgery, any blood cell disease like **thalassemia, sickle cell** and **leukaemia**, *etc.*

Before blood transfusion blood group of recipient and donor are tested. If transfusion is carried out between two incompatible blood groups, antigen, antibody reaction will occur in recipient and as a result agglutination *i.e.* clumping of red blood cells will occur. Therefore, the transfusions are carried out on the basis of donor's antigens and recipient's antibodies. Due to these limitations the persons with type A can receive blood from type A or O because they have anti B antibody so they cannot be given any blood carrying B antigen. The person with blood type B can receive blood from a person with blood group B or O. The person with blood group AB can receive blood from all other types *i.e.* A, B, AB and O while a person with blood group O can only receive blood from its own type. Therefore, blood group 'O' is called universal donor and blood group AB is called universal recipient.

Extra Information

An erythroblast is a type of RBC which still retains a cell nucleus. It is intermediate precursor of normal erythrocytes.

Genetic Problem

The woman with blood group B has a child with blood group O what is the genotype of mother and child? What are the genotypes father could have?

Genetic Problem

The father has hybrid blood type 'A' and mother hybrid blood type B what are possible blood groups of their children?

Guess

The blood group O is more frequent in human population. Can you expl-ain why this is so?

Interesting Information

ABO blood group antigens are not only found on the surface of RBCs. They are also normally secreted by some people in their body fluids, including saliva, tears and urine. Such persons are called antigen secretors. Whether someone is able to secrete them is generally controlled by dominant secretor gene "Se" present on chromosome 19.

22.4 Rh Blood Group System and Erythroblastosis Foetalis

Rh blood group system is defined on the basis of Rh factor present on the surface of red blood cells. Rh factor is another blood group system. The ABO blood type is represented by + or – sign. The +ve sign indicates the presence of Rh factor while –ve sign indicates the absence of Rh factor. Landsteiner discovered Rh antigen from the blood of Rhesus monkey in 1930.

Antigens of Rh Blood Group System and Genetic Basis

Rh blood group system is encoded by three genes C, D and E. These genes occupy two loci *i.e.* locus D and C or E loci. Gene D is located on D locus while the gene C or E located on other locus. However, D locus has prime importance. The gene D has two alleles, D and d. D is completely dominant over d. Therefore, the person with DD or Dd are Rh +ve. The person dd genotype is Rh –ve.

The O –ve blood type is **universal donor** because it can donate blood to all blood groups. The AB +ve is **universal recipient** because it can receive blood from all blood groups.

Table 22.4: ABO and Rh Blood Groups system

Recipient	Donor							
	O-	O+	A-	A+	B-	B+	AB-	AB+
O-	✓	✗	✗	✗	✗	✗	✗	✗
O+	✓	✓	✗	✗	✗	✗	✗	✗
A-	✓	✗	✓	✗	✗	✗	✗	✗
A+	✓	✓	✓	✓	✗	✗	✗	✗
B-	✓	✗	✗	✗	✓	✗	✗	✗
B+	✓	✓	✗	✗	✓	✓	✗	✗
AB-	✓	✗	✓	✗	✓	✗	✓	✗
AB+	✓	✓	✓	✓	✓	✓	✓	✓

Extra Information

The positive blood groups can receive all times nega-tive blood groups while negative blood groups can only receive one time positive blood group but not second time.

Anti Rh-antibody and Transfusion Principle

The Rh antibody is not present naturally in the body. This antibody is produced in reaction of Rh antigen. Rh +ve donor is totally incompatible for Rh –ve recipient. Sometimes Rh –ve person receives Rh +ve antigen through wrong Rh +ve blood transfusion. He starts producing anti Rh antibodies against Rh antigen and reaction occurs.

A donor who has never been exposed to Rh antigen can be transfused to Rh +ve recipient.

22.4.1 Erythroblastosis Foetalis

Erythroblastosis foetalis or **hemolytic disease** (Haemo : blood, lytic : breakdown) of new born babies occurs when baby's red blood cells break down at a fast rate. Erythroblastosis foetalis develops in a foetus, when anti-Rh antibodies produced by the mother pass through the placenta and start **hemolysis**.

Problems and Complications in Foetus

Babies who suffer erythroblastosis foetalis, develop the symptoms of anaemia, pale and swollen body at birth. Enlarged liver or spleen. The anaemic foetus starts to release many immature erythroblastosis into his blood system; therefore, the disease is called erythroblastosis foetalis. The anaemic foetus may lead to abortion or still birth. If the pregnancy continues the liver and spleen produce and breakdown RBCs at fast rate. The breakdown of RBCs produces **bilirubin**. The high concentration of bilirubin in foetus blood damages brain and turns the skin yellow. This condition is called **jaundice**.

Causes and Risk Factors

The most common cause of erythroblastosis foetalis is **maternal foetal** Rh **incompatibility**. Sometime, an Rh –ve woman marries to an Rh +ve man. The women conceive a child with Rh +ve blood group maternal foetal Rh incompatibility. If the man's genotype is DD, all offspring will have Dd genotype *i.e.* Rh +ve. If the man genotype is Dd, half of the offsprings will be Dd *i.e.* Rh +ve while half of the offsprings will have genotype dd *i.e.* Rh –ve.

The Rh –ve offspring will remain safe in mother body but Rh +ve offsprings will be at risk in mother's body. Can you guess how?

Prevention and Treatments

During a pregnant woman's first prenatal doctor's visit, she should be screened for blood and Rh type. If she has Rh-negative blood, the father's blood and Rh type should be tested. If the father has Rh-positive blood, then Rh-positive foetus may develop in the woman. In this cause the Rh sensitization of Rh-negative mother can be avoided by a simple therapy. In this therapy she is given an injection of Rh antiserum (serum containing anti-Rh antibodies) during early pregnancy (1st trimester) and immediately after birth within 72 hours of delivery. This causes any of the baby's red blood cells that may have crossed into the mother's blood to be destroyed before sensitizing the mother's immune system to produce maternal anti-Rh antibodies. The injected antiserum disappears before the next pregnancy. This has to be done with each pregnancy whether it ends in a delivery or an abortion. (Fig.22.4)

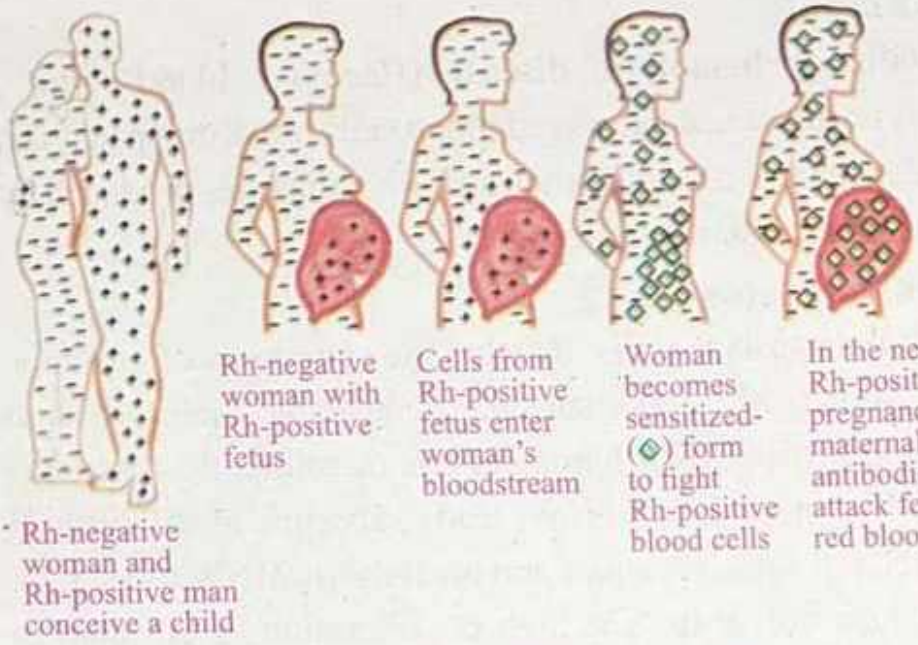


Fig.22.4: Maternal Foetal Rh-incompatibility

Genetic Problem

An Rh negative woman marries to an Rh positive man. The father of man was also Rh –ve. What will be the possible genotypes of their offsprings? What will be the chances of erythroblastosis foetalis?

22.5 Polygenic Inheritance and Epistasis

Polygenic inheritance, also known as **quantitative inheritance**, refers to a single inherited phenotypic trait that is controlled by two or more different genes.

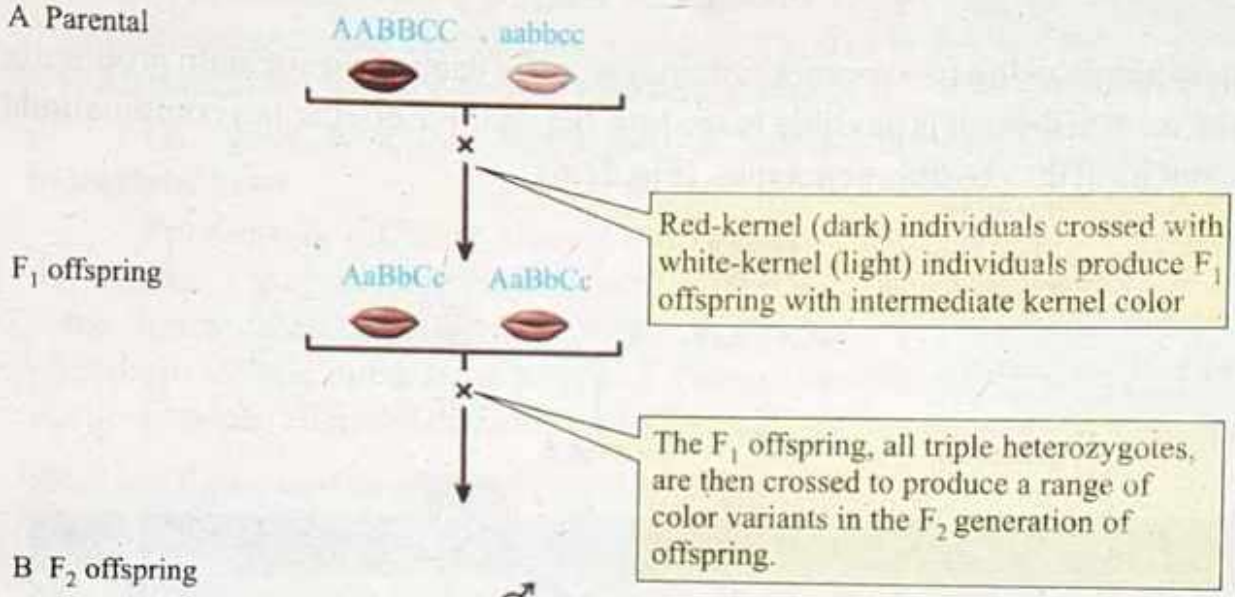
The traits that are determined by polygenic inheritance are not simply an effect of dominance or recessive trait and do not exhibit complete dominance. Infact polygenic inheritance exhibits incomplete dominance so the phenotype displayed in the offsprings, is a mixture of phenotypes displayed by the parents. Each of the genes that contributes to a polygenic trait has an equal influence and each of the alleles has an additive effect on the phenotype outcome.

The polygenic inheritance should not be confused with the effects caused by multiple alleles.

22.5.1 Wheat Grain Colour (an example of polygenic inheritance)

Nilsson Ehle performed many crosses between varieties of wheat having red seeds and those having white seeds. The noteworthy feature of his experiment was the variation in the intensity of the red pigment in the wheat grains produced by F_2 plants. There were many gradations from the deep red of one parent to pure white of the other parent so that plant could be divided into 7 different colour classes in the ratio of 1, 6, 15, 20, 15, 6, 1. Nilsson Ehle could distinguish 6 phenotypic classes with varying intensities of red as follows: 1 deep red, 6 dark red, 15 reds, 20 mediums red, 15 light red and 6 very light red. Only one of 64 plants produced completely white grain and other one of 64 had red grains identical to the parents in the first cross. (Fig.22.5)

Nilsson Ehle postulated three pairs of genes controlling grain colour in wheat with genes for red (ABC) dominant over genes for white abc. It is also appeared that all alleles contributed equally in the production or absence of red pigment. Each of the three gene pairs when considered singly in crosses segregated in expected Mendelian fashion producing F_2 progeny of three red and 1 white.



All contributing	= 1/64
5 contributing	= 6/64
4 contributing	= 15/64
3 contributing	= 20/64
2 contributing	= 15/64
1 contributing	= 6/64
All non-contributing	=1/64

Fig.22.5: Inheritance of Wheat Grain Colour

22.5.2 Inheritance of Human Skin Colour

The pigment melanin is responsible for dark coloration in the skin and there are at least three genes, which control human skin colour. Using a hypothetical example where the production of melanin is controlled by contributing alleles denoted as A, B and C resulting in dark skin colour, and therefore, light skin color is

What is Pleiotropy?

The ability of a single gene to have multiple phenotypic effects *e.g.* sickle cell anaemia causes multiple systems, only one of which is the actual sickle celled conditions.

produced by non-contributing allele, denoted as a, b and c, it is possible to see how the spectrum of different skin color can result in the offsprings.

It is important to remember that in polygenic inheritance alleles do not display dominance over other rather each contributing allele gives an additive effect rather than masking effect, and so the way that the alleles interact is different to those in Mendalian genetics.

In an example using two parents, heterozygous for each of the melanin producing genes AaBbCc × AaBbCc, it is possible to see how the additive effects and combinations of alleles result in all the possible genotypes. (Fig.22.6)

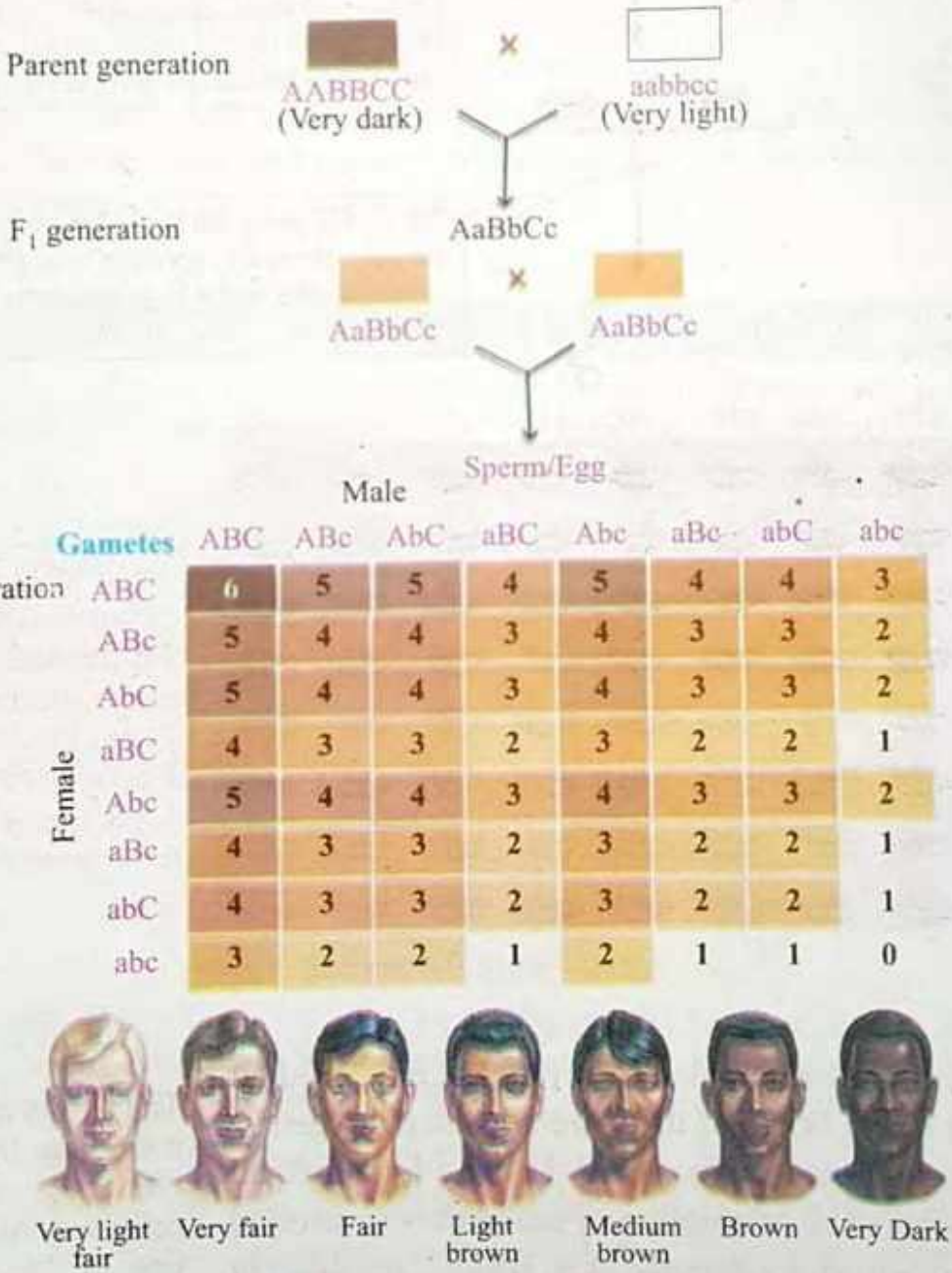


Fig.22.6: Inheritance of Human Skin Colour

22.5.3 Epistasis

"Epistasis" is a word composed of Greek roots that means "standing upon". The epistasis is a form of interaction between non allelic genes in which one combination of such genes has a dominant effect over other combinations. A gene is said to be **epistatic** when its presence suppresses the expression of a gene which is present on another locus of same or other chromosome.

The gene which is suppressed is known as **hypostatic gene**.

Epistasis is different from dominance because dominance is the phenomenon in which the alleles of the same locus interact with each other to produce a phenotype. While epistasis is a type of interaction that occurs between alleles of different loci. (Table 22.5)

Bombay Phenotype

The Bombay Phenotype discovered in 1952 in Bombay city of India. Individuals with the Bombay phenotype have the genes to make the ABO antigen at one loci but lack the genes that produce the H substance produced at another locus. Individual with Bombay phenotype can receive blood from other individual with blood group O but cannot donate blood.

Table 22.5 Difference between Dominance and Recessive Epistasis

S.No.	Epistasis	Dominance
i)	This type of gene interaction involves two non-allelic pairs of genes.	In this type only one pair of gene is involved, therefore, there is no interaction.
ii)	One pair of gene masks the effect of another pair of genes.	An allele mask the effect of another allele of the same gene pair.
iii)	Expression of both the dominant and recessive alleles may be suppressed by the epistatic gene.	Expression of recessive allele is masked by dominant allele.

Relationship of Epistasis with Polygenic Inheritance

The epistasis is a type of polygenic inheritance where the alleles at one gene locus can hide or prevent the expression of alleles at a second gene locus. **Labrador retrievers** (type of dog) one gene locus affects coat colour by controlling how densely the pigment eumelanin is deposited in the fur. A dominant allele (B) produces the black coat while the recessive allele (b) produces a brown coat color. However, a second gene locus control whether any eumelanin at all is deposited in fur. Dogs that are homozygous recessive at

Continuous and Discontinuos Variation

Continuous variation is where there is complete range of measurements from extreme to another *e.g.* height, weight, skin color. Discontinuous variations are where individuals fall into distinct categories *e.g.* pea plants with either purple flower or white flower, tongue roller and non-roller in human.

this locus (ee) will have yellow fur no matter which alleles are at the first locus.

The polygenic inheritance is not controlled by a single gene locus, but by the combined interaction of many gene loci. In epistasis, the interaction between genes is antagonistic, such that one gene masks or interferes with the expression of another.

An example of epistasis is pigmentation in mice. The white type coat color, agouti (AA), is dominant to solid colored fur (aa). However, a separate gene (c) is necessary for pigment production. A mouse with a recessive (c) allele at this locus is unable to produce pigment and is albino regardless of the allele present at locus "A". Therefore, the genotype AAcc, Aacc and aacc all produce the same albino phenotype. A cross between heterozygotes for both genes AaCc × AaCc would generate offspring with a phenotypic ratio of an agouti 3 solid color: 4 albinos. In this case, the gene 'c' is epistatic to the 'A' gene.

Coat Color in Labrador Retriever

The Labrador retriever is highly popular type of dog found all over the world. This dog is trained to perform different task *e.g.* screening and detection work for law enforcement agencies. These are also used for hunting. There are three basic coat color in the Labrador: black, yellow and chocolate. (Fig.22.7)



Fig. 22.7: Three types of Labrador Retriever

In Labradors, the B and E genes result in black, yellow and chocolate Labrador *e.g.* BB become a black Labrador. The Bb dog is also black but it carries the chocolate gene which can be passed on its offspring. So bb genotype have chocolate Brown coat color while yellow Labrador is characterized by a recessive epistatic gene (ee). But every Labrador retriever has both sets of genes which can come in any combination of capital and lower case letters *i.e.* dominant and recessive alleles. Regardless of the combination of B genes, any time the ee genotype is present, it masks the B coloration *e.g.* BbEE dog would have a black coat but Bbee dog would have a yellow coat. The black Labradors are dominant, therefore, having the most possibilities. Both yellow and chocolate Labradors are recessive, but because a yellow Labradors 'ee' genes mask both the black and chocolate coloration. So yellow Labradors are more common than chocolate Labrador. (Fig.22.8)

complementary gene interaction because it involves the interaction of both the genes. If anyone locus has homozygous recessive genotype *i.e.* AAbb or aaBB then it will interfere with dominant allele and hide their expression of purple color and flowers will be white in color. In this case the epistatic alleles are recessive and both types of recessive alleles cause same epistatic effect so this type of epistasis is called duplicate recessive epistasis.

Parents: Purple flower AABB × White flower aabb

F_1: AaBa Purple flower

	AB	Ab	aB	ab
AB	AABB [P]	AABb [P]	AaBb [P]	AaBb [P]
Ab	AABb [P]	Aabb [W]	AaBb [P]	Aabb [W]
aB	AaBb [P]	AaBb [P]	aaBB [W]	aaBb [W]
ab	AaBb [P]	Aabb [W]	aaBb [W]	aabb [W]

P = Purple flower, W = White flower

Fig.22.9: Inheritance of Flower Color in Sweet Pea

Batson and Punnett crossed white flower plant AAbb with another white flowered plant aaBB and got F_1 generation. In F_1 generation all plants were purple flower plants. Then they self-crossed F_1 offsprings and got F_2 generation. In F_2 generation they got two types of plants *i.e.* purple and white in 9:7 ratio. This result confirms the duplicate recessive epistasis. (Fig.22.9)

22.6 Gene Linkage and Crossing Over

The term gene was introduced by Wilhelm Johannsson (Danish botanist and geneticist) in 1909. Gene is a small segment of DNA as chromosome. It consists of specific sequence of nucleotides which code a specific protein or polypeptide chain. The place on chromosome where the gene resides is called the **gene locus**. Mendel did not know about gene. He used the term **factor or element** which is now called gene.

22.6.1 Gene Linkage

Genes that are located on the same chromosome are called linked genes. Alleles for these genes tend to segregate together during meiosis, unless they are separated by crossing over. Crossing over occurs when two homologous chromosomes exchange segments during meiosis. The close together two genes are on a chromosome, the less likely their alleles will be separated by crossing-over.

Linkage explains why certain characteristics are frequently inherited together *e.g.* genes for hair color and eye color are linked, so certain hair and eye colors tend to be inherited together such as brown hair with blue eye.

If genes are linked at autosomes, called **autosomal linkage** and if genes are linked on sex chromosomes, called **sex linkage**. Linked genes violate the law of independent assortment because these genes are not free to participate in independent assortment.

Detection of Gene Linkage

A test cross is an ideal method to know whether the genes are linked or not. Any

deviation from the ratio of offsprings as expected by the law of independent assortment is to be verified for linkage. A test cross with one of the parents being homozygous recessive. All the offsprings exhibit the possible combination of traits in equal ratio if the alleles are not linked and other parents of the original cross is heterozygous. Any significant deviation from this indicates the possibility of linkage. Approaches to test cross can include two-point test crosses for double heterozygous and three point test crosses for analysis with three genes. If offsprings in test cross are all parental types than it is called **complete or light linkage** and if less recombinant and more parental types are produced, then this is called **incomplete or partial linkage.** To determine the effect of linkage on inheritance, Morgan performed an experiment on Drosophila (fruit fly).

SRY Gene Located on Y chromosome encodes a transcription factor protein which controls expression of other genes. It stimulates male development *i.e.* developing testes, secrete anti mullerian hormone and destroy female structure. Testosterone hormone develop the male structure.

Morgan Experiment

Thomas Hunt Morgan (1866-1945) was an American geneticist and embryologist. He performed several experiments on ***Drosophila melanogaster*** (fruit fly). In one of his experiments he crossed long winged and broad abdomen with vestigial wing and narrow abdomen fly. The long wing and broad abdomen are dominant while



P_1 ⟶ Long wing Broad Abdormen

Genotype ⟶ WA/WA

Vestigeal Wing Narrow Abdormen wa/wa

Gametes ⟶ 100% WA 100% wa

F_1 ⟶ All long wing broad abdomen WA/wa

P_2 ⟶ (Self crossed) F_1 ♀ × F_1 ♂

Genotype ⟶ WA/wa WA/wa

Gametes ⟶ 50% WA, 50% wa 50% WA, 50% wa

♂ \ ♀	WA	wa
WA	WA/WA	WA/wa
wa	WA/wa	wa/wa

Phenotype Type Ratio ⟶ 3/4 : 1/4

75% Long wing broad abdomen

25% Vestigeal wing narrow abdomen

Fig.22.10: Morgan Experiment

vestigial wing and narrow abdomen are recessive traits. So in F_1 generation all flies were long winged and broad abdomen. Then he self-crossed two flies of F_1 generation. In F_2 generation he obtained 3/4 of offspring with long wings and broad abdomen and remaining 1/4 of the total had vestigial wings and narrow abdomen. (Fig.22.10)

Interpretation of Results

These results were unexpected and violation of Mendel's law of independent assortment *i.e.* 9:3:3:1. Morgan concluded that the genes of long wings and broad abdomen located on the same chromosome, so they could not assort independently during meiosis and rather inherited together. Therefore, no recombinant types were produced.

Linkage Detection

Gene linkage can only be detected accurately if the number of offsprings are quite large. It is because the probability *i.e.* chance of occurring an event determine the kind of gametes and chances of their fusion. Thus as large number of offsprings will be, the more chance of accuracy in detection of result. More parental type and less or no recombinant

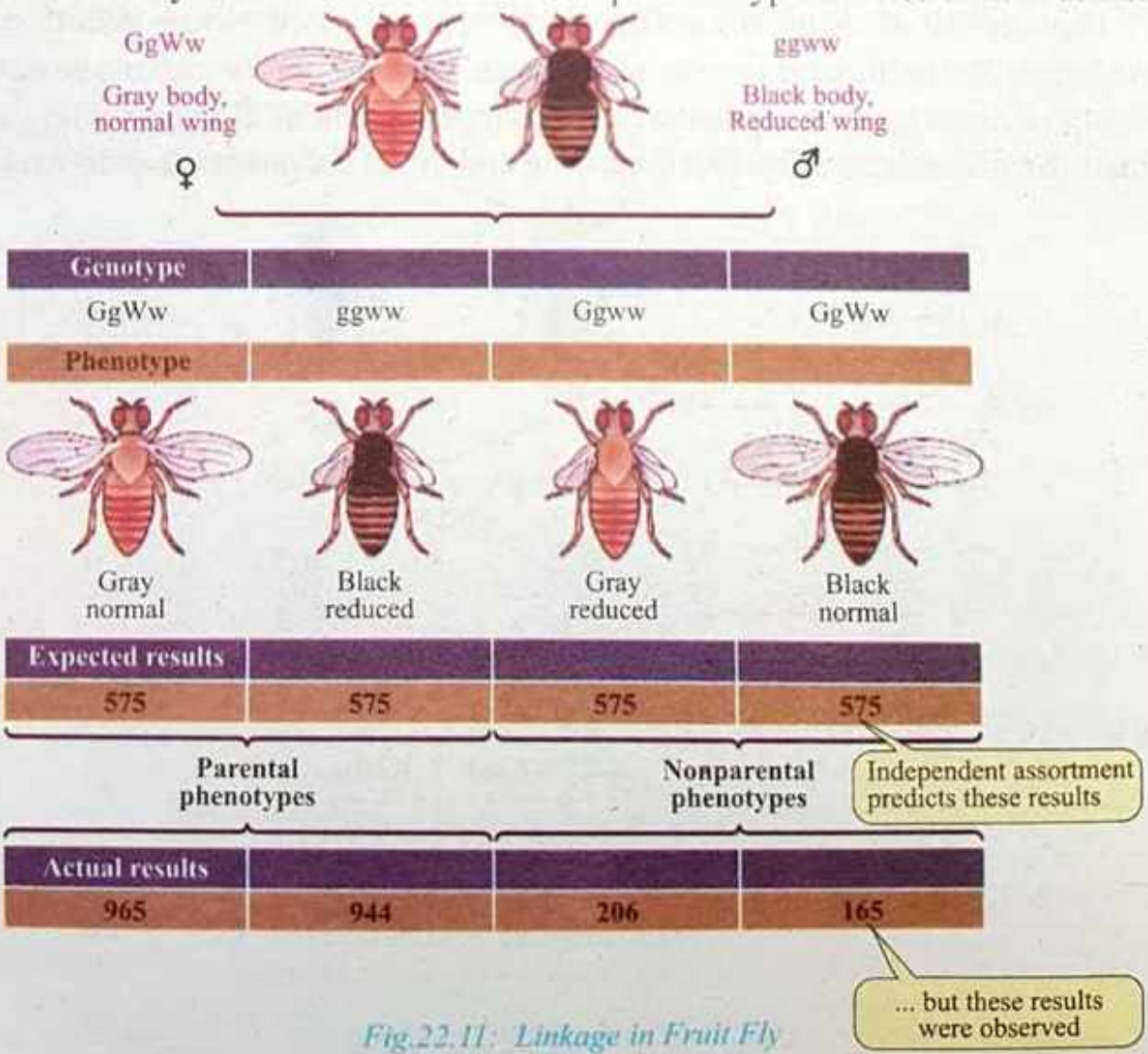


Fig.22.11: Linkage in Fruit Fly

is indication of gene linkage. For detection of linkage Morgan mated the dihybrid (Gg Ww) with recessive parental type flies (gg ww). Morgan's result was very different from the results, he expected based on the law of independent assortment *i.e.* 1: 1: 1: 1, while the actual result were quite different *i.e.* more parental types and less recombinant types. (Fig.22.11)

Crossing Over

During the formation of gametes, the homologous pairs of chromosomes exchange their segments. This process is called crossing over. Crossing over results in a shifting of genetic material and an important cause of genetic variation. The crossing over brings alleles together in new combinations. When these alleles distribute in gametes, a wide variety of gametes are produced. This is why the siblings are not identical. The cross-over data may also be used to determine the location of gene on chromosome *i.e.* gene mapping. (Table 22.6) (Fig.22.12)

Table 22.6: Difference between Crossing Over and Linkage

S.No.	Crossing Over	Linkage
i)	It leads to separation of linked gene.	It keeps the genes together.
ii)	It involves non-sister chromatids of homologous chromosomes.	It involves individual chromosome.
iii)	It increases variability.	It reduces variability.
iv)	It provides equal frequency of parental and recombinant type in test cross progeny.	It provides higher frequency of parental type in test cross progeny.

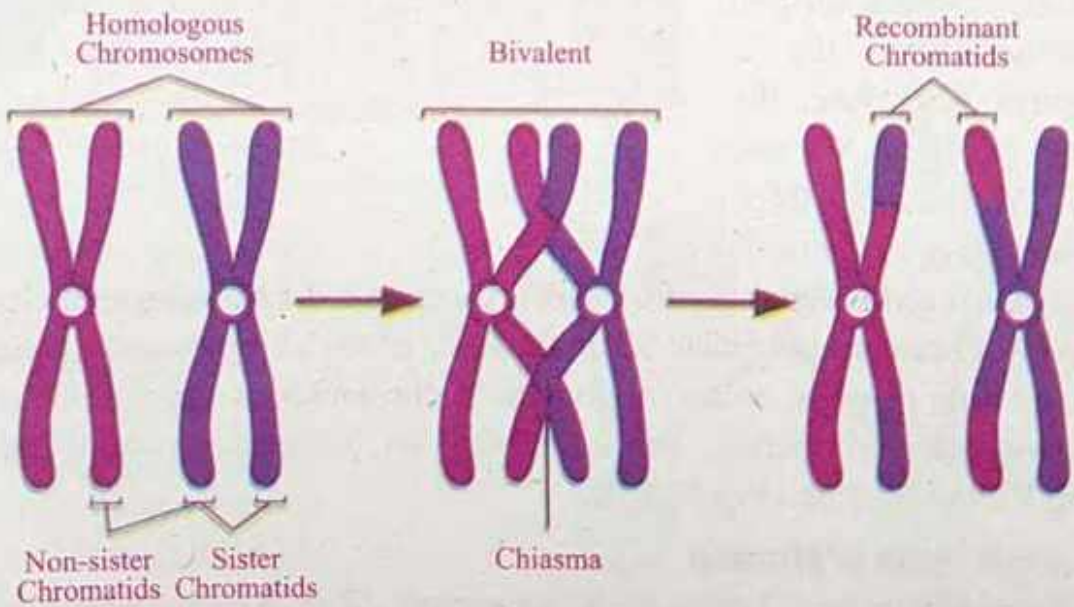


Fig.22.12: Chromosomal Crossing Over

22.7 Sex Determination

In an organism which is hermaphrodite, *i.e.* having both male and female sex organs, the homologous pairs of chromosomes in body cell are similar. However, in unisexual organism where sexes are separate, the chromosome in the male and female differ in one pair which is associated with sex differentiation. These chromosomes are called sex chromosomes.

Extra Information

Not all organisms have sex chromosomes such as wasp, bees, ants do not have sex chromosomes. Sex is, therefore, determined by fertilization. If egg fertilizes the sex will be female and if unfertilized egg then it develops into male.

22.7.1 Genetic Identification of Sex Phenotype

The difference between male and female phenotypes are generally because of their sex chromosomes. In bisexual animals all pairs of chromosomes are similar but in unisexual animal one pair is different either in male or female.

Sex Determination in Drosophila

Drosophila has four pairs of homologous chromosomes of which one pair is rod like in female and are called **sex chromosome**. These are usually called X chromosomes. However, each body cell in male has only one X chromosome, the other one replaced by a hook-shaped chromosome called the Y chromosome. Therefore, the female has genotype XX and the male XY. The other three pairs of homologous chromosomes are called **autosomes**. So drosophila has three pairs of autosomal chromosomes and one pair of sex chromosomes. So on the basis of sex chromosomes, the female will produce one type of eggs, each will contain X chromosome. However, the male will produce two types of sperms, one containing an X chromosome while the other containing Y chromosome. (Fig.22.13)

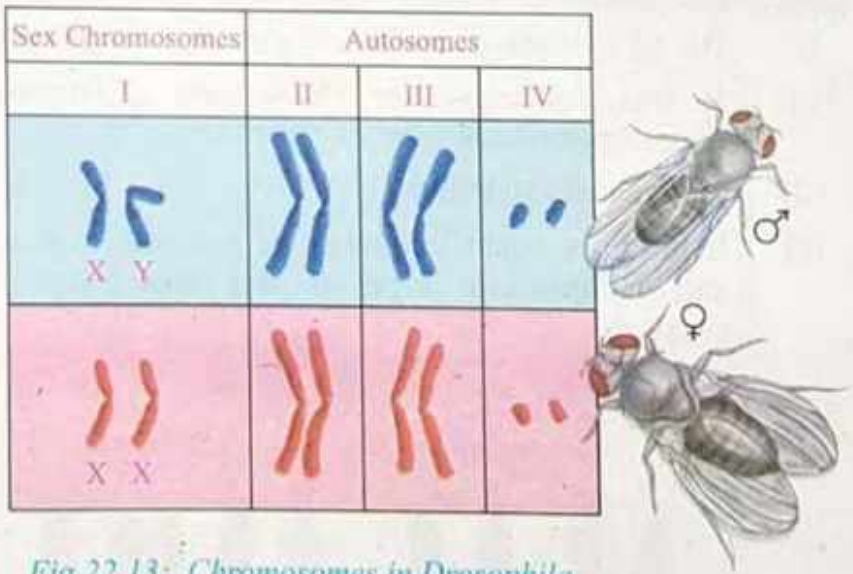


Fig.22.13: Chromosomes in Drosophila

Sex Determination in Human

In human there are 23 pairs of chromosomes, 22 pairs of autosome, and 1 pair of sex chromosome. In human male, both sex chromosomes are quite different from each

other. The male has X chromosome and much shorter Y chromosome. In female both sex chromosomes are similar in shape *i.e.* XX chromosome. So like drosophila, in human, male determines the sex of the baby. A girl has inherited one X chromosome from her mother, and one from her father. A boy baby has received X chromosome from his mother and Y chromosome from his father. (Fig.22.14)

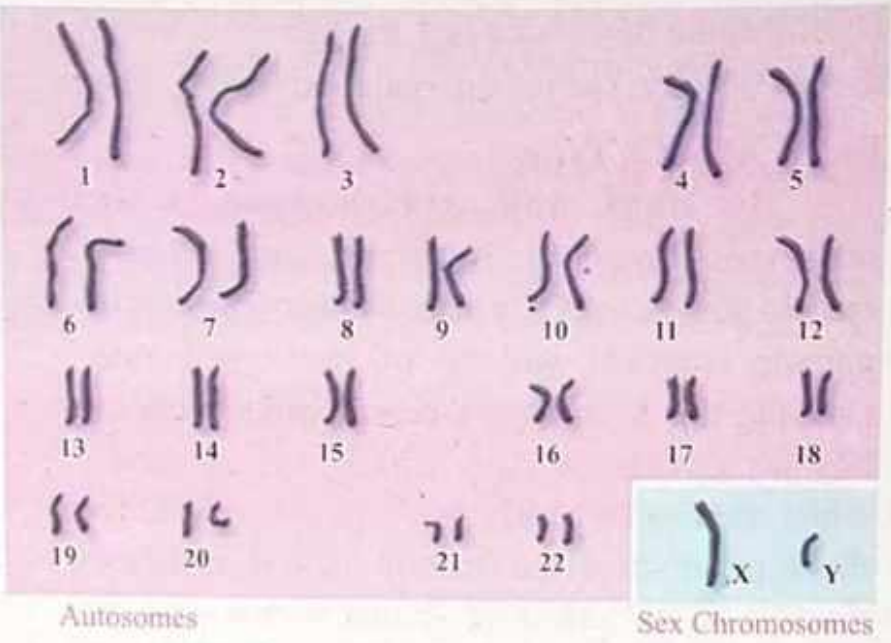


Fig.15.14: Chromosomes in Human

22.7.2 Patterns of Sex Determination

In different organisms there are different mechanisms of sex determination. In some groups of animal's male, and in some groups, female determines the sex. Some common patterns are as follows:

What is Genetic Screening?

Testing of a population who are at risk for a genetic disease or for transmitting a gene for a genetic disease.

Male Heterogamy

i) XY-XX Type

In this case male possesses single X-chromosome with Y-chromosome, while female possesses two X-chromosomes. This type of sex determination is found in human, drosophila and many other animals. In these animals' male produces two types of sperms, *i.e.* X and Y, while female produces only X type of eggs. Therefore, if male gamete with X chromosome fuses with egg (female gamete), the baby will be girl and if sperm with Y

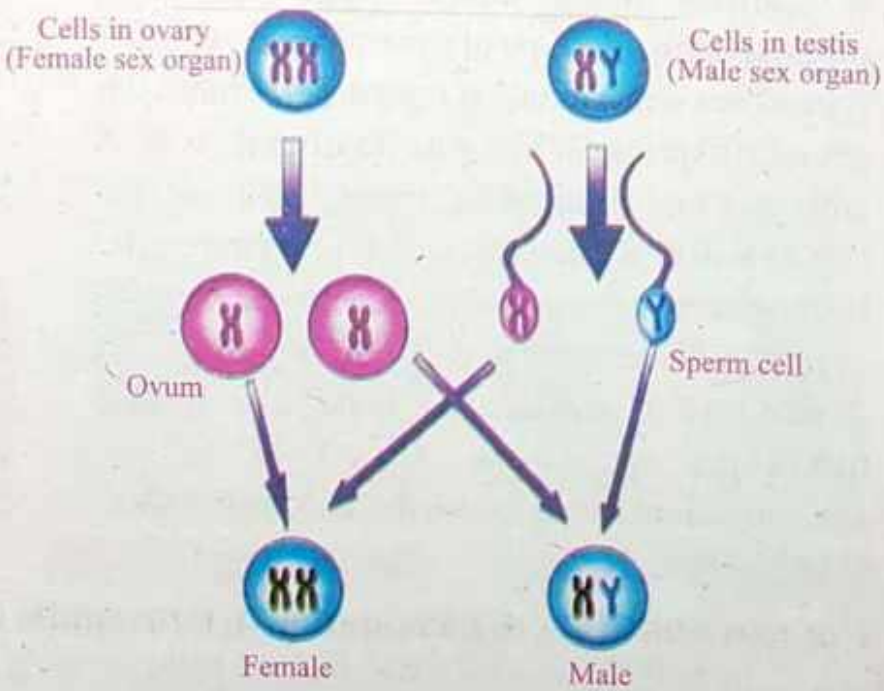


Fig. 22.15: XX-XY Male Heterogamy

chromosome fuses with egg, the baby will be boy. So this is the male which determines the sex of baby. The ratio of male and female offsprings will be 1:1. (Fig.22.15)

ii) XO-XX Type

In **bugs and grasshopper**, male possesses unpaired X-chromosome, while female possesses XX chromosomes. Thus male gamete (sperms) will be of two types, one carrying the X chromosome and other without any sex chromosome thus called **nullogamate**, while the eggs are only one type. Therefore, in this type of sex determination male determines the sex of the offspring. When sperm with X chromosome fuses with egg the zygote will be XX and it will develop into female and if the sperm without X chromosome fuses with egg the zygote will be XO and it will develop into male. The ratio of male and female offsprings will be equal. (Fig.22.16)

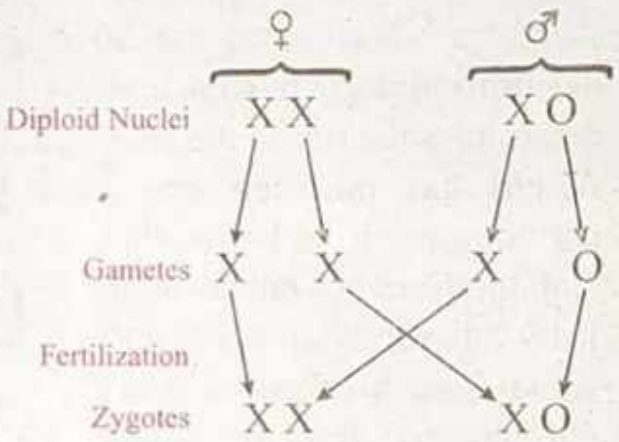


Fig. 22.16: XX-XO type male Heterogamy

Female Heterogamy

WZ-ZZ Type

In this case the female produces two types of gametes *i.e.* W and Z type, while male produces only one type of gamete *i.e.* Z, so in this type of sex determination female determines the sex of offspring. When gamete of male with Z chromosome fuses with female gamete, the zygote will be ZZ and this will develop into male. If the gamete of male fuses with W type egg, the zygote will be WZ and it will develop into female. Thus chances of male and female offsprings are equal. This type of sex determination found in **birds and butterflies**. (Fig.22.17)

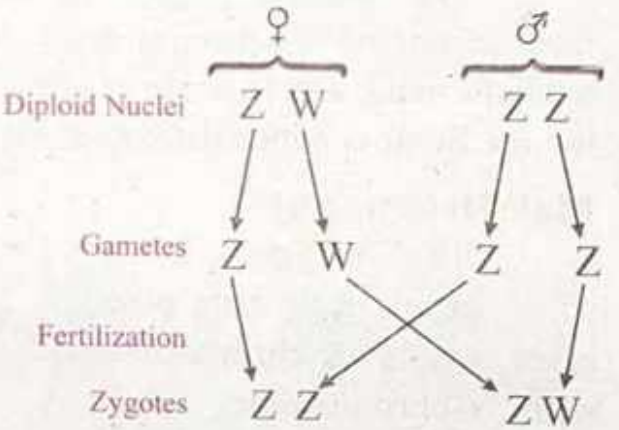


Fig.22.17 ZZ-ZW Female Heterogamy

Genetic Problem

Why the chances of male and female are equal in case of male heterogamy or female heterogamy?

Comparison of sex determination in Drosophila and Human

In both Drosophila and human there is male heterogamy. Therefore, in both groups male determines the sex of offspring. However, there are some differences

between two groups. In human the male sex is determined by **SRY gene** (sex determining region of Y chromosome) is located on short arm of Y chromosome. The absence of this gene in zygote will develop a female. However, absence of entire Y chromosome in zygote will develop into sterile female called **Turner's syndrome** but in Drosophila XO will be a sterile male. Similarly, XXY individuals in human are sterile male called **Klinefelter's syndrome** but this XXY condition in Drosophila will develop into fertile female. Therefore, the sex chromosomes in Drosophila has less influence than in human.

22.8 Sex Linkage

The sex chromosomes (X and Y) contain genes which are related to sexual character (traits) of male and female. However, besides controlling sexual traits, the sex chromosomes also contain other genes which are not concerned with sexual traits. This phenomenon is called sex linkage *e.g.* gene for **blood clotting factor VIII**, gene for **opsin pigment** in eye, gene for **hairy pinna**, *etc.* An allele that is located only on X-chromosome (*i.e.* non-homologous portion) is called **x-linked**. The allele that is only located on the (non-homologous portion) of Y chromosome is called **Y-linked or holandric traits**. All those such allele which are located on homologous portion of X and Y chromosome are called **XY linked genes or pseudo-autosomal genes** because their pattern of inheritance is like autosomal genes.

22.8.1 Sex Linkage in Drosophila

T.H Morgan (1910) for the first time discovered sex linkage in Drosophila. Morgan when experimenting noted the sudden appearance of one white eyed male in the culture of normal red eyed Drosophila. This white eyed male was crossed with red eyed female. The F_1 flies were all red eyed indicating that white eye color is recessive to normal red eye color. When these F_1 flies were self-crossed freely, the red and white eyed flies appeared in the ratio 3:1 in F_2 generation. The white eyed flies were male. Among the red eyed flies two third were female and one third

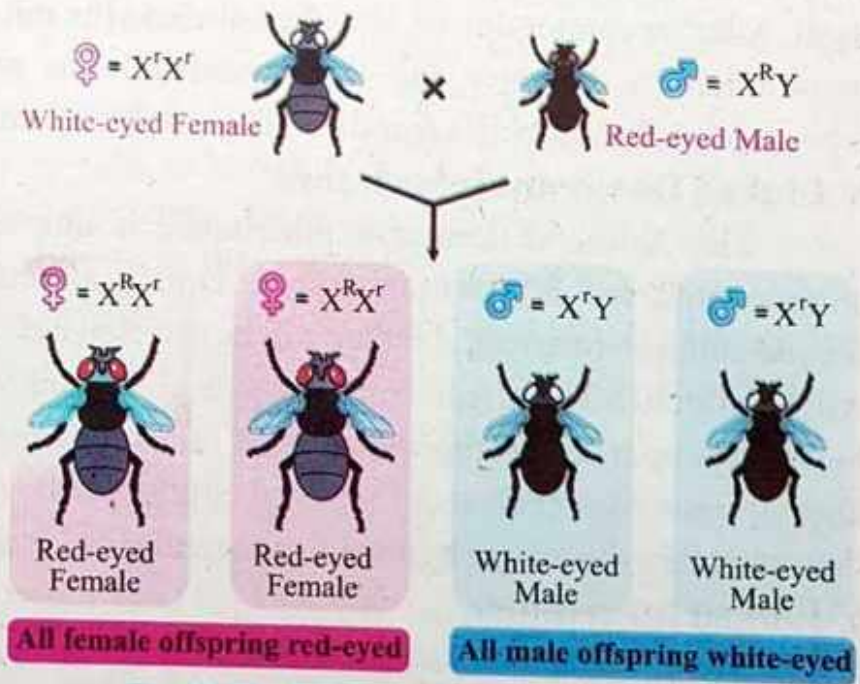


Fig.22.18: Sex determination in Drosophila

were male. The female are all red eyed whereas 50% males were white eyed and remaining 50% male were red eyed. When a reciprocal cross was performed between white eyed female and red eyed male, all female in F_1 generation are red eyed and all male are white eyed. When these two types of individuals from F_1 generation were self-crossed, female population in F_2 generation will consist of 50% red eyed and 50% white eyed individuals.

Similarly, the male population in this generation consists of 50% red eyed and 50% white eyed individual. (Fig.22.18)

Morgan Conclusion

On the basis of these results Morgan concluded that the white eye trait gene is located on X chromosome and this gene is recessive for eye color.

22.8.2 Sex Linkage in Humans

There are many traits in human which are linked with sex chromosomes. The sex linked traits may be X-linked or Y-linked. The X-linked may be recessive or dominant.

X-Linked Recessive Inheritance

The X-linked recessive inheritance is due to recessive allele on X chromosome. These are more common in male than female. It is because female possessing one X-linked recessive is considered carrier. A female for X-linked recessive trait can only be affected if it carries allele on its both X chromosomes. On the other hand, as male has only one X chromosome, so if a recessive allele is present on X chromosome it will express itself. A father cannot donate X-linked allele to his son. So pattern of inheritance is from grandfather to daughter and then grandson. The examples of X-slinked recessive inheritance is haemophilia A and B, color blindness and testicular feminization.

X-Linked Dominant Inheritance

The X-linked dominant inheritance is due to dominant allele present on X chromosome, so this type of inheritance equally affects in male and female. However, all female children of affected father will be affected but no male children of affected father will be affected. The affected mother may affect 100% children if this dominant allele is located on both X chromosomes but if this dominant allele is located only on one sex chromosome then chances of affected children will be 50%. The examples of X-linked dominant inheritance are **hypophosphatemia** (rickets), **incontinentia pigmenti**, *etc.*

Y-Linked Inheritance

The inheritance of genes located on 'Y' chromosome. Since only male have 'Y' chromosome. Therefore some 'Y' linked genes can only be transmitted from father to son. The Y-linked inheritance is also called **holandric inheritance**. The concepts of dominant

and recessive do not apply to Y-linked traits, as only one allele is ever present in any one (male) individual. 'Y' linked inheritance never occur in females. The examples of Y-linked trait in male are **hypertrichosis** (growth of hair on ear pinna), **porcupine man** (straight hair on body) and **webbing of toes**, *etc.* (Fig.22.19)



Fig.22.19: Hairy Pinna (Example of Y-linked Inheritance)

Extra Information

Recently two more genes located on Y chromosomes have been discovered.

i) Testis determining factor (TDF).

ii) Minor Histocompatibility gene (H-Y)

22.8.3 Sex Linked Disorders in Human

Sex linked disease are passed down in families through one of the X or Y chromosomes. Some sex linked disorders will be discussed here:

Genetics of Haemophilia

It is a serious disease of human in which blood fails to clot after it starts flowing from an injury site of haemophilia patient. It is an X-linked recessive trait *i.e.* its recessive allele is located on 'X' chromosome, say X^h. Its dominant allele says X^H favors blood clotting. It is very rare in females as female requires allele from her both father and mother which is very rare, as very few diseased males survive to marry and reproduce. On the other hand, male can easily get this disease, as they only need to get a recessive gene form the mother.

History of Haemophilia

The haemophilia is called royal disease because haemophilia gene was passed from Queen Victoria, who became Queen of England in 1837 to ruling families of Russia, Spain and Germany. Queen Victoria's gene of haemophilia was caused by spontaneous mutation.

There are three types of haemophilia *i.e.* haemophilia A, B and C. The allele for haemophilia A and B are located on X chromosome, so these two types are X linked. The allele for haemophilia C is located on autosome, so its chances are equal in male and female. However, haemophilia A and B are more common. Haemophilia A is caused due to missing blood clotting factor VIII and is about 80% of total haemophiliac patients. Haemophilia B is due to absence of blood clotting factor IX and it is about 20%. haemophilia C is due to missing of blood clotting factor XI and it is very rare (less than 1%).

Table 22.7: Comparison between different Types of Haemophilia

A	B	C
It is most common type.	It is 2nd most common type.	It is least common.
It is very severe.	It is moderate.	It is mild.
It is caused by missing of blood clotting factor VIII.	It is caused by blood clotting factor IX.	It is caused by blood clotting factor XI.

Genetics of Color Blindness

Color blindness is not a form of blindness at all, but a difficulty in distinguishing certain colors, such as blue, yellow, red and green. The color blindness is infact a color vision deficiency. It is X-linked recessive inheritance, therefore, more common in males than females. There are three fundamental colors. *i.e.* Red, green and blue. There are two types of photoreceptor cells in retina of eye *i.e.* Rod and cone cells. The rod cells are more abundant but these are incapable of perceiving color. The cone cells are responsible for color vision. There are three types of cone cells *i.e.* red, green and blue color receiving. The cone cells can receive these colors if they have opsin proteins. The three type of opsin protein is coded by different genes. The gene for red and green opsin are on X chromosomes while gene for blue opsin is on chromosome No.7 which is autosomal chromosome, so equally expressed in male and female. The color blindness may be in the form of dichromacy and monochromacy.

Extra Information

Some women can have a genetic mutation that makes them **tetra chromatic**, which causes their eyes to have 4 different types of cone cells enabling them to see 1000 million different colors as compared to a normal person who can see 100 million.

Dichromacy

A color blind patient with dichromacy can perceive two primary colors but unable to one primary color so dichromacy can further have three sub types

1) **Protanopia** is red color blindness.
2) **Deuteronopia** is green color blindness.
3) **Tritanopia** is blue color blindness.

Monochromacy

It is severe type of color blindness in which patient perceive only one color. It is true color blindness. Usually monochromate cannot perceive red and green colors. It's pattern of inheritance is same as other X-linked recessive inheritance like haemophilia. (Fig.22.20)



Normal Vision Protanopia

Fig.22.20: Color Blindness Test Protanopia

Genetic Problem

When a color blind man marries with a carrier woman, what will be the probability of color blind sons and daughter?

Genetics of Muscular Dystrophy

Muscular dystrophy is a group of diseases that cause progressive weakness and loss of muscle mass. In muscular dystrophy, abnormal gene (mutations) interfere with the production of proteins (dystrophin) needed to form healthy muscles. There are many different kinds of muscular dystrophy. **Duchene type muscular dystrophy (DMD).** It is X-linked recessive trait so more common in male than female symptoms typically appear in early child-hood. The patient feels trouble in running and jumping, difficulty in rising from lying or sitting up position, muscle pain and stiffness, large calf muscles, *etc.* The patients of Duchene muscular dystrophy hardly survive further and usually die before the age of twenty. (Fig.22.21)

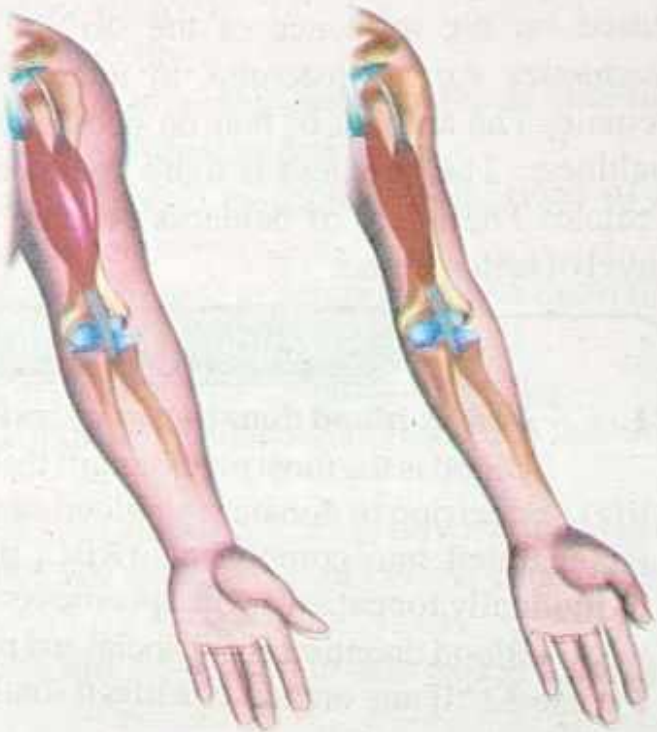


Fig.22.21: Muscular Dystrophy

22.8.4 Sex Related Traits

Such traits which are associated with male or female are called sex related traits. These traits may be sex linked or autosomal. There are two types of sex related traits.

i) Sex Limited Traits
ii) Sex Influenced Traits

i) Sex Limited Traits

Sex limited traits are those characters that are expressed physically in one sex of a species. These genes are controlled by sex limited genes or autosomal genes. Although

these genes are present in both sexes but express only in one sex while in other sex they remain turned off. Example of such traits are human breast development in female and beard development in male. A woman does not grow a beard herself but she can pass the genes of heavy beard to her son. These traits are primary concerned with sexual dimorphism.

ii) Sex Influenced Traits

These are autosomal traits that are expressed based on the influence of the sex, in particular sex hormones *e.g.* testosterone, in male and estrogen in female. The amount of hair on body, muscle mass and baldness. The baldness is more common in male than female. The allele of baldness become active to high level of testosterone.

Genetic Problems

1. Albinism is a recessive trait in humans. Two normal parents have an albino child. What is the probability that their next child will be normal or albino?
2. Two tall, yellow seeded pea plants were crossed, and some dwarf, green seeded plant resulted.

(a) What were the genotypes of the parent plant?

(b) What possible genotypes might there be among the tall, yellow-seeded offspring?

Science, Technology and Society (STS)

1. Justify blood donation as a service to suffering humanity.

Blood is the most precious gift that anyone can give to another person (the gift of life). A decision to donate your blood can save a life or even several lives if your blood is separated into components (RBC, platelets, plasma, WBC) which can be used individually for patients with specific conditions.

Blood donation is our social and religions responsibility, as Quran says in Surah 5 verse 32 "If any one saves a life, it shall be as thought he had saved the life of all man kinds".

The donor also gets benefits of donating blood. These includes good health and reduced risk of cancer and hemochromatosis. It helps in reducing the risk of damage to liver and pancreas. Moreover, donating blood may also help in improving cardiovascular health and reducing obesity.

2. Justify why a recessive blood group allele 'i' is more frequent in the population.

The genotype of blood group 'O' is 'ii'. The chances of union of gametes with allele 'i' are more because if the cross between blood group O 'ii' and O 'ii' will have blood group O 'ii' in all the offspring. The cross between heterozygous I^Ai and I^Ai will produce 25% offspring having blood group O 'ii' and likewise heterozygous I^Bi and I^Bi will produce 25% offspring having blood group O 'ii'. Cross between heterozygous I^Ai and I^Bi will produce 25% offspring having blood group O 'ii'. That's why blood group allele 'i' is more frequent in the population.

SUMMARY

- Inheritance is the process by which genetic information is passed from parents to offsprings.
- Gregor JohnMendel through his work on pea plants, discovered the laws of inheritance.
- According to Mendel's law of segregation, the two factors in each pair separate or segregate during gamete formation and each gamete will contain only one factor.
- The law of independent assortment states that two or more gene assort independently of each other pairs of allele during gamete formation.
- The chance of occurring an event is called probability.
- The product rule states that probability of two or more independent events occurring together can be calculated by multiplying the individual probability.
- When two contrasting characters are crossed and if in F_1 generation none of the characters are fully expressed, is called incomplete dominance.
- When two contrasting characters are crossed and if in F_1 generation both of them fully express themselves, is called co-dominance.
- When a character is controlled by more than two alleles is called multiple allele.
- Rh blood group is defined on the basis of Rh factor present on the surface of red blood cells.
- Erythroblastosis foetalis occurs when baby's red blood cells break down at a fast rate.
- Polygenic inheritance refers to a single intertied phenotypic trait that is controlled by two or more different genes.
- The pigment melanin is responsible for the dark coloration in skin and at least three genes control skin color in human.
- Epistasis is a Greek word which means standing upon.
- The Labrador retriever is highly popular type of dog.
- The term Gene was introducing by Wilhelm Johnson in 1909.
- The genes that are located on same chromosome are called linked gene and phenomenon is called gene linkage.
- The exchange of segments between homologous chromosomes during meiosis cell division is called crossing over.
- The one pair of chromosomes which are different in male and female are called sex chromosomes.
- WZ-ZZ type of sex determination is found in birds, butterflies, *etc.*
- The genes present on sex chromosomes but not controlling sexual characters are called sex linkage.
- X-linked recessive traits are more commonly expressed in male than female.

- Y-linked inheritance only occurs in male.
- Haemophilia and color blindness are X-linked recessive inheritance.
- Such traits which are associated with male or female are sex related traits. These include sex limited and sex influenced traits.

EXERCISE

SECTION-I: OBJECTIVE QUESTIONS

Multiple Choice Questions (MCQs)

A. Select the correct answer.

1. All the genes found in a breeding population.
   (a) Genotype (b) Genome
   (c) Gene frequency (d) Gene pool
2. Incomplete dominance was discovered by 4'o clock plant in 1899 by:
   (a) De-veries (b) Johannsen
   (c) Carl Correns (d) Tschermach
3. Bilirubin damages brain cells and turns the skin and white of eyes yellow, condition is known as:
   (a) Hepatitis (b) Leukemia
   (c) Botulism (d) Jaundice
4. Green Colour Blindness is called:
   (a) Deuteranopia (b) Protanopia
   (c) Tritanopia (d) None of these
5. What is the risk of a color-blind child in a family when father is color-blind but mother is normal?
   (a) Zero % (b) 25%
   (c) 50% (d) 100%
6. The law of independent assortment can be determined by
   (a) Test cross (b) Backcross
   (c) Dihybrid cross (d) None of these
7. Each character is controlled by a pair of
   (a) Chromosome (b) Allele
   (c) Proteins (d) Enzymes
8. An allele is another word for
   (a) Gene (b) Genotype
   (c) Phenotype (c) Different forms of a gene

9. Phenotype refers to
(a) Genetic makeup (b) Physical appearance
(c) Recessive alleles (d) Dominant allele

10. The idea that different pairs of alleles are passed to offspring independently is Mendel's principle of:
(a) Unit inheritance (b) Segregation
(c) Independent assortment (d) Law of probability

11. What type of inheritance do two alleles have if their traits blend together?
(a) Incomplete dominance (b) Co-dominance
(c) Over dominance (d) Complete dominance

12. An allele whose trait only shows up when no dominant allele is present.
(a) Hidden allele (b) Dominant allele
(c) Recessive allele (d) Present allele

13. This type of inheritance pattern shows both traits in possible offspring.
(a) Complete dominance (b) Incomplete dominance
(c) Co-dominance (c) Dominant pattern

14. Which of the following gives information about phenotype but not genotype?
(a) X^HY (b) X^hY
(c) Tall pea plant (d) Female carrier to colorblindness

15. If two white sheep produce a black offspring, the parent's genotype must be
(a) Heterozygous white (b) Homozygous white
(c) Homozygous black (d) Heterozygous black

16. One of the blood group would not be possible for children of a type AB mother and a type A father?
(a) Blood group O (b) Blood group A
(c) Blood group B (d) Blood group AB

17. All chromosomes other than sex chromosomes are called
(a) Polysome (b) Autosomes
(c) Mesosome (d) Acrosome

18. If a gene is found on X-chromosome only then it is said to be
(a) X-Linked (b) Y-Linked
(c) Sex linked traits (d) XY linked

19. The pattern of sex determination found in Drosophila is
(a) WZ-ZZ Type (b) XY-XX
(c) XO-XX (d) Diploid, haploid type

20. The phenomenon of sex linkage was discovered by
(a) Carl Correns (b) Nilsson Ehle
(c) T.H. Morgan (d) Calvin Bridge

B. Fill in the blank.

1. Alternate form of gene is known as .....
2. ..... refers to presence of more than two allele at a locus.
3. The term gene was coined by .....
4. ABO blood group is an example of .....
5. Polygenic inheritance, also known as .....
6. The pigment ..... is responsible for dark coloration in the skin.
7. A gene is said to be ..... when its presence suppresses the expression of a gene which is present on another locus.
8. The Labrador retriever is highly popular type of .....
9. Genes that are located on the same chromosome are called .....
10. Drosophila has ..... pair of chromosomes.
11. In grasshopper male possesses unpaired X .....
12. The allele for haemophilia 'C' is located on .....
13. There are three basic types of cone cells which receive red, geen and ..... light.

SECTION-II: SHORT QUESTIONS

C. Give the short answers of the following questions.

1. Write the limitations of law of independent assortment.
2. Describe briefly incomplete dominance.
3. Write short note on crossing over.
4. Describe two types of blood antigen make 4 types of blood group
5. Erythroblastosis foetalis is a haemolytic disease of new born babies. Explain how?
6. Define epistasis and its types.
7. Differentiate between epistasis and dominance.
8. Describe Y linked inheritance in man.
9. In human male determines the sex of offspring. Explain how?

10. Describe sex limited traits.
11. Define monochromacy.
12. Differentiate between X-linked recessive and X-linked dominant inheritance.
13. Write reason that X-linked recessive traits are more common in male than female.
14. Describe XX-XY type pattern of sex determination.
15. Illustrate is WZ-ZZ type pattern of sex determination.
16. Compare sex determination in human and Drosophila.
17. Differentiate between monohybrid and dihybrid cross.
18. Differentiate between homozygous and heterozygous.
19. Write reason that Y-linked inheritance is present only in male.
20. Write the reason that haemophilia and colorblindness cannot be transmitted from father to son directly.

SECTION-III: EXTENSIVE QUESTIONS

D. Give detailed answers of the following questions.

1. Define and explain Mendel's law of segregation.
2. Explain Mendel's Law of Independent assortment.
3. Explain in detail the ABO blood groups.
4. Define and explain multiple alleles.
5. Write a note on transfusion principle of blood.
6. Define erythroblastosis foetalis and describe its problem complications, causes and risk factors.
7. Define polygenic inheritance and also explain wheat grain color as an example of polygenic inheritance.
8. Explain epistasis with reference to inheritance of coat color in Labrador retriever.
9. Describe Gene linkage by the help of Morgan's experiment.
10. Define sex linkage and explain sex linkage in Drosophila.
11. Explain color blindness and haemophilia as examples of X-linked recessive inheritance.
12. Human skin color is an example of polygenic inheritance. Explain.

UNIT 23

CHROMOSOME AND DNA

Major Concept

23.1 Chromosomal Theory of Inheritance
23.2 DNA as the Hereditary Material
23.3 DNA Replication
23.4 Gene Expression
23.5 Regulation of Gene Expression
23.6 Mutation

Learning Outcomes

Students will be able to:

- Critically analyze the history of chromosomal theory with reference to Correns' work.
- Critically analyze the experiments of T. H. Morgan in support of the above mentioned theory.
- Annotate the detailed structure of a chromosome.
- Describe the concept of gene and gene locus.
- Explain the concept of alleles as the alternative forms of a gene.
- Narrate the experimental work of Griffith and Hershey-Chase, which proved that DNA is the hereditary material.
- Describe the three models proposed about the mechanism of DNA replication.
- Narrate the work of Meselson and Stahl to justify the semi-conservative replication as the correct method of replication.
- Describe the events of the process of DNA replication.
- Explain DNA stability and variability as two characters of the replicating DNA molecule.
- Describe the central dogma of gene expression.
- Define gene and genetic code.
- Describe the characteristics of genetic code (universal, triplet, non-overlapping, degenerate, punctuated).
- Differentiate between the terms genetic code and codon.
- Explain the mechanism of transcription.
- Explain why the length of transcribed m-RNA molecule (in Eukaryotes) shortens as it enters the cytoplasm for translation.
- Describe the mechanism of protein synthesis.
- State the difference between protein synthesis in prokaryotes and eukaryotes.
- Suggest possible ways in which the synthesized protein can be used within or outside a cell that synthesized it.
- State the importance of the regulation of gene expression.

- Describe the negative control of gene expression by repressor proteins.
- Describe the positive control of gene expression by activator proteins.
- Relate gene expression with introns and exons.
- Define mutation and identify various sources of mutation.
- Differentiate between neutral and induced mutations and mutagens.
- Justify that most mutations are harmful.
- Rationalize that mutations might be a contributing factor towards evolution.
- Describe the symptoms, causes and possible available treatments of some of the chromosomal mutations. (Down's, Klinefelter's and Turner's syndrome).
- Describe the symptoms, causes and possible available treatments of some of the gene mutations (Sickle cell anaemia, Phenylketonuria).

Introduction

The bright stained bodies in figure 23.4 are human "instructions" called **chromosomes,** but they cannot be read in the usual way. Instead using a special code (on DNA) that can be "understood" by other special molecules, they direct all the chemical reactions that take place in your body. Instructions in the chromosomes determine such things as whether your hair is red or brown and whether you are male or female. The chromosomes are made up of DNA and protein. The Mendel's "factors" now called **genes,** are specific segments of DNA.

23.1 Chromosomal Theory of Inheritance

Charles Darwin's and Mendel's work laid the foundation for formulating a research based theory of heredity. Darwin was first, who in 1864 suggested that traits could be transferred from parents to offsprings in the form of **units**. He named these units a "**gemmules**" or factor. While in 1865, Mendel proposed that traits are governed by separate and distinct units, termed "**elementens**" or **factors**. Mendel's work remained unnoticed till 1900. However, Mendel's hereditary principles were rediscovered by three European scientists, **Hugo de Vries**, **Carl Correns** and **Erich Won Tschermak**. However, **Carl Correns was named rediscoverer of Mendel's work** because he republished the Mendel's work and proposed laws from his work *i.e.* law of dominance, law of segregation and law of independent assortment. He was first, who suggested that there is a central role of chromosomes in hereditary.

23.1.1 Origin of Chromosomal Theory of Inheritance

Definition:- This theory revealed that "**genes,** the units of inheritance, are located on the **chromosomes**, thus these act as carriers of heredity". Many scientists had contributed

in this respect, the contribution of these scientist are given below:



Fig. 23.1: Walter Fleming

i) Contribution of Walter Fleming and Waldeyer

Chromosomes were first observed by German embryologist Walter Fleming in 1882, when he was examining the rapidly dividing cells of salamander (an amphibian) larvae, Waldeyer, assigned the name "**Chromosome**" (chromas; color: soma; body). In eukaryotic cells chromosomes are composed of DNA and proteins while in prokaryotic cells it is made of only DNA. (Fig.23.1)

ii) Contribution of Karl Correns

German geneticist Karl Correns (1900) put forward this idea, in one of his published papers, in which he explained the relationship of heredity units with chromosomes. However, he had not given any supportive evidence for this idea. (Fig.23.2)



Fig. 23.2: Karl Correns

iii) Contribution of Theodor Boveri and Walter Sutton

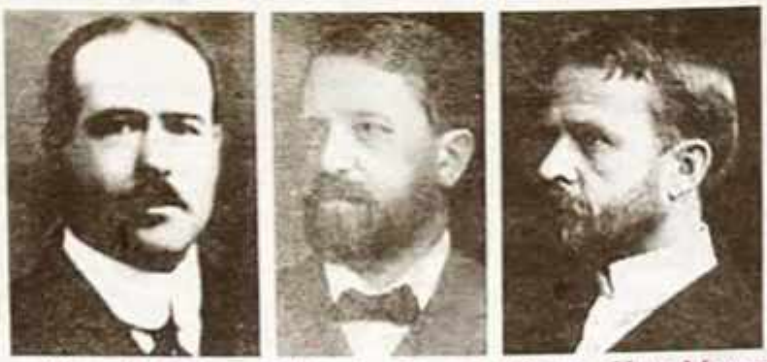
Theodor Boveri, a German biologist was one of the leading cytologists of his time. Between 1896 and 1904, he carried out experiments on sea urchin (an echinoderm) eggs, studying the behavior of the cell nucleus and chromosomes during meiosis and after fertilization.

The independent studies by Walter Sutton (1902-04) and Boveri's (1902) contributed to **chromosomal theory of Inheritance.**

Walter Sutton, an American cytologist studied meiosis in cells of **plain lubber grasshopper** (*Brachystola magna*). He was a young, graduate student who produced remarkable and detailed drawings of his finding in cytology. As a result of his observations, he (1902-4) made the connection between the behavior of chromosomes during meiosis and Mendel's laws of heredity.

Boveri and Sutton's chromosomes theory linking chromosomes and heredity had faced serious objections. According to many investigators, Mendalian traits are determined by the factors located on chromosome. If these genes separate due to segregation of chromosomes. The independent assortment of genes is reflected by the independent assortment of chromosomes in meiosis then the number of genes are much greater than the number of chromosome pairs that the organism possesses.

The objections of investigators were cleared with advancement in scientific understanding, development in cytology and after the contribution of T. H. Morgan. (Fig.23.3)



Water Sutton Theodor Boveri Thomas Hunt Morgan

Fig. 23.3

23.1.2 Contribution of T. H. Morgan

Thomas Hunt Morgan (1910) a Cytologist began his famous work on fruit fly. His work showed without any doubt that:

- The gene for eye color in fruit flies is located on the "X" chromosome and hereditary factors can be exchanged between the "X" chromosomes of an individual.
- The result of Morgan's studies led to a greater understanding of how genes are arranged on chromosomes and how genetic material can be exchanged (during crossing over) in meiosis.
- He was awarded the Nobel prize for physiology (Medicine) in 1933.

Thus all above contributions confirmed that the chromosomal theory of inheritance was not proposed by a single scientist, but rather the collaborative result of many researchers work over multiple decades.

Walter S. Sutton described the parallel behavior between genes and chromosomes. (Table 23.1)

Table 23.1: Parallel behavior of Genes and Chromosomes During Meiosis

S.No.	Behavior of Genes	Behavior of Chromosomes
i)	The genes that control the particular characteristics mostly occur in pairs.	Diploid cell contain the pairs of homologous chromosomes.
ii)	Pairs of the genes separate during the gamete formation so that the gametes have only one of the paired genes.	Each gamete cell has only one out of a homologous pair of chromosome *i.e.* gametes are haploid (n).
iii)	When the gametes unite the gene pairs are formed again.	When the gametes unite during the fertilization chromosome pairs restore again in pair. The zygotes are diploid (2n).
iv)	Genes are transmitted from one generation to the next and remain as unchanged units.	Individual chromosomes are transmitted from generation to generation as unchanged structure.
v)	There is independent assortment of genes *i.e.* possible gene combination can be calculated.	There is independent assortment of chromosomes *i.e.* possible chromosomes combination can be calculated.

23.1.3 Structure of Chromosomes

Chromosomes (Chomo = colored; soma = body) are compact coils of thread like structure, clearly visible only during cell division, so named because chromosomes take up stains easily when being prepared for microscopy. After cell division *i.e.* during interphase, these become uncoiled and look like very fine network called chromatin network (DNA and proteins). Thus DNA of eukaryotic cell most often occurs in the form of chromosomes. They carry information necessary for cell to exist. Chromosomes allow the organisms, whether unicellular or multicellular to survive.

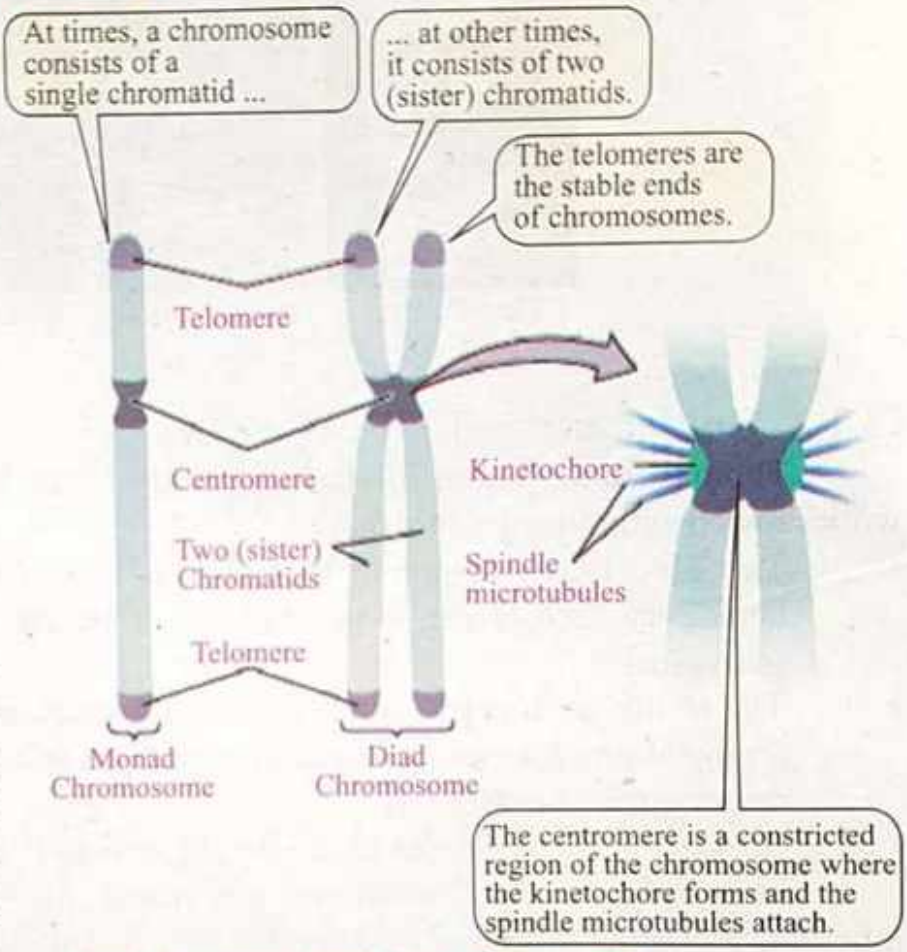


Fig. 23.4: Monad and Diad Chromosomes

They were first recorded by a German embryologist Walther Fleming in 1882, in rapidly dividing cells of **Salamander larvae**. Later chromosomes were observed in all eukaryotic cells and found linear while circular in prokaryotes.

The number of chromosomes vary from species to species and remains constant in each species generation after generation. ***Penicillium*** (a fungus) has only one pair, in fruit fly 4 pairs, mosquito 3 pairs, lettuce 9 pairs, corn 10 pairs, Honey bee 16 pairs, frog 13 pairs, mouse 20 pairs, human 23 pairs, monkey 24 pairs, camel 35 pairs, sugarcane 40 pairs and some ferns have more than 500 pairs.

Karyotype

It is a particular array of chromosomes that an individual possesses, which sometime may differ even among individuals of the same species, chromosome vary in size, shape, number, centromeric position, number and arrangement of genes.

Most species of animals and plants are **diploid** (having two sets of chromosomes), many plants are **polyploids** (more than two sets of chromosomes). There are many plants like, Bryophytes and many fungi are **monoploid** (Haploid).

The term "**haploid**" is referred to the number of chromosome exactly half than the somatic number of chromosomes *e.g.* gametes and mostly spores are haploid. (Fig.23.4)

Structure/Components of Chromosome

Typically, a chromosome is made of chromatids and a centromere (Primary constriction).

A typical **diad** (duplicated state) chromosome consists of two strands while **monad** (unduplicated state) chromosome has one strand called chromatid. Each **chromatid** is made up of a long DNA molecule which is tightly coiled along with **histone proteins**. The duplicated chromosome narrows down in one region along its length to form point of union called **primary constriction** or **centromere**. The both sides of primary constriction are covered by disc-shaped proteins known as **kinetochore**, the attachment site for microtubules that move the chromosome during nuclear division.

Some chromosomes may have another point of union along the length of each chromatid called **secondary constriction** or **nuclear organizer**. It gives rise to nucleoli during interphase. The portion of chromosome after secondary constriction becomes a knob like structure called **satellite**, contains useless sequence of DNA known as **junk DNA**. The terminal ends of each chromosome are called **telomeres** which prevent the two chromosomes to attach with each other from their ends.

Shape, Types of Chromosomes based on the location of the centromere

There are four types of chromosomes:

1. **Metacentric** are "V" shaped chromosome, the centromere is located in centre of chromatids.

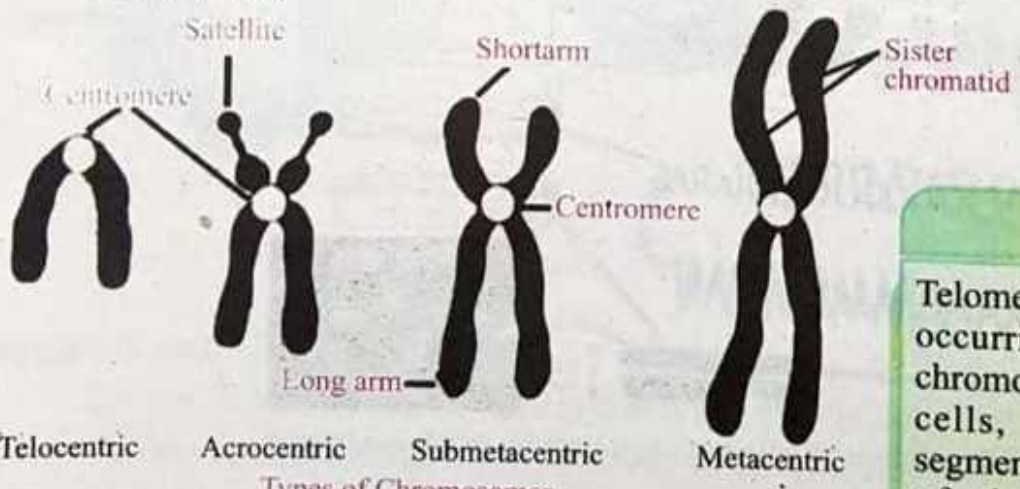


Fig. 23.5: Types of Chromosomes

Telomere

Telomere, segment of DNA occurring at the ends of chromosomes in eukaryotic cells, made of repeated segments of DNA that consist of the sequence 5' end TTAGGG-3' end.

2. **Submetacentric** are "L" shaped chromosomes, their centromere is either below or above the centre of the chromatids.
3. **Acrocentris** are "J" shaped chromosomes, the arms of one side of centromere are very short and other side very long.
4. **Telocentric** are "i" or rod shaped, the centromere is at the tip or at one end of chromosomes. (Fig.23.5)

23.1.4 Chemical Composition of Chromosomes

Chromosomes are **nucleoprotein** in nature. A typical chromosome contains about 60% proteins, 40% DNA and a significant amount of RNA (because DNA is the sites of RNA synthesis). Each duplicated chromosome has almost two identical DNA molecules.

An average size human chromosome has approximately 5cm long DNA that consists of about **140 million nucleotides**. In the cell the DNA is coiled allowing it to fit into a much smaller space. (Fig.23.6)

Interesting Information

It is estimated that the amount of information, a single chromosome contains would fill about 280 printed books each book with 1000 pages. Each nucleotide corresponds to a word and each page had about 500 words on it.

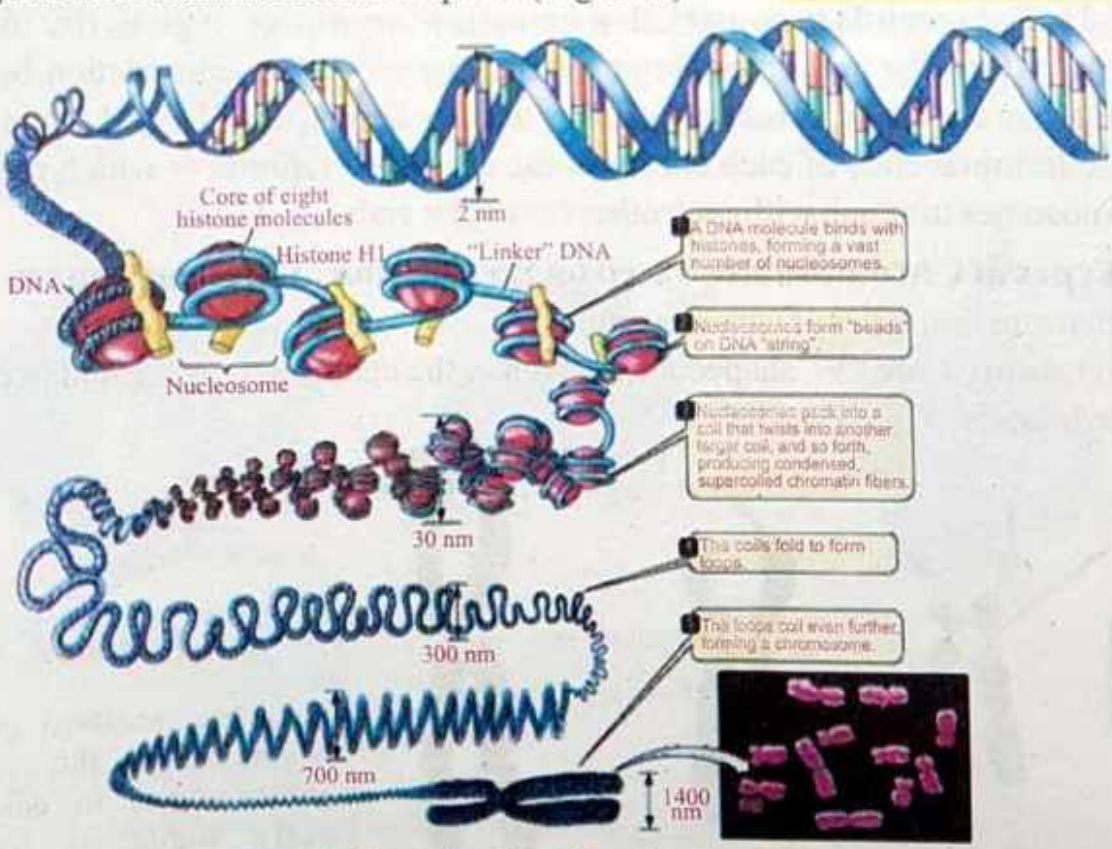


Fig. 23.6: Different levels of Organization of Chromosomes

Ultra Structure of Chromosome

The detailed structure of a molecule under electron microscope is called ultra

structure. The ultra-structure of chromosome revealed that each chromosome is made of repeated units called nucleosomes. About every 200 nucleotides of the DNA duplex is coiled around a core of eight histone protein (octamere) forming a bead like complex called **nucleosome** or **chromomere**. The **octamere** made up of four types of histone, two of each **H_2A, H_2B, H_3 and H_4**. The **histone** proteins possess positive charge, due to abundance of positive charged basic amino acids, **arginine** and **lysine**. Therefore, histones are strongly attracted to the negatively charged phosphate groups of the DNA. A small segment of DNA between two successive nucleosomes is called **linker or spacer DNA**. This is associated with another molecule of histone called **linker histone (H_1)**. Thus in this way the whole DNA which is 2 nm thick turns into chain of bead like appearance known as **nucleosome string** about 10nm thick. This immediately begins to coil again about its axis to form yet another thicker fibre called **chromatin solenoid** (about 30 nm).

During **interphase** *i.e.* in **G_1 and G_2 phases**, the chromosomes are in form of **chromatin fibres**. The chromatin is either in highly condensed form known as **heterochromatin**, which mostly do not express or less or non-condensed form called **euchromatin**, it becomes condensed during cell division and its genes can be expressed after cell division. (Fig.23.7)

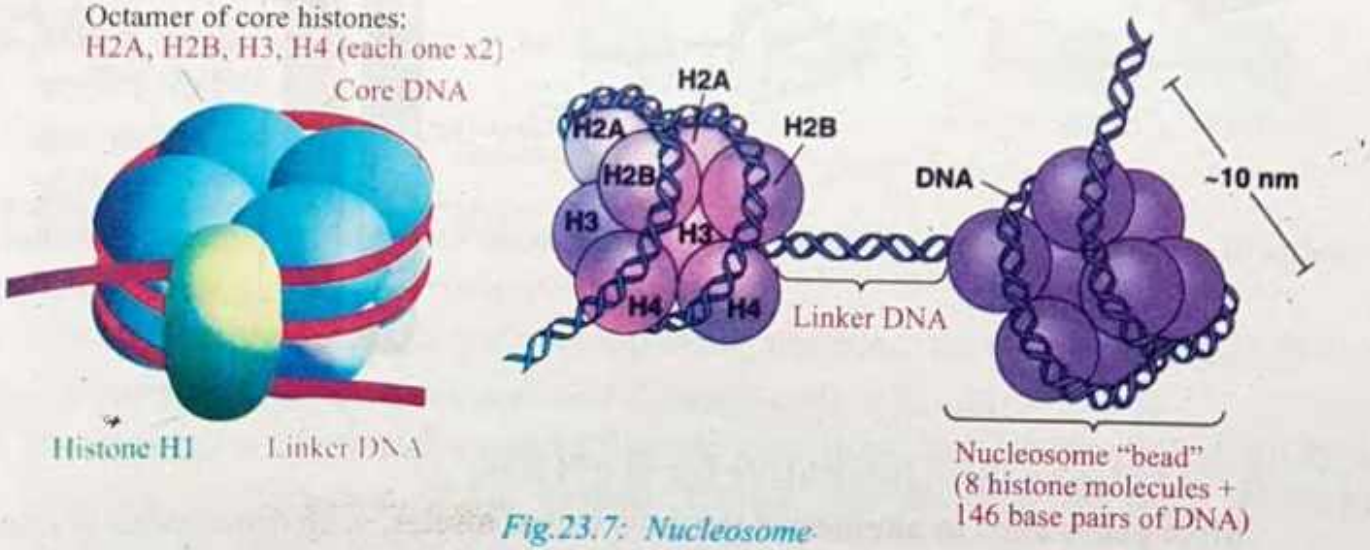


Fig.23.7: Nucleosome

Supercoil and Chromatids

During cell division, chromatin fibres are greatly coiled, which have diameter of 300nm further coiling occurs when the string of nucleosomes wraps up into higher order coils called super coils (about 700nm). The super coil is established into the chromatids and chromosome.

23.1.5 Molecular Concept of a Gene

The units of inheritance are called gene, which are composed of nucleotides sequence of a short specific segment of DNA, which transcribes an mRNA. The mRNA encodes the sequence of amino acid of a particular polypeptide.

Earlier, many names were used for genes by different scientists such as **gemmules** (by Darwin in 1868), **elementens** (by Mendel in 1865), **factors** (by Correns 1900), **pangens** (by De Vries in 1890). The present name **gene** was introduced by Wilhelm Johansson in 1909, while the term **genetics** was first used by William Bateson in 1906. The particular place or location where a gene resides is called **gene locus** (Plural = loci). (Fig.23.8)

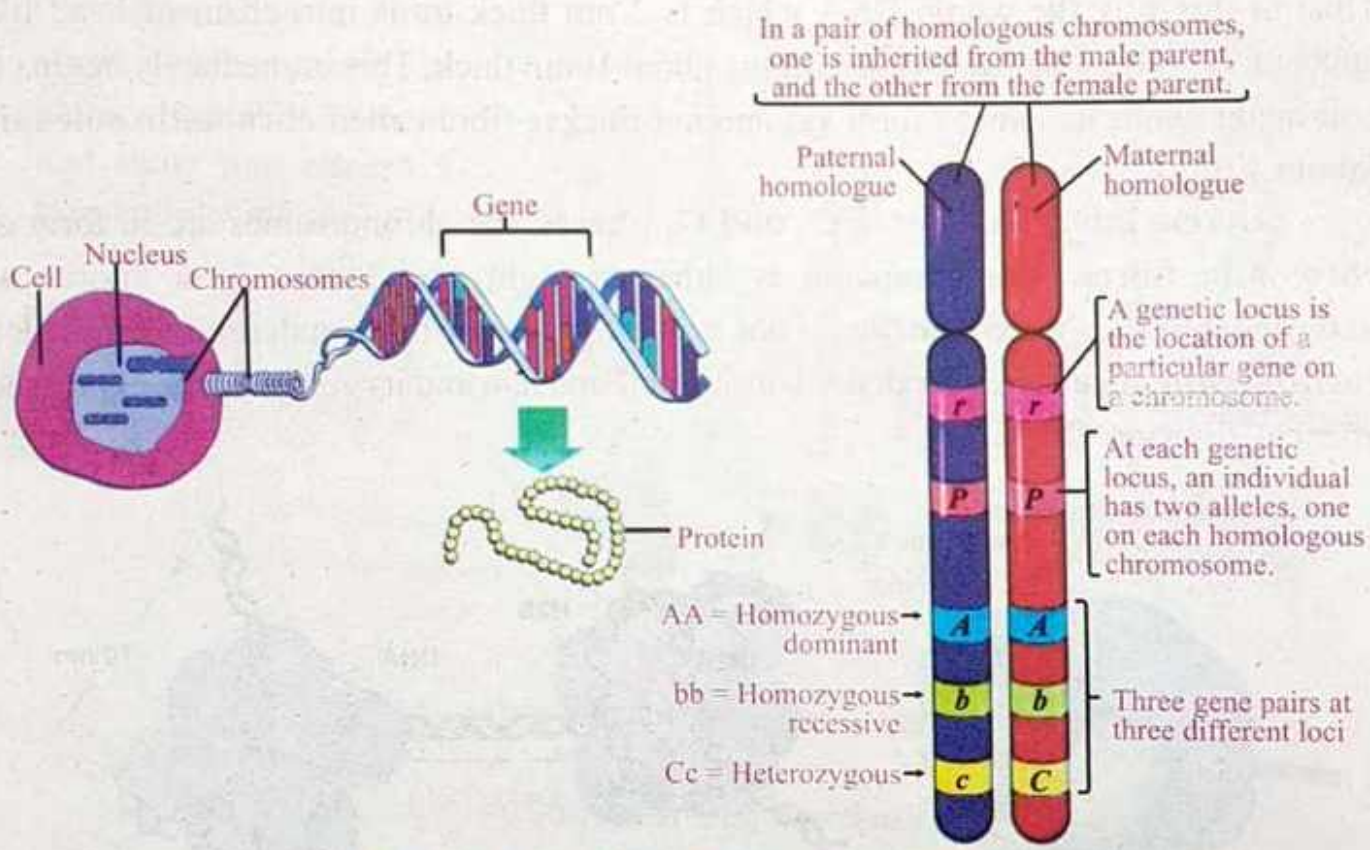


Fig. 23.8: Homologous Chromosomes and Gene

23.1.6 Alleles as the Alternative form of Gene

Most genes exist in alternative versions called **alleles**, with differences at one or more nucleotide positions in the DNA. The alleles related to the same trait occupy the same locus, such as gene of ABO blood group *i.e.* **"I" (isoagglutinogen)** exist in three different alleles **(I^A, I^B, i),** which are found on the same locus at chromosome No.9. The allele which fully expresses is called the **dominant** such as **"I"** allele, while the allele which either does not express or no noticeable effect on the organism's appearance is called **recessive**, such as **"i"**.

23.2 DNA as the Hereditary Material

The chromosomal theory of inheritance had confirmed that heredity units are found in the chromosome. It was known that the chromosomes contain both DNA and protein, but it was not confirmed, which one acts as hereditary information. Many experiments were performed by different researchers to confirm this issue.

23.2.1 Experiment of Griffith

The first **evidence** of hereditary nature of DNA was provided by British microbiologist **Fredrick Griffith** in 1928. He made some unexpected observations while experimenting with pathogenic bacteria, ***Streptococcus pneumonae***.

This pathogen is found in two types:

1. One type has a poly-saccharide capsule, it's colony appears as smooth and shiny thus named S-type and is virulent.
2. The other type is devoid of polysaccharide capsule, it's colony is rough thus named R-type, which is non-virulent.
3. When Griffith injected mice with S-type bacteria, the mice died of blood poisoning (Pneumonia).

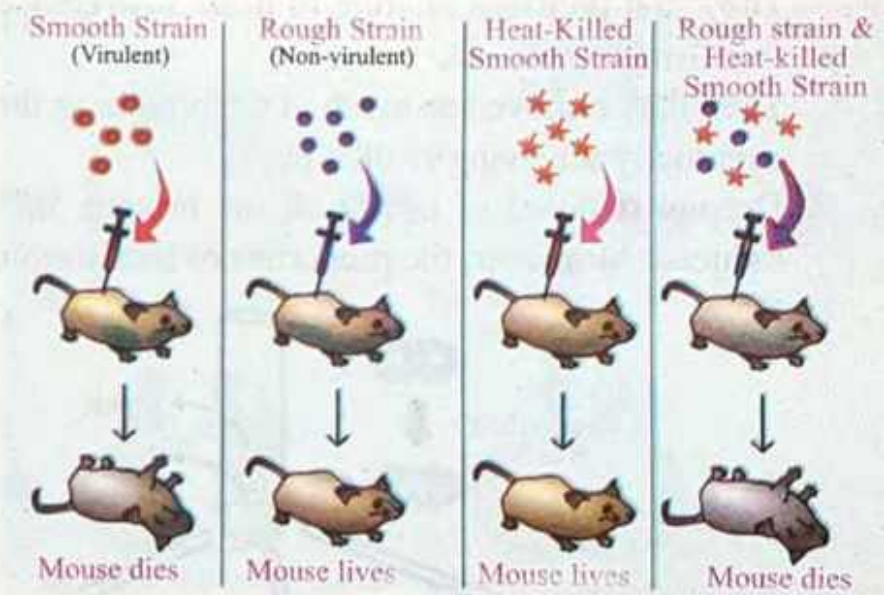


Fig. 23.9: Griffith's Experiments on Mouse

4. When he injected R-type bacteria to similar mice, the mice showed no ill effects (blood poisoning).
5. The Griffith observed that coat was apparently necessary for virulence. (Fig.23.9)

Decisive experiment

1. To determine whether the polysaccharide coat itself had virulent effect, Griffith injected dead bacteria of the **virulent S-type** into the mice; the mice remained perfectly healthy.
2. As a control, he injected mice with a mixture containing dead S-bacteria of the virulent strain and live R-type bacteria, each of which by itself did not harm the mice, when induced separately.

Result: Unexpectedly, the mice developed the disease symptoms and many of them died. The blood of the dead mice was found to contain high levels of live, **virulent**

Streptococcus (**S-type**) bacteria, which had surface protein. Somehow, the information specifying the polysaccharide coat had passed from the dead, virulent S-type bacteria to the live, coatless R-type bacteria in the mixture, thus permanently transforming the coatless R-type bacteria into the virulent S-type variety.

This transfer of genetic material from one cell to another which may alter the genetic makeup of the recipient cell, is called **transformation**.

23.2.2 Work of Avery, Macleod and McCarty

In 1944, in a classic series of experiments, Oswald Avery along with Colin Macleod and Maclyn McCarty repeated Griffith's experiments and characterized what they referred to as the transforming principle.

1. They first prepared mixture of dead ***S-Streptococcus*** and live ***R-Streptococcus*** that Griffith had used.
2. Then they removed as much of the protein as they could from their preparation, eventually achieving 99.98% purity.
3. Despite removal of nearly all the protein, the transforming activity was not reduced. Moreover, the properties of transforming principle resembled those of DNA.

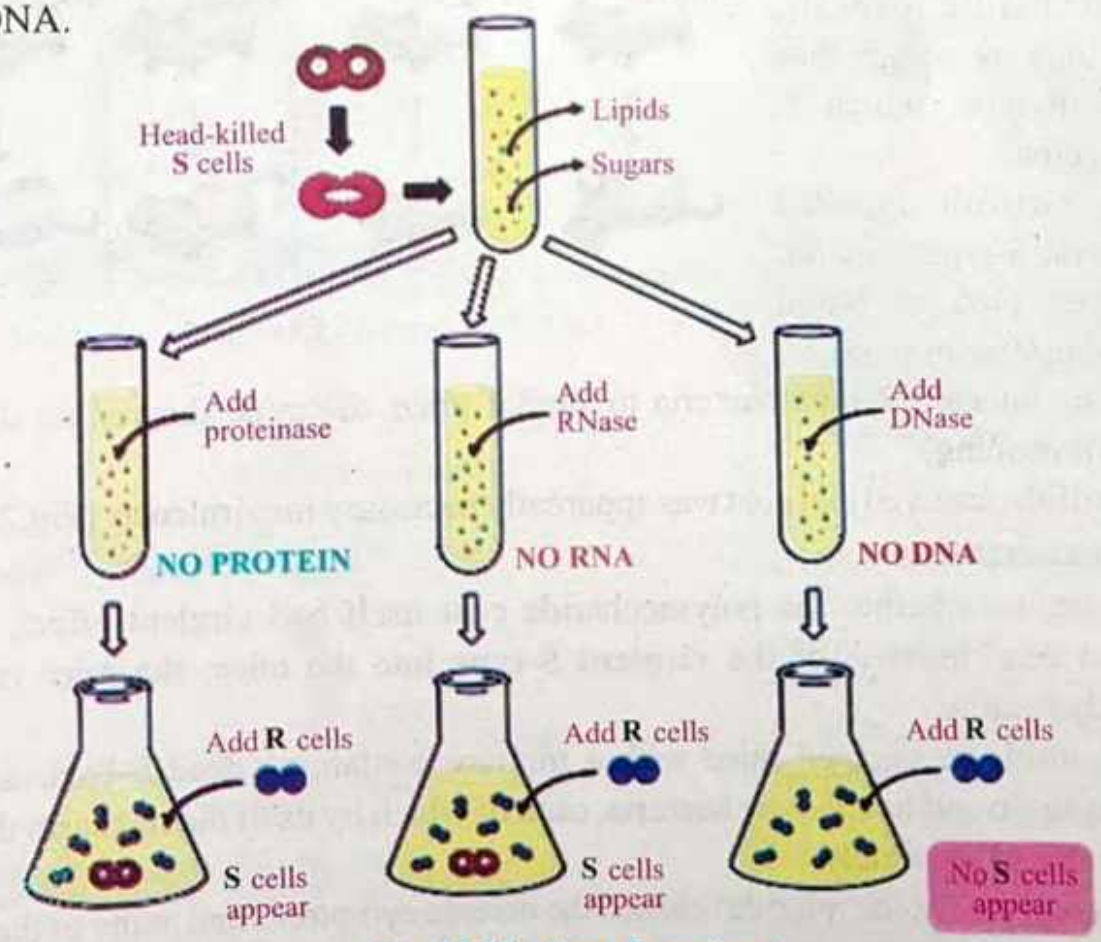


Fig. 23.10: Avery Experiment

4. The protein digesting enzymes or RNA digesting enzymes did not affect the transforming activity, but the DNA digesting enzyme DNAase destroyed all the transforming activity.

23.2.3 Hershey and Chase Experiment

Alfred Hershey and Martha Chase (1952) experimented with **bacteriophage T_2** and provided additional evidence supporting Avery's conclusion. Bacteriophages attack on bacteria, these viruses are made of DNA and protein, just like chromosome. In some experiments they labelled viruses with radioactive isotope ^{32}P, which was incorporated into the newly synthesized DNA of growing phage.

In other experiments, they labelled viruses with radioactive isotope ^{35}S, which is present in their protein coats. (Fig.23.11)

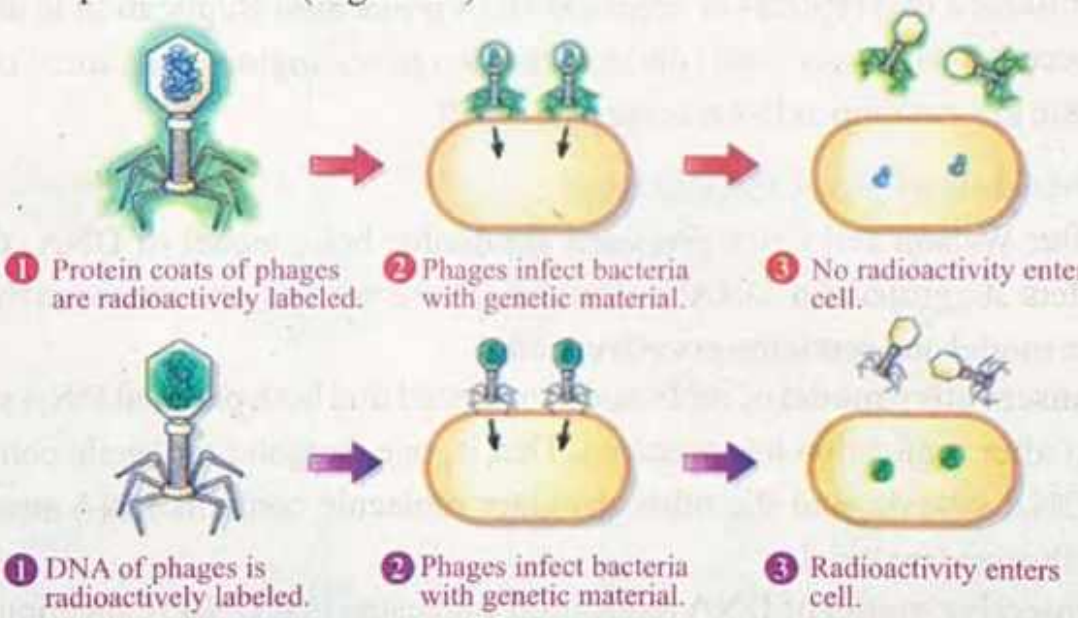


Fig. 23.11: Hershey and Chase Experiment

Exposure of Bacteria to labelled Viruses

Now one bacterial culture was exposed to radioactive ^{32}P labelled viruses and other culture was exposed to radioactive ^{35}S labelled viruses.

The bacterial cells were agitated violently in a blender to remove the protein coats of the infecting viruses from the surfaces of the bacteria.

When bacteria were tested for the presence of label, it was found that bacteria had lost nearly all of radioactive ^{35}S label. However, ^{32}P label was present in bacteria of the other group.

Bacteriophage T_2 is more properly called enterio-bacteriophage T_2. It is a virulent bacteriophage, which infects ***Escherichia coli*** bacteria, it contains linear double-stranded DNA. It is tailed phage.

It is because ^{35}S was only present in protein coat while ^{32}P was present in DNA that had transferred to the interior of the bacteria.

Confirmation

It was confirmed when viruses were released from the infected bacteria. The viruses released from ^{32}P culture were labelled while viruses released from ^{35}S culture were unlabelled.

Thus, it was proved by Hershey and Chase that the hereditary information injected into the bacteria that specified the new generation of viruses was DNA and not protein.

23.3 DNA Replication

DNA replication is the process by which a double stranded DNA molecule is copied to produce two replicas or identical DNA molecules. Replication is an essential process, because whenever a cell divides, the two new daughter cells must contain the same genetic information or DNA as the parent cell.

23.3.1 Models of DNA Replication

After Watson and Crick proposed the double helix model of DNA, there were three models suggested for DNA replication. These models are **conservative model**, **dispersive model** and **semiconservative model**.

1. **Conservative model** of replication suggested that both parental DNA strands are kept intact after replication has occurred. That is, one daughter molecule contains both parental DNA strands, and the other daughter molecule contains DNA strands of all newly synthesized material.
2. **Dispersive model** of DNA replication suggested that DNA replication results in two DNA molecules that are mixture of parental and daughter DNA. In this model, each individual strand is a patchwork of original and new DNA.
3. **Semiconservative model** of DNA replication revealed that the two strands of parental DNA isolate and each of these serves as template for synthesis of a new DNA strand. It produces two copies of the original DNA molecule, each of which contains one of original strand, and one newly synthesized strand.

23.3.2 Meselson and Stahl Experiments

The experiment was performed by Mathew Meselson and Franklin Stahl in 1958, which evaluated the three models of DNA and won Nobel Prize. In this experiment, it was concluded finally that the replication of DNA occurs according to semiconservative model. (Fig.23.12)

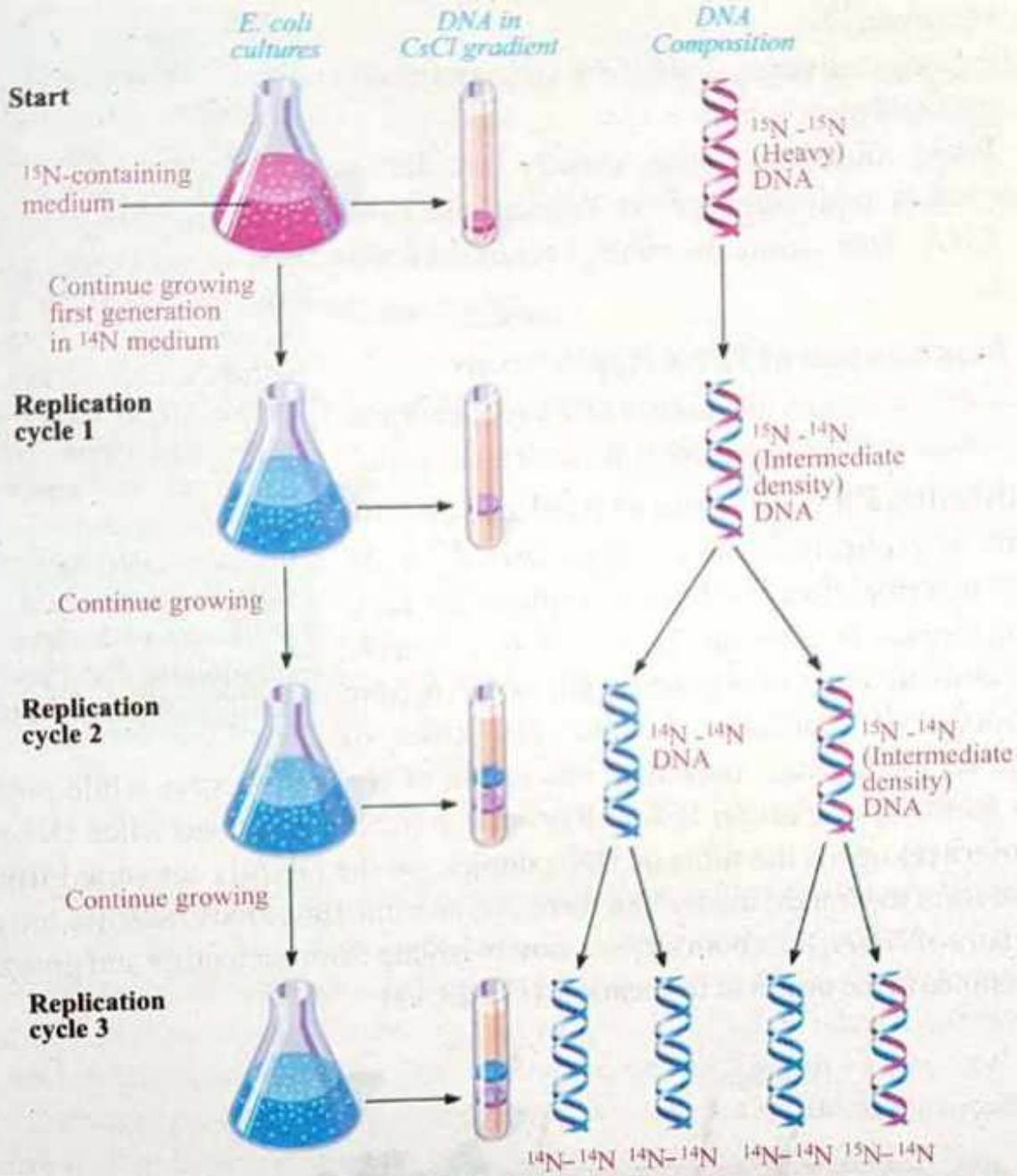


Fig. 23.12: Meselson-Stahl Experiment

The confirmation of semiconservative replication by Meselson and Stahl

The semiconservative replication of DNA was tested in 1958 by Mathew Meselson and Frank Stahl in California institute of technology.

The two scientists grew bacteria for several generations in a medium containing the heavy isotopes of ^{15}N (heavier).

So the DNA of the bacteria was eventually denser than normal (^{14}N lighter).

Now they transferred the growing bacteria to a new medium containing the lighter isotope ^{14}N. After one division only hybrid DNA molecules were in the cells (one strand

^{15}N and other strand ^{14}N).

After second division, half of the DNA molecules were light and half were hybrid.

Result: These divisions were exactly similar to semiconservative replication of the Watson and Crick model of DNA. Thus semiconservative replication was confirmed.

Extra Information

Cesium chloride (CsCl) solution were made by Meselson and Sthal, to dissolve DNA. They spun the solution at a very high speed in an ultracentrifuge for many hours. The ions of cesium and chloride pushed towards the bottom of solution containing tube and thus formed a gradient of cesium and chloride was established in the test tube. DNA molecule were settled down and formed sediments to the level of their appropriate densities ($^{15}N^{15}N$, $^{14}N^{14}N$, $^{15}N^{14}N$) in the test tube.

23.3.3 Mechanism of DNA Replication

For convenience, we discuss DNA replication in different phases and to make it easy and understandable.

1) Initiation Phase (Origin of Replication site)

The origin of replication site is characterized by the formation of **replication bubble** and **replication fork**, which are formed at a particular site. It is a specific sequence of nucleotides along the length of DNA from where process of replication begins. The DNA of eukaryotic cells possesses more than one origin of replication sites while prokaryotic DNA has normally one origin of site. Replication bubble is formed when **DNA gyrase (topoisomerase)** opens the turns of DNA duplex, so the DNA is converted from spiral ladder like form to straight ladder like form. At the same time **DNA helicase** break down the base pairs of DNA, thus both strands slowly isolate from each other and give a bubble like appearance at the origin of replication. (Fig.23.13)

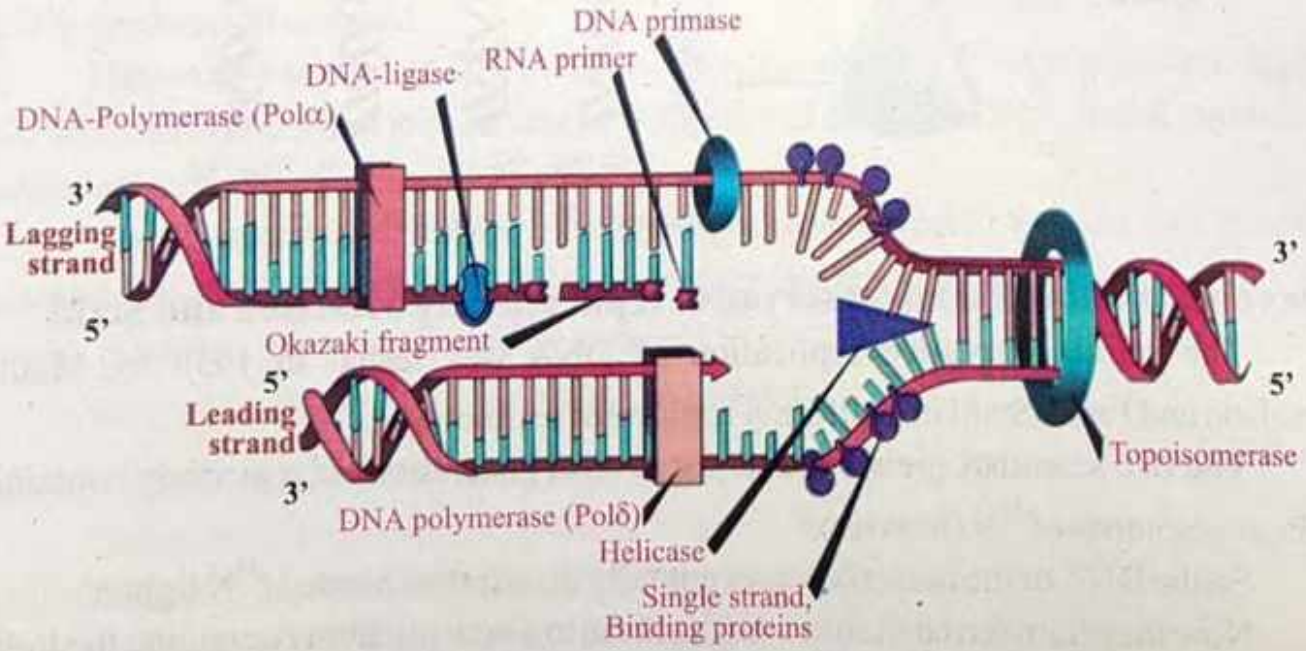


Fig.23.13: Process of DNA Replication

After breakdown of base pairs, the DNA strands are prevented to pair up again by specific proteins, known as **Single Stranded Binding (SSB)** proteins. Now, these isolated strands of DNA will act as **template strand** in next phase and direct the synthesis of daughter strands along themselves. Each side of replication bubble is now termed as replication fork which is a site on a DNA molecule at which uncoiling of the helices and synthesis of daughter molecules are both side occurring.

2) Elongation Phase (Polymerization)

This phase is referring to the formation of two types of daughter strands along the template strand *i.e.* **leading and lagging strands**. Both daughter strands are synthesized by **DNA polymerase** but this enzyme has a property that it cannot work on its own unless some nucleotides arranged on template. Therefore, **RNA primer** (a short oligonucleotide (10-20) strand of RNA) acts as initiation site for the activity of DNA polymerase. The enzyme **primase** helps in the synthesizing of primer.

Mechanism of DNA Polymerase III activity

DNA polymerase III is a dimer (made of two units) and each unit further consists of several subunits. It adds nucleotide at 3-OH group (*i.e.* carbon No.3 of deoxyribose), thus the direction of replication becomes 5′ to 3′ end (5′ carbons to 3′ carbon). One subunit of DNA polymerase III also helps in proof reading *i.e.* removes the mismatch nucleotide.

The two subunits of DNA polymerase III are interlinked by a small polypeptide chain, first subunit works on one template and continuously synthesizes a daughter strand towards **replication fork** (leading or continuous strand). While the second subunit allows to polymerize daughter strand up to a specific length then it has to jump back (100 to 200 nucleotides in prokaryotes and 1000-2000 nucleotides in eukaryotes) to a new primer to perform polymerization again. Thus the growing strand that runs away from replication fork by forming short fragments interrupted by primers known as **Okazaki fragments**. This discontinuous growing strand is called **lagging strand**.

Termination Phase

i) Termination phase is characterized by the replacement of primers by DNA nucleotides and joining of Okazaki's fragments in lagging strand to form a continuous strand.

ii) The replacement of primers of DNA nucleotides is carried out by DNA **polymerase-I** that have dual function *i.e.* besides polymerase it also acts as exonuclease (removes primer).

iii) It is attached to the 3′ end of Okazaki's fragment where it adds DNA nucleotide, so that it can extend, while on the other hand it cleaves nucleotide from 5′ end of

primer.

iv) In this way primers are removed and each Okazaki's fragment is extended up to the next Okazaki's fragment but they do not join together.

v) The joining of Okazaki's fragment is carried out by DNA **ligase enzyme** that finally constructs **phosphodiester bonds** between Okazaki's fragments, so a continuous strand is formed.

Extra Information

DNA polymerase adds nucleotides in growing template strand at a rate of some 1000 nucleotide/second.

23.4 Central Dogma of Biology (Gene Expression)

All the organisms use the same basic mechanism of reading and expressing of genes, which is often referred to as **central dogma**. The genes reside in DNA. The genetic information (genes) flows down into mRNA (this process is called **transcription**), which is then converted **(translation)** to polypeptide chain (one or more polypeptide chains unite to form protein).

Thus the gene expression includes transcription and translation processes or we can say that proteins are a link between the genotype (DNA) and phenotype (synthesize of protei

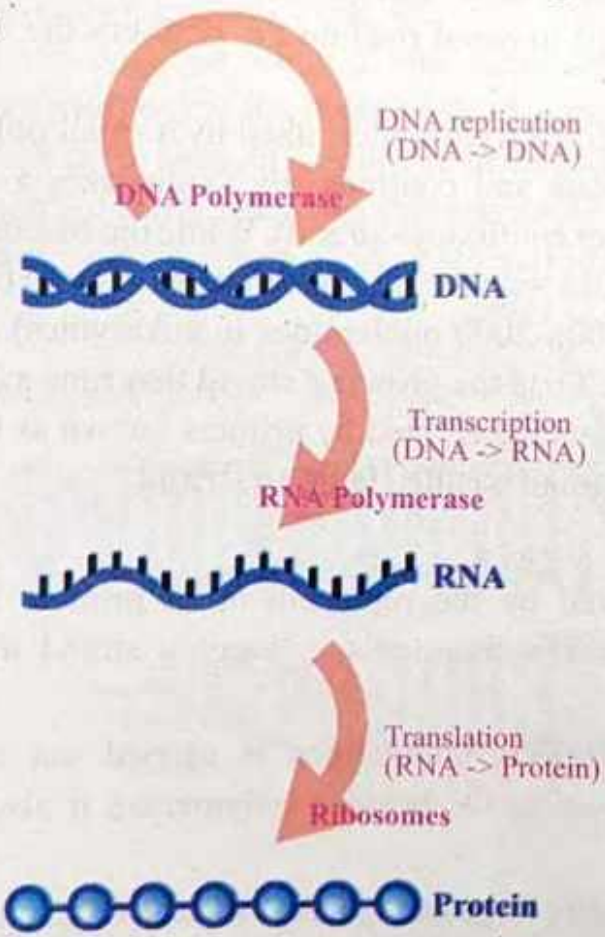


Fig. 23.14: Central Dogma of Biology

3 Types of DNA polymerase

I DNA Polymerase I: It is relatively small enzyme which catalysis the replacement of RNA primers by DNA nucleotides in termination phase of replication. Thus it provides a support to the DNA polymerase III in the main replication.

ii. DNA Polymerase II: It involves the repairing process of DNA damage during the life time of a cell.

iii. DNA Polymerase III: It is the main enzyme that synthesizes both daughter strands along the template process. It is 10 time larger and complex than other two polymerases.

23.4.1 Gene and Genetic Code

Gene is the specific sequence of nucleotides in DNA which determines the amino acid sequence of protein while **Genetic code** is the combination of three nucleotides, which specify a particular amino acid or the relationship between amino acids sequence and nucleotide sequences, known as genetic code.

The genetic codes are coded language which are placed on one of the two strands of DNA, which is called **sense or coding strand** *i.e.* 3′ to 5′ and while the other strand is called **antisense / non-coding / template strand** (*i.e.* 5′ to 3′ end). The codes are based on "alphabet" consisting of only four types of nucleotides adenine (A), guanine (G), Cytosine (C) and thymine (T). These bases are variously arranged in DNA to form code words known as codes. Each code word is a unique combination of 3′ letters (bases). During transcription these **codes** are passed (as written record) to mRNA called **codons**. The codon on mRNA eventually is

Extra Information

The three nucleotide sequence on DNA is called code while its complementary sequence on mRNA is called codon. The complementary sequence of codon on tRNA is called anticodon.

Interesting Information

Codes are universal but genetic code of mitochondrial DNA, however, showed that genetic code is not quite universal, for example, UGA instead of stop codon, it code for tryptophan amino acid, AUA instead of isoleucine code for methionine and AGA, AGG instead of arginine for stop codon.

Table 23.2: Genetic Codon

First Base of Codon	Second Base of Codon: U		C		A		G		Third Base of Codon
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 codon	UGA	STOP codon	A
	UUG		UCG		UAG		UGG	Tryptonphan 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 gin	CGA		A
	UUG		UCG		UAG		UGG		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
	A	Methionine met (start codon)	ACG		AAG		AGG		G
G	GUU	Valine val	GCU	Alianine 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

interpreted as a single amino acid in a polypeptide chain. There are total 64 codons possible from an "alphabet" of four letters. Out of 64 codons, 3′ are **non-sense codon** which act as termination or **stop codons** (UGA, UAG and UAA), while rest of 61 are sense codons that encode specific amino acids. One of this sense codon is called start codon (**AUG code for methionine amino acid**) that must be located at the beginning of all the sequences that code for amino acid chains (polypeptide). (Table:23.2)

23.4.2 Characteristics of Codons

The common characteristics of codons are:

Genetic Code is degenerative: Some amino acids are encoded by a single codon (AUG = Methionine and UGG = Tryptophan). Some other encoded by more than one codons, *e.g.* isoleucine (AUU, AUC and AUA), proline (CCU, ACC, ACA and ACG), Leucine (CUU, CUC, CUA, CUG, UUA, UUG), *etc.* This property of genetic code that some amino acids are coded by more than one codon, is called degeneracy.

Triplet codon: Three nucleotides code for one specific amino acid.

Genetic code is universal: It is same in most organisms *e.g.* AUU for isoleucine, UUU for phenylalanine.

No Punctuation: There is no punctuation between successive codon on mRNA or DNA.

Genetic Code is Non-overlapping: mRNA sequence AUGGUAGCG is not read as AUG/UGA/AGC, *etc.* it will be read as AUG/GUA/GCG. (Fig.23.15)

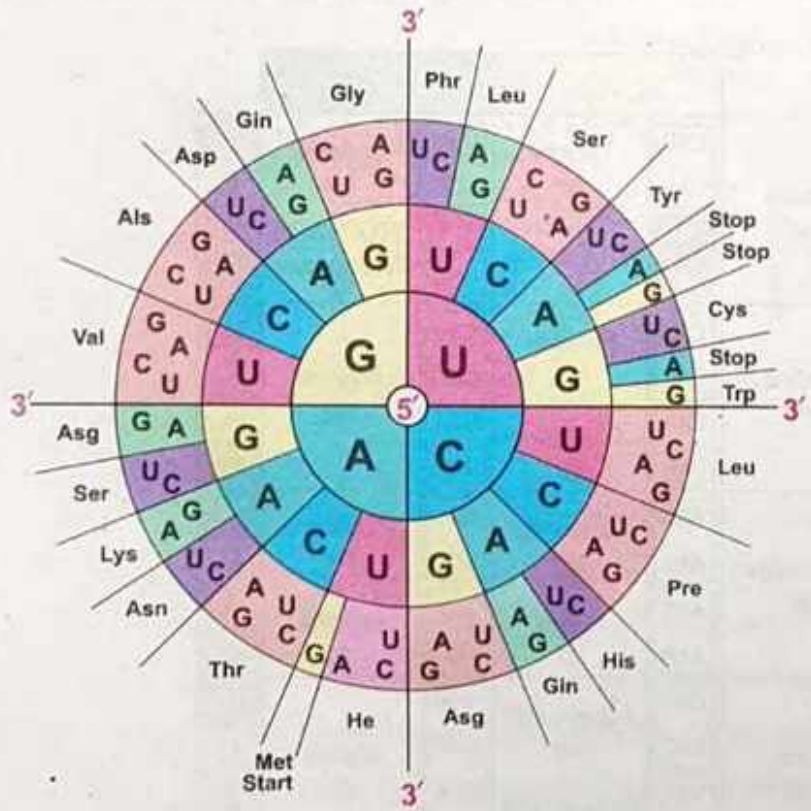


Fig. 23.15: Genetic Codon Wheel Diagram

Interesting Information

Codon is always in triplet form. Each codon consist of three nucleotides, usually cross ponding to a single amino acid.

23.4.3 Transcription

Transcription is the first step in gene expression. It involves copying a gene's DNA sequence to make an RNA molecule. RNA polymerase is the main transcription enzyme.

Extra Information

In human, 45 sense codons are recorded so far instead of 61 sense codons.

Mechanism of Transcription

The process of transcription can be divided into three phases: initiation, elongation and termination. (Fig.23.16)

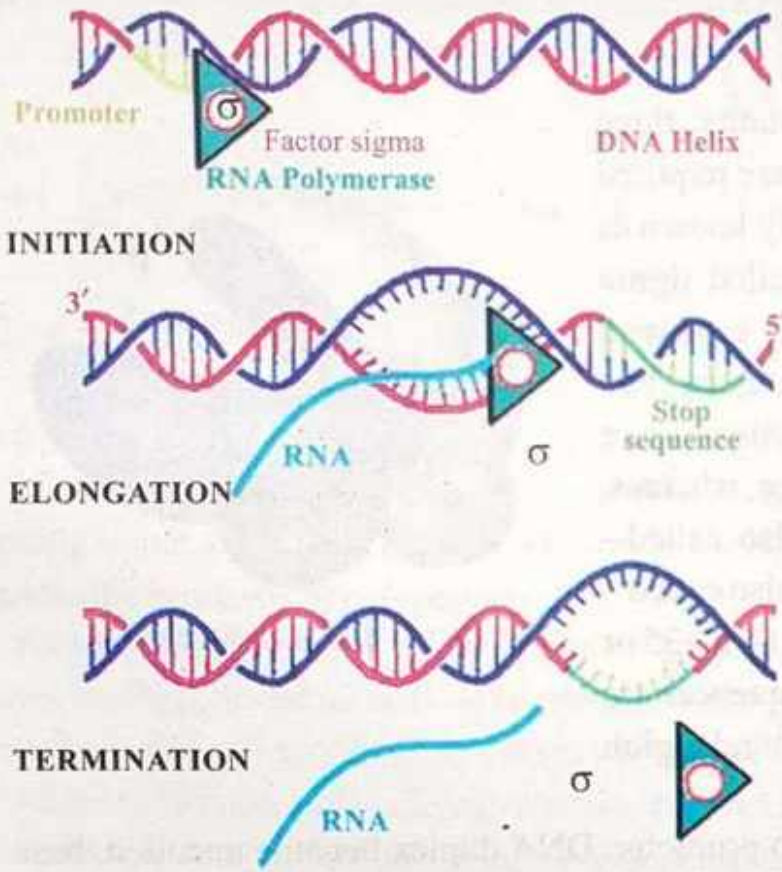


Fig. 23.16: Three steps of Transcription

Eukaryotic Cell

These cells contain membrane bound organelles including nucleus. Eukaryotic organisms may be single celled or multi celled such as human, plants, insects, birds, fungi, *etc.*

Prokaryotic Cells

These cells do not contain prominent nucleus and membrane bound organelles. These are always single celled *e.g.* bacteria and cyanobacteria.

Initiation phase

Transcription initiates with the binding of RNA polymerase at promoter region. It is regulator region of gene where binding site for RNA polymerase is located.

The RNA polymerase synthesizes RNA from **5′ to 3′ direction**. In **prokaryotes**, only one type of RNA polymerase that is responsible for the synthesis of all three major types of RNAs while in **eukaryotes**, three types of RNA polymerase, RNA polymerase-I for rRNA, RNA polymerase-II for messenger RNA (mRNA) and RNA polymerase-III for tRNA. (Fig.23.17)

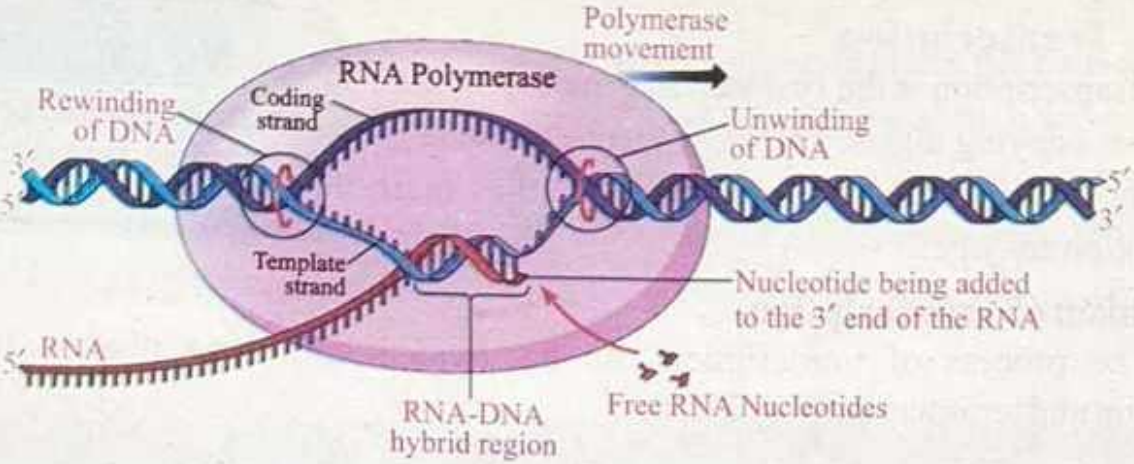


Fig. 23.17: Mechanism of Transcription

These enzymes have four subunits, three subunits *i.e.* **alpha, beta, beta prime** are required for polymerase activity and collectively known as **core enzyme**. The fourth subunit is called **sigma factor,** required for RNA polymerase to bind with promoter region. In prokaryotes, there are two binding sites *i.e.* TATAAT, also called 10 sequence and TTGACA, also called – 35 sequence, whereas, in eukaryote, **TATAAT (TATA box),** also called – 25 sequence and **CAAT (CAAT box)** also called – 70 sequence, names of these sequences (-10, -35 or -25, -70) refer to position that these sequences are located before the initiation site of structural region of the gene.

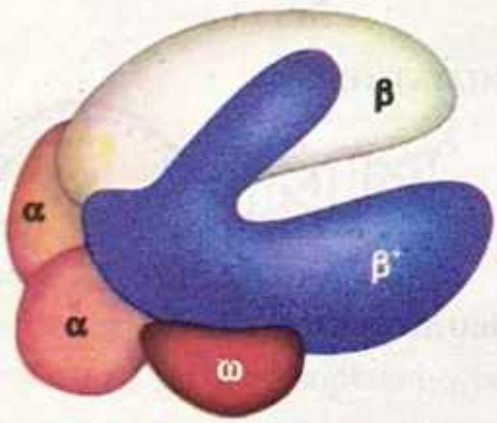


Fig. 23.18: Bacterial RNA Polymerase

When RNA polymerase binds to promoter, DNA duplex become uncoiled, base pairs are broken down and a bubble like structure called the transcription bubble, is appeared. (Fig.23.18)

Elongation Phase

This phase is also polymerization phase, as soon a sigma subunit of RNA polymerase binds to promoter, transcription begins and sigma factor is released. The rest of enzyme, which is now called core enzyme, extends the polymerization of ribonucleoside triphosphate (rNTP).

In elongation phase, RNA polymerase keeps on moving from 5′ to 3′ direction towards the terminator region. The RNA polymerase copies the DNA sequence accurately at a rate of 30 to 40 nucleotides / second.

Termination Phase

The terminator sequence at the end of the gene terminates the transcription. The terminator region consists of a series of GC base pair followed by a series of AT base pairs. The part of mRNA which is transcribed in this region, project to form a loop like structure called GC hairpin followed by a small tail of AU nucleotides. The GC hairpin causes RNA polymerase to terminate synthesis of RNA.

Table 23.3: Differences between mechanism of transcription between Prokaryotic and Eukaryotic Organisms

S.No.	Prokaryotes	Eukaryotes
i)	Three RNA polymerase enzymes are involved.	Only one polymerase enzyme is involved.
ii)	DNA is circular.	DNA is linear.
iii)	Transcription starts only from one point.	Transcription starts from may points.

24.4.4 Post Transcriptional Modification of mRNA (mRNA processing)

It is a process by which newly synthesized mRNA (primary mRNA or immature mRNA) is transformed into mature mRNA (functional mRNA).

In prokaryote, this process is not needed because it has no **intron** (non-protein coding sequence) and no nucleus. Thus it is directly released into the cytoplasm, where it guides the synthesis of polypeptide chain.

In eukaryotes, mRNA has to travel long distance from nucleus to ribosomes (cytoplasm). During this journey, mRNA is modified in several ways, cap and tail is added so that the molecule may remain stable and save the mRNA from variety of nucleases and phosphatases enzymes. The cap is the form of **GTP (7-methyl triphosphate guanosine)** which is linked with the first nucleotide of mRNA by 5 to 5 to Triphosphate Bridge. The tail is in the form of **poly A (poly-adenylic acid)** link to 3 end of the mRNA (about 30-500 nucleotides long).

Extra Information

The phosphatases and nucleases degrade nucleic acids by hydrolyzing the phosphodiester bond.

Difference between Primary mRNA and Secondary mRNA (mature RNA)

The primary mRNA in eukaryotic cells comprise many non-coding sequences called **introns** and protein coding sequences called **exons**. Thus these introns from a primary mRNA transcript are to be removed. (Fig.23.19)

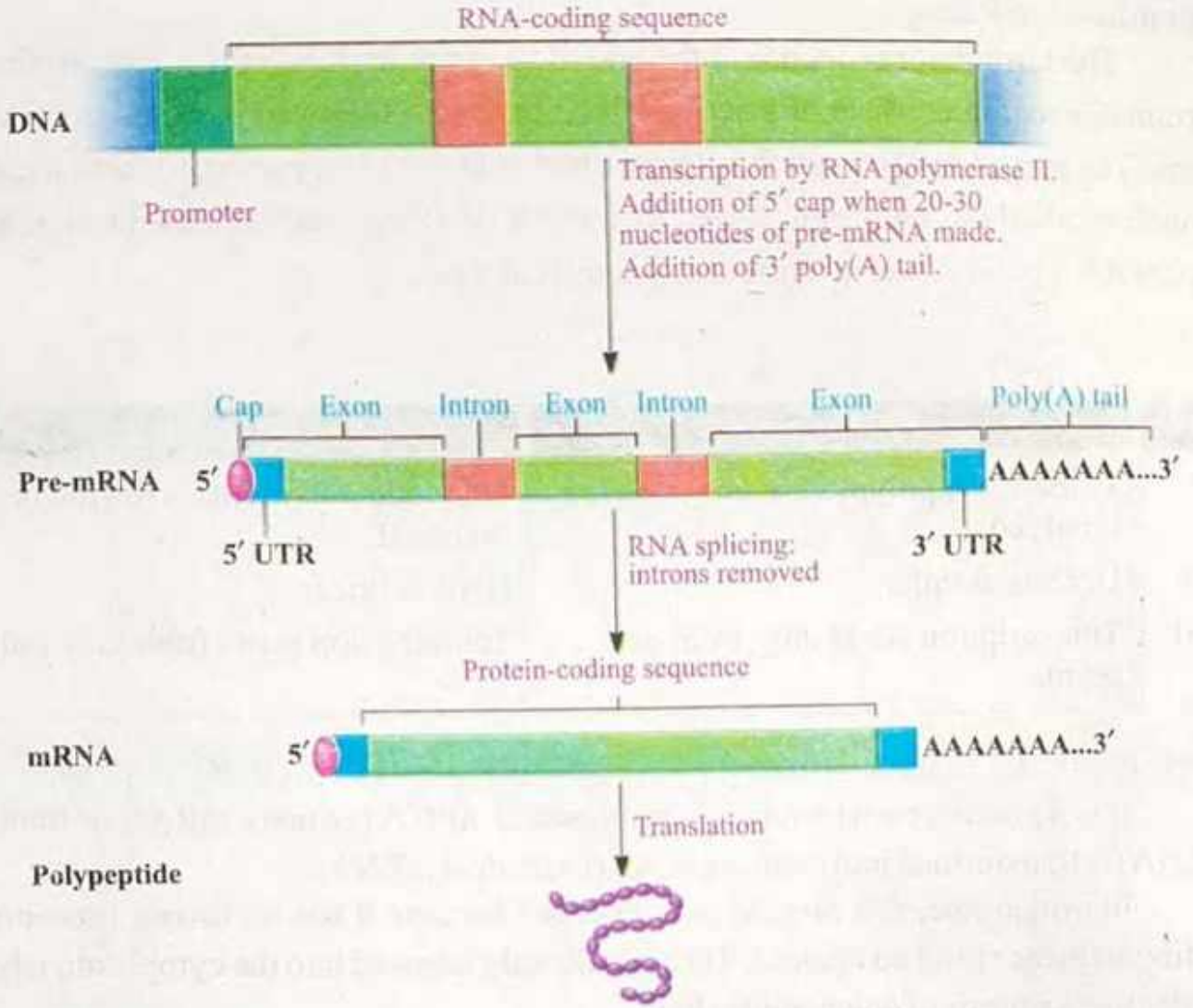


Fig. 23.19: mRNA Processing

The removal of introns and maturation of primary mRNA to **functional and secondary mRNA** is called RNA splicing. This process is completed by spliceosome. A **spliceosome** is a large and complex molecular machine found primarily, within the nucleus, which is assembled from **small nuclear RNAs (snRNA)** and approximately 80 proteins. It removes introns from a primary mRNA. Later on the spliced exon fragments are joined together with the help of **RNA ligase enzyme**.

23.4.5 Translation (Protein Synthesis)

Translation is the formation of protein with the help of RNA. It is second stage of gene expression or protein synthesis. In translation, mRNA is decoded by the ribosome to produce a specific amino acid chain (Polypeptide) that will later folds into active protein.

In **prokaryotic cells**, translation occurs freely in the cells cytoplasm while in **eukaryotic**, occurs across the membrane of the endoplasmic reticulum.

The process of translation can be divided into four phases: activation, initiation,

elongation and termination.

i) Activation

The store house of cytoplasm contains inactive amino acids. They should be activated before they react with tRNA. The amino acids are activated when they react with ATP in the presence of activating enzyme, **aminoacyl tRNA synthetase.**

Amino acid (AA) + ATP + Enzyme AA.AMP.Enzyme Complex

Now the same activating enzyme catalyzes the attachment of amino acid to specific tRNA. (Fig.23.20)

AA + AMP + Enzyme Complex + tRNA AA.tRNA.AMP.Enzyme complex

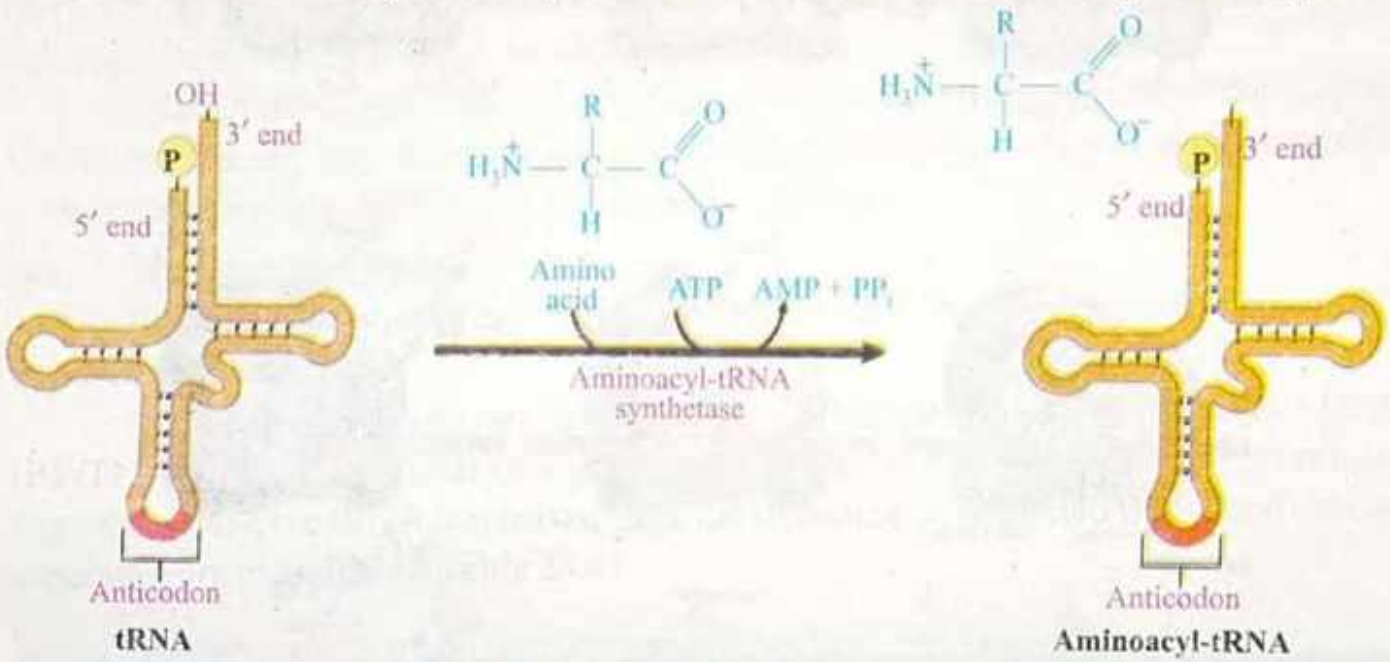


Fig. 23.20: tRNA with Activated Amino Acid

ii) Initiation (Formation of initiation complex)

First the separation of two subunits of ribosome occurs, then initial portion of an mRNA molecule binds to an rRNA molecule in a small ribosomal subunit in the presence of initiation factors (IF_3). Now a tRNA molecule carrying chemically modified initial amino acid, methionine (known as N-formyl methionine) binds to small ribosomal subunit at P-site (peptidyl site) where peptide bond will form. This binding is controlled by an enzyme called initiation factors (IF_1 and IF_2). There are two other sites which will form A-site (for aminoacyl site), where successive amino acids bearing tRNA will bind and the E-site (for exit-site) where empty tRNA will exit the ribosome.

After the initiation complex has formed, the large ribosome subunit binds to small subunit. This exposes the mRNA codon adjacent to initiating AUG codon and preparing

it for interaction with another amino acid bearing tRNA molecule at A-site. Now initiation factors (IF_1, IF_2 and IF_3) are released and reutilized. (Fig.23.21)

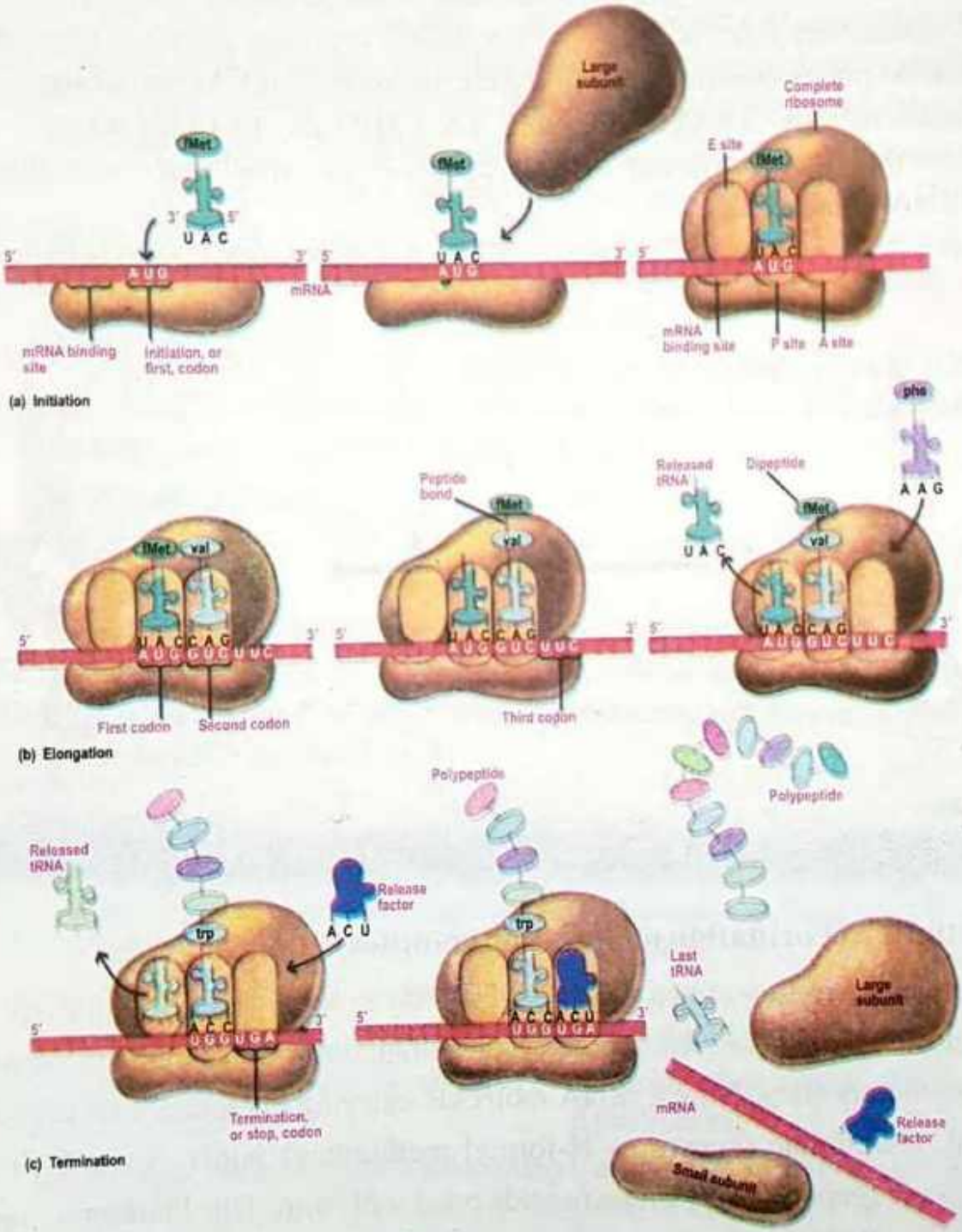


Fig. 23.21: Steps of Translation

iii) Elongation Phase

During this phase ribosomal units move along mRNA, amino acids are brought by tRNAs, which are linked together to form a polypeptide chain.

The Binding of Second Aminoacyl tRNA

When a tRNA molecule with the appropriate anticodon appears, enzyme called **elongation factors** assist in binding it to the exposed mRNA codon at the A site.

The two amino acids undergo a chemical reaction, catalyzed by the large ribosomal subunit which releases the initial methionine from its tRNA and attaches it by a **peptide bond** to the second amino acid in the presence of enzyme, **peptidyl synthetase.**

The ribosome now moves (translocate) three more nucleotides along the mRNA molecule in the $5' - 3'$ direction, guided by other elongation factors. This movement translocate the initial tRNA to the E-site and liberates it from the ribosome, repositions the growing polypeptide chain (at this point containing two amino acids) to the P-site, and exposes the next codon on the mRNA at the A-site.

When a tRNA molecule recognizing that codon appears, it binds to the codon at the A-site, placing its amino acid adjacent to the growing chain. The chain then transfers to the new amino acid and the entire process is repeated.

iv) Termination Phase

Elongation continues in this fashion until a chain-terminating non-sense codon is exposed at A-site.

Non-sense codons do not bind to any tRNA, but they recognize the release factors (RF/TF), the RF/TF terminate the process of translation and the polypeptide is released from the tRNA, the tRNA is released from the ribosome, and the two ribosomal subunits separate from the mRNA. (Table 23.4)

Table 23.4 Difference between Protein Synthesis in Prokaryotes and Eukaryotes

S.No.	Prokaryotes	Eukaryotes
i)	Ribosomes are 70s (small subunit 30s and large 50s).	Ribosomes are 80s (small subunit 40s and large 60s).
ii)	It occurs in the cytosol of cytoplasm.	It occurs in both cytosol and endoplasmic reticulum *i.e.* in RER.
iii)	The initiating amino acid is modified N-formyl Methionine.	The initiating amino acid is modified, it is methionine.
iv)	mRNA is polycistronic (synthesis of many protein).	mRNA is monocistronic (synthesis of only one protein).
v)	Need single initiation factors.	Need more than one initiation factors.
vi)	Only one releasing factor.	Two releasing factors.

23.5 Regulation of Gene Expression

Regulation of **gene expression** means the control of amount and timing of

appearance of a gene. The genes of our body cells either turn on or turn off in response to signals that come from external or internal environment. The body of adult human being contains more than 37 trillion cells, the genome of all cells is same. However, all genes do not express in each and every body cell, only some genes are turned on. Our body is composed of about 200 types of cells, which differ on the basis of differential gene expression *i.e.* expression of different genes by cells with the same genome.

23.5.1 Importance of Regulation of Gene Expression

It is essential for both prokaryotes and eukaryotes as it increases the adaptability and versatility of an organism. The regulation of gene expression is extremely helpful to the cells for the fulfilment of their proteinaceous needs, derives the process of cellular differentiation, morphogenesis and physiology. It also helps to create different types of body cells. If regulation of gene expression is disturbed, some serious diseases may occur such as cancer.

Morphogenesis

It is shaping of an organism by embryological process of differentiation of cells, tissues and organs and the development of organ systems according to genetic "blueprint" of the organism and environmental conditions.

23.5.2 Methods of Gene Regulation

The regulation of gene expression is either positive or negative.

Regulatory protein: If the expression of gene is quantitatively increased due to the activator proteins which are specific regulatory proteins, then it is called **positive gene regulation.**

Repressor protein: If the expression of genes is seized, due to presence of some specific regulatory protein known as **repressor protein**, then it is called **negative gene regulation.**

23.5.3 Lac Operon (An Example of Negative and Positive Control of Gene Expression)

In bacteria and viruses, a cluster of genes having related functions that are regulated as a unit is called an **operon**. These genes are:

1. **Structural genes**, which direct the synthesis of enzymes having related functions.
2. A **promoter**, which marks the starting point for transcription of the genes.
3. An **operator**, which acts as an on or off switch. The operator region is either located within the promoter or overlaps it and is the region that serves as a binding site for RNA polymerase.

***Escherichia coli* (*E. coli*)** is one of the bacterium species, scientists study to learn about gene expression in prokaryotes. Interestingly, scientists discovered that if the sugar lactose is not present in the environment of a population of *E. coli*, the bacterium has very few enzymes present within their cells that can take lactose into the cell and break it down. *E. coli* is "fed" on lactose, such as when you drink a glass of milk, the bacterium quickly manufactures the enzyme that does this job. Scientists discovered that the metabolism of lactose in *E. coli* is programmed by a cluster of genes they named the **lac operon**. (Fig.23.22)

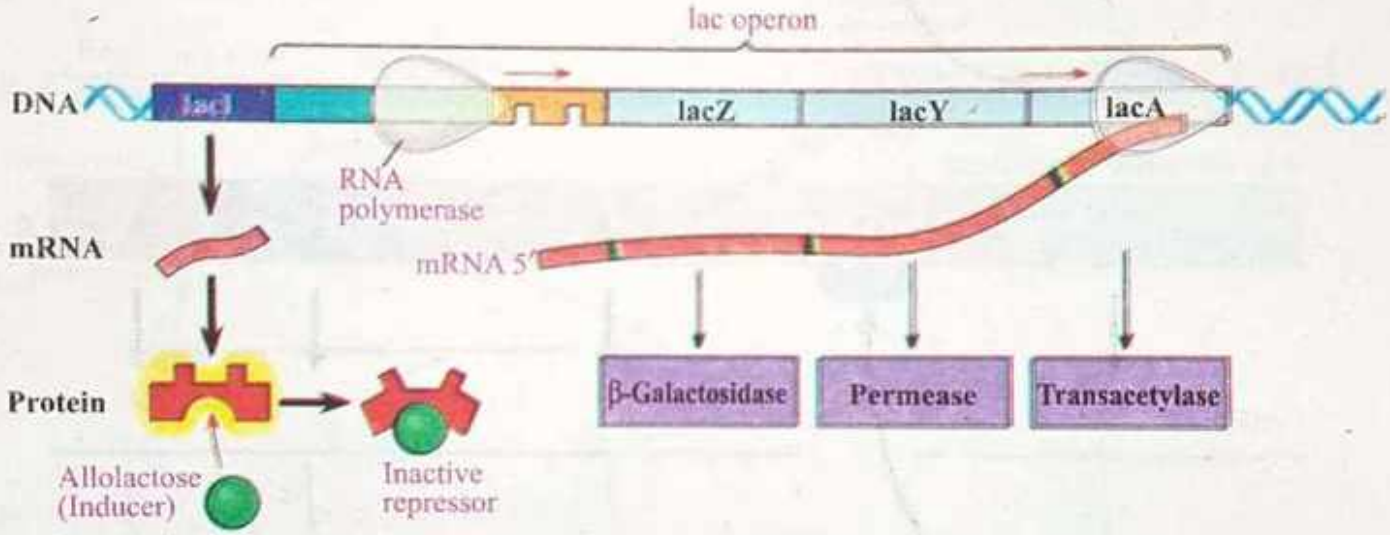


Fig.23.22: Lactose Present, Repressor Inactive, Operon on

The lac operon has three genes (**lac-Z, lac-Y and lac-A**) that direct the synthesis of enzymes that metabolize milk sugar (lactose). It has become one of the most widely studied operons in bacteria and is often used as an example of gene expression in prokaryotes.

Mechanism of Negative Control

The lac operon is on (meaning it is transcribed) until transcription is switched off (block). This type of system operates, by **negative control**. The off switch is a protein known as the **lac repressor**, which is produced by a regulatory site and fit into the operator region of the lac operon like key fits into a lock. Thus it blocks the attachment of RNA polymerase to the promoter and transcription cannot occur. When lactose is present in the cells environment, however, it binds to the repressor, changes its shape. The repressor is no longer able to bind to the operator, and the cell is able to produce the enzymes that direct the metabolism of lactose. (Fig.23.23)

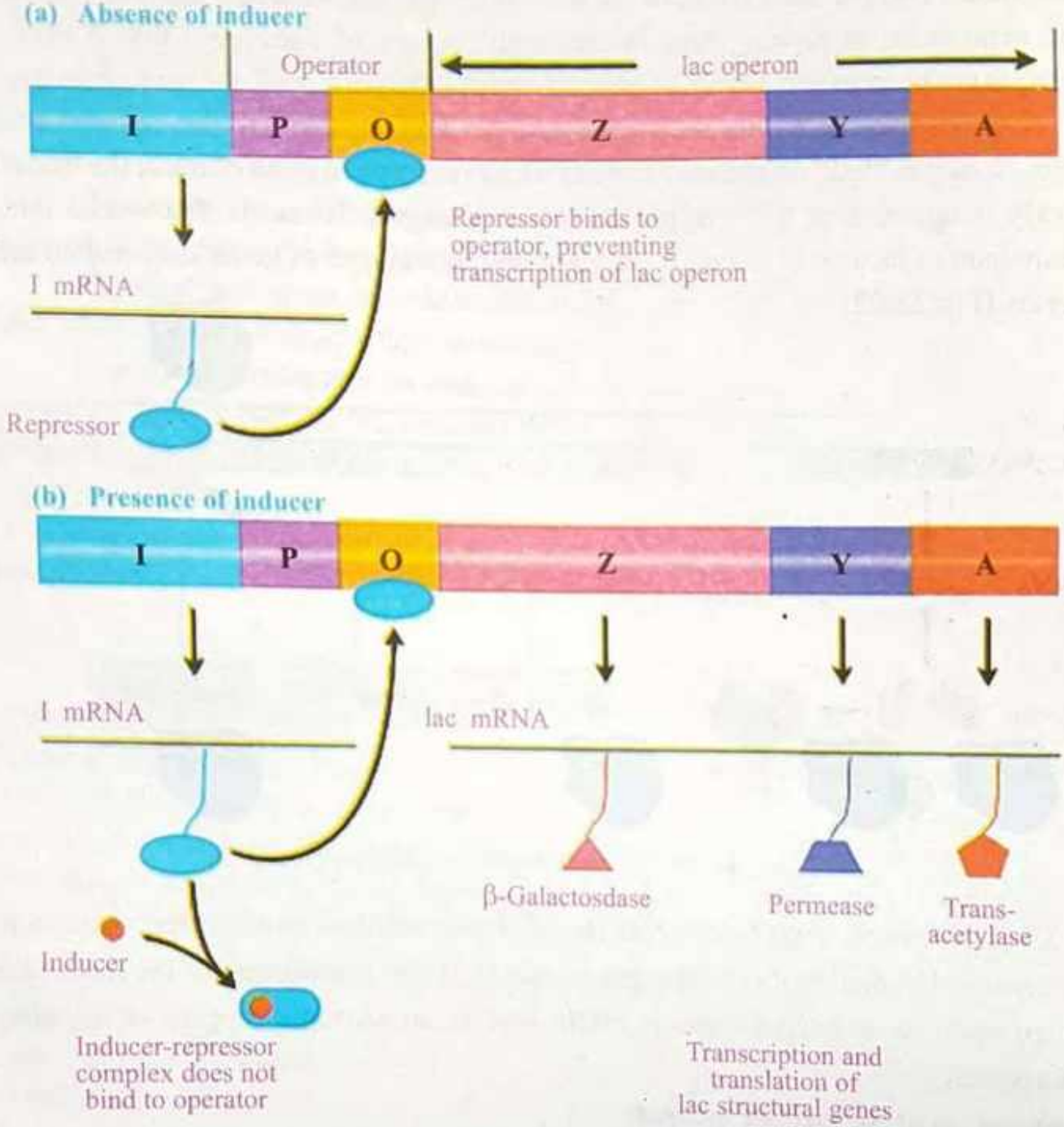


Fig.23.23: Mechanism of Negative control of Gene Expression

Mechanism of Positive Control

The lac operon is on unless it is switched off by a repressor; some operons must be switched on by proteins called activators. This type of control is called **positive control**. Activators bind to a specific nucleotide sequence at or within the promoter and stimulate transcription. Operons regulated by both activators and repressors have both positive and negative control. Regulatory sites code for activators proteins as well as for repressor proteins. (Fig.23.24)

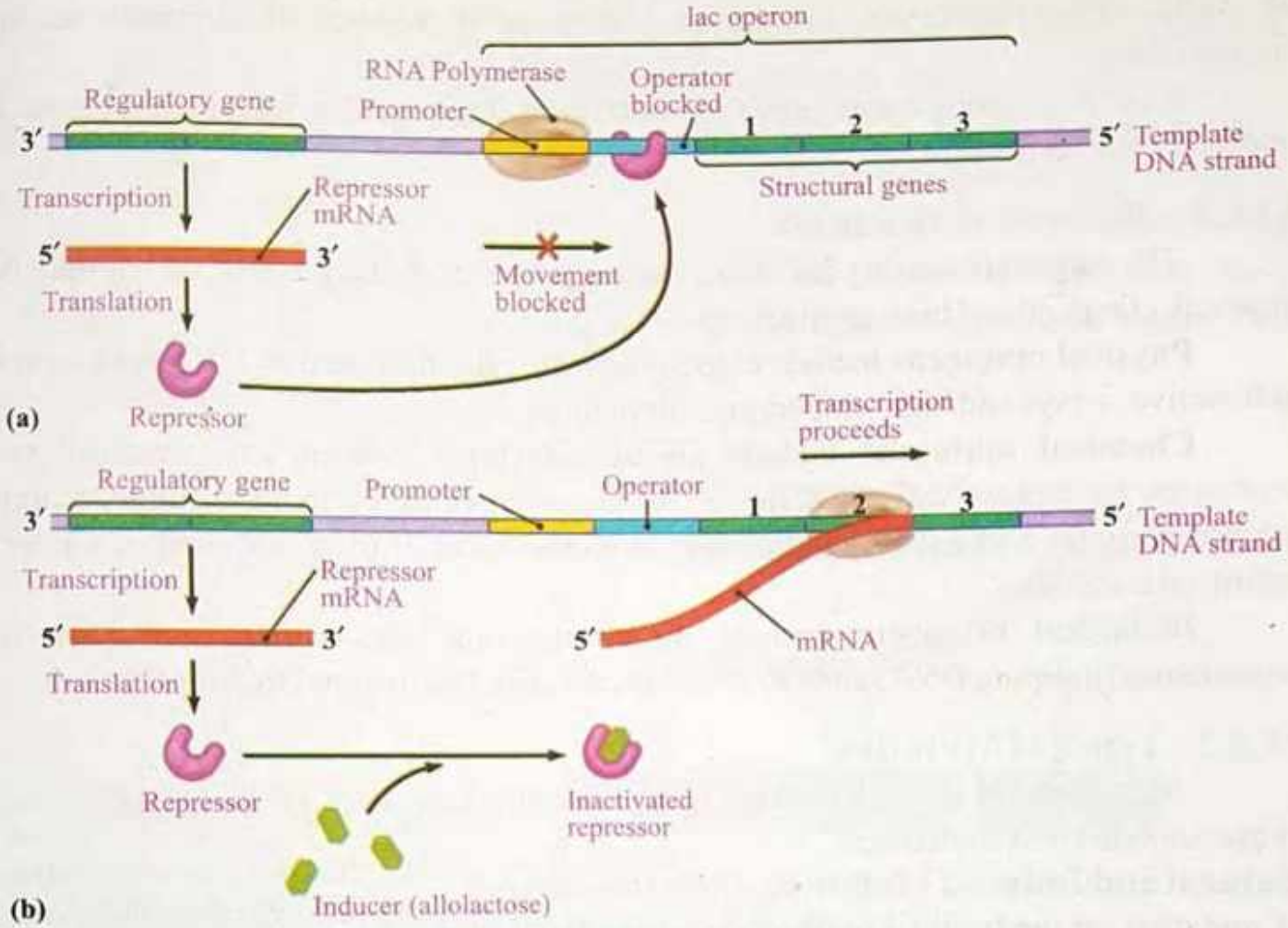


Fig.23.24: Mechanism of Positive Control of gene Expression

23.5.4 Relationship of Gene Expression with Introns and Exons (in Eukaryotes)

In eukaryotes primary mRNA is processed in the nucleus and then mature mRNA is exported to the cytoplasm provides many opportunities for regulating gene expression that are not available in prokaryotes. Such as the regulation at RNA processing level is alternative RNA splicing, in which different mRNA molecules are produced from the same primary transcript, depending on which RNA segments are treated as exons and which as introns. Regulatory proteins which are specific to a cell type control intron-exon choice by binding to regulatory sequences within the primary transcript.

23.6 Mutation

Mutation is an alteration in the genetic material (genome) of a cell of a living organism or of a virus that is more or less permanent and make up a new allele in the population. It can be transmitted to the cells or the virus descendants. Mutation range in size from change in a single DNA nucleotide (codon) to a large segment of chromosome

or whole chromosome *i.e.* change in chromosome number or complete set of chromosome.

Mutation causing agents are called **mutagens**. The organism with mutated genetic material is called **mutant**.

23.6.1 Sources of Mutation

The mutation causing agents *i.e.* **mutagens** are of many types, which may be physical, chemical and biological agents.

Physical mutagens include electromagnetic radiation such as UV, gamma rays, radioactive, x-rays and high temperature alternation.

Chemical mutagens include nitrosomethylurea, nitrous gas, mustard gas, pesticides, food preservatives, acridine orange, colchicines, caffeine, nicotine, atomic oxygen particles and reactive radioactive isotopes. Most of these are used in modern industrial societies.

Biological mutagens include micro-organisms like viruses and bacteria, transposons (jumping DNA) and errors that occur during meiosis or DNA replication.

23.6.2 Types of Mutation

Mutagenesis is the formation (origin/creation) of mutation in DNA molecules.

Natural and Induced Mutation: There are two types of mutation on the basis of mutagenesis, *i.e.* natural or spontaneous and induced. The **spontaneous mutation** takes place naturally and automatically due to internal or external factors. The **induced mutation** is occurred by external factors for the establishment of new verities of organisms.

Gene and Chromosomal Mutation: There are two other types of mutations on the basis of site of mutation and to what extent *i.e.* gene mutations and chromosomal mutations.

i) Gene Mutation may be point mutations and frame shift mutations.

Point mutation causes

Alkaptonuria

It occurs due to point mutation there is enzyme deficiency and homogenitsic acid does not further change into 4-maley acetic acid. Thus urine becomes black when expose to air.

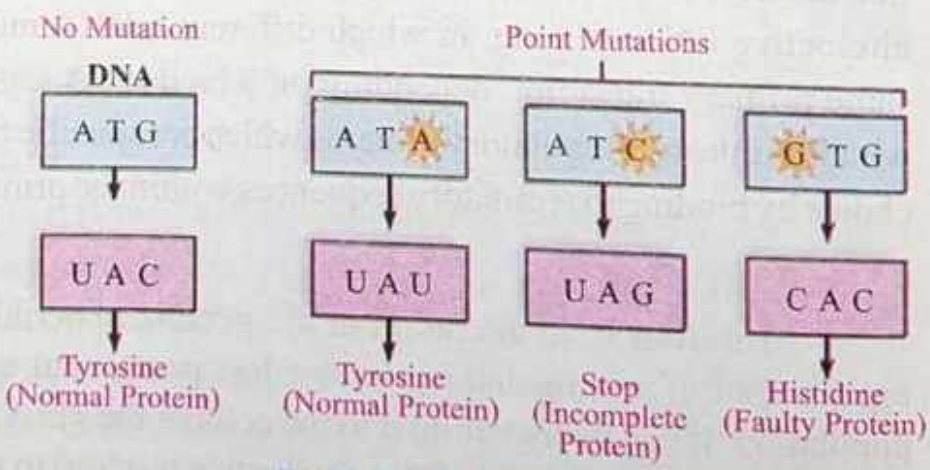


Fig.23.25: Point Mutation

change of one or few nucleotides in the DNA. Some point mutations occur due to spontaneous pairing errors (purine replaced by purine, pyrimidine replaced by pyrimidine, purine replaced by pyridine and vice versa) *e.g.* sickle cells anaemia, phenylketonuria. (Fig.23.25)

In **frame shift mutation** one or more nucleotides either deleted or inserted in the DNA of gene. This results in completely new sequence of codon and a non-functional protein is produce. Thus it is fatal. (Fig.23.26)

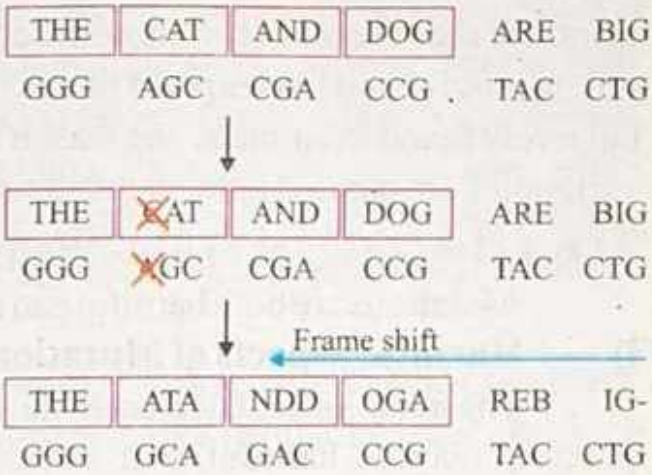


Fig. 23.26: Frame Shift Mutation

ii) Chromosomal Mutation or Chromosomal Aberration: This type of mutation causes change in the structure or number of chromosomes.

Change in Chromosomal structure occur during meiosis, when due to certain mutagen chromosome is broken down into many pieces but later on reunite, its new pattern become change from original one.

These may be:

Deletion or Deficiency

Deletion or deficiency, as the name shows is the loss of a segment of a chromosome or of a part of the genes.

Duplication

When a part of chromosomes is repeated or present more than once, it is called **duplication** *i.e.* segment of a chromosome is in excess.

Inversion

When a part of chromosome becomes inverted it is called **inversion**. It can be identified genetically by the alteration of the genetic map of the chromosome.

Translocation

Transfer of a segment of chromosome to a non-homologous chromosome is called **translocation**.

23.6.3 Change in Chromosome Numbers

This occurs due to non-disjunction during meiosis, change in chromosome number due to addition or loss of one or more chromosomes is called **aneuploidy.** Exampies are, **monosomy** (2n – 1) *e.g.* Turner's syndrome, **nullisomy** (2n – 2) loss of a pair of chromosomes, **Trisomy** (2n+1) *e.g.* Klinefilter's syndrome and Down's syndrome, Tetrasomy (2n+2) addition of a pair of homologous chromosomes.

There is another condition in which an organism shows a change in one or more

complete set of haploid chromosome called **euploidy.** Examples are, **monoploid** (single set), triploid (3 sets), **tetraploid** (4 sets), **pentaploidy** (5 sets), *etc.* It is favorable in plants but rarely found in animals, one reason is that the sex balance is important in animals and variation from haploid number results in sterility.

23.6.4 Importance of Mutations

Mutations are both harmful and useful for organisms.

i) Harmful aspects of Mutations

The mutation that decreases the fitness of organisms in their environments, which possibly may be harmful to it and causes serious effect *e.g.* cancer, developmental abnormalities like cleft palate, microcephaly, Down's syndrome, Klinefelter's syndrome, Turner's syndrome, heredity disorders like sickle cell anaemia, haemophilia, *etc.*

ii) Useful aspects of Mutations

Sometime mutation increases the fitness of organisms to their environment. It is also helpful to originate new species *i.e.* evolution because less favorable mutations are removed from the gene pool by natural selection. The more favorable ones tend to accumulate which ultimately leads to origin of new species by natural selection.

23.6.5 Chromosomal Mutation or Chromosomal Aberrations

There are many types of chromosomal mutations. Here we will discuss causes, symptoms and possible treatment of some of these.

i) Down's Syndrome

It is also called **mongolism**. The affected person contains an extra autosomal chromosome number 21 (trisomy 2n+1). It was first described in 1866 by J. Langdon Down. For this reason, it is called Down's Syndrome. (Fig.23.27)

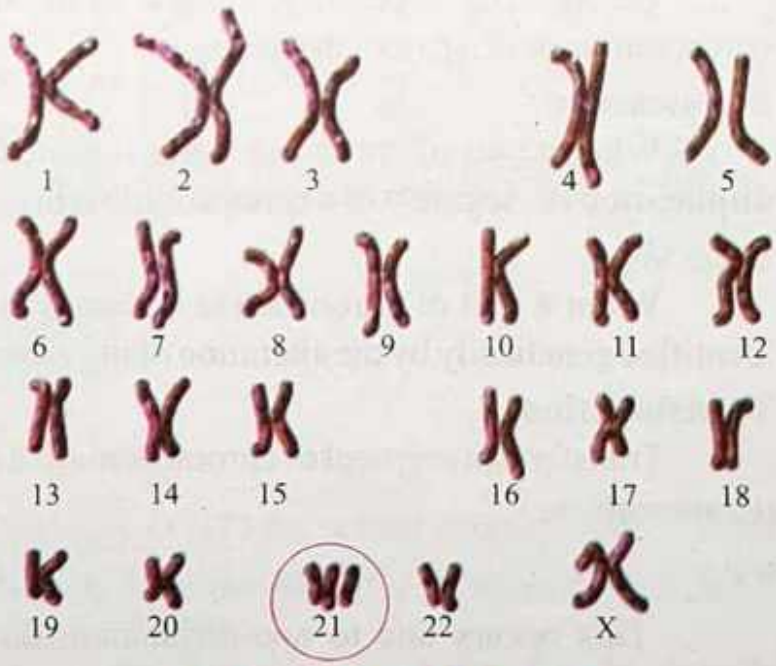


Fig. 23.27: Down's Syndrome

Cause:

During gamete formation, the non-disjunction occurs in autosome number 21st and the resulting gamete (either egg or sperm) with 24 chromosomes is produced. The fertilization of such gametes produces a child having 47 chromosomes (2n+1).

Symptoms of Abnormalities: In the individuals the maturation of skeletal system is delayed, so person having Down's syndrome are generally short and have poor muscle tone, in addition, they are mentally retarded, defected nervous system and blood vascular system. Some other symptoms are protruding tongue, flat nose, flat broad face, small ears, small mouth, short hands with short fingers, gap between, large toe (thumb) and second toe, rounded head, excessive skin at the nape of the neck, squint eyes. Their life expectancy is approximately 16 years.

Treatment: There is no treatment for chromosomal disease. But Down's syndrome can be managed to some extent by taking few measures like regular medical check-up and screening medications, surgery, counselling and support.

ii) Klinefelter's Syndrome

It is sex chromosome non-disjunction, occurs only in male. Dr. Henry Klinefelter described it in 1942.

Cause and Symptoms: If the XX gamete joins a Y gamete, the result is quite serious. The XXY zygote develops into a sterile male who has, in addition to male genitalia and male characteristics, also possesses some female characteristics, such as breast, high pitched voice, some have a lower than average intelligence (occur in about 1/600 male birth). They are sterile, because small testes (no sperm productions), poorly developed male secondary sexual characters, wide hips like female, tendency to tallness, long legs, short trunk and shoulder equal to hip size. (Fig.23.28)

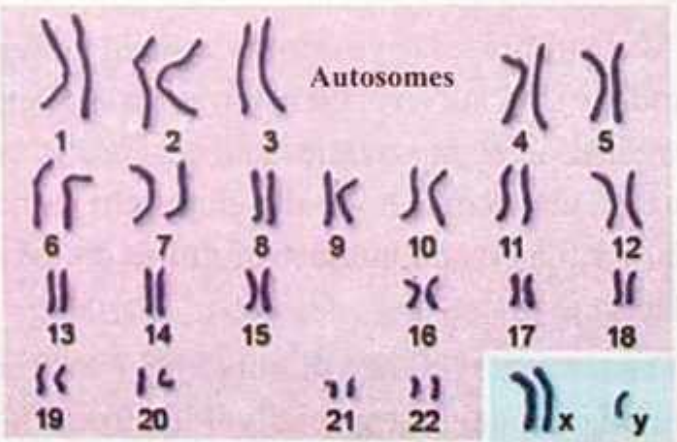


Fig. 23.28: Klinefilter's Syndrome

Treatments

- **Testosterone Replacement Therapy (TRT)** for sexual development like males around the age of puberty, it can help a boy have more normal body development. They can live normal, confident boy-like life.
- The **treatment usually continues throughout a man's life** but does not help infertility.

iii) Turner Syndrome

It is found in females with missed X-chromosome **2n-1(44+XO)**. The (44+XO) is female, (44+OY) is male who cannot survive.

Cause: It is caused by **non-disjunction of sex chromosomes pair** during paternal or maternal meiosis. The normal females have two X chromo-somes, but in Turner syndrome one of the X chromosomes is absent *i.e.* with only 45 chromosomes (44 autosomes + Y, or 44 autosomes + X). In 1938, Henry Turner first described it. (Fig.23.29)

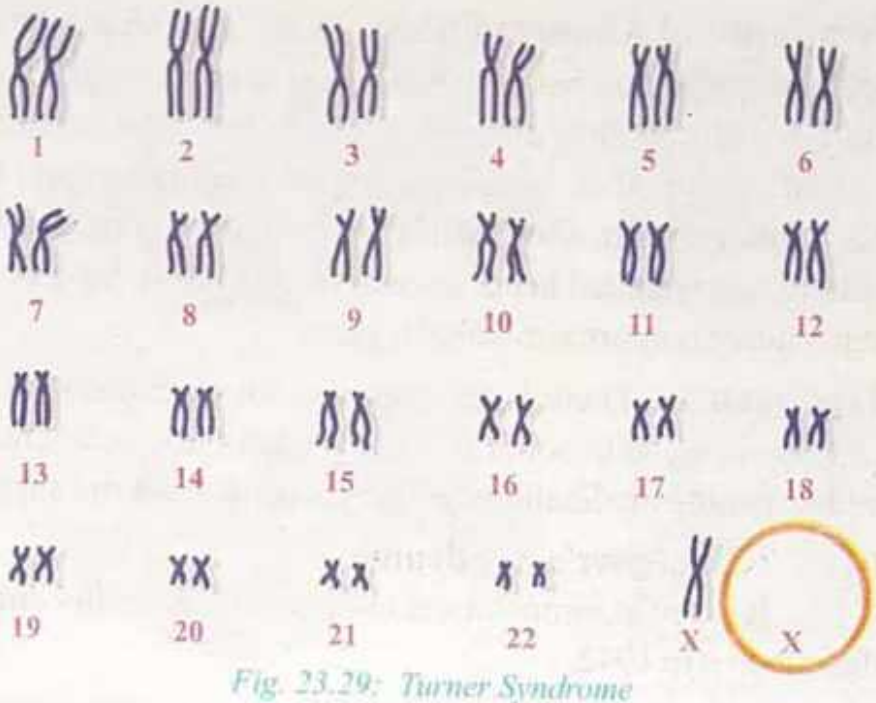


Fig. 23.29: Turner Syndrome

Abnormalities (Symptoms): Such individuals do not survive long pregnancy (aborted mostly), if survive then have female appearance. They have short stature (height), webbed neck, no ovaries and germ cells *i.e.* infertility, a low **hairline** at the back of the **neck, abnormal bone development** (especially the bones of the hands and elbows), a larger than usual number of **moles** on the skin, **oedema** or extra fluid in the hands and feet.

Treatments: **Growth hormone** treatments can improve growth and influence a girl's final adult height especially if treatment is started early enough in childhood. **Estrogen replacement treatment (ERT)** helps the girl develop the physical changes of puberty, including breast development and menstrual periods. This treatment is often started when a girl reaches about age 12 or 13.

23.6.6 Gene Mutation

Some examples of gene mutations are as under:

Sickle Cell Anaemia

The sickle cell anaemia is also known as **Hemoglobin SS disease (Hb SS).**

Cause: It is autosomal recessive trait, which is caused by, Point Mutation-Base substitution, a defect in hemoglobin. Acutely the 6^{th} amino acid *i.e.* **glutamic acid** in the **beta** chain of the normal hemoglobin is replaced by **valine.** The abnormal sickle cell hemoglobin is called Hb^S which have **lost the oxygen binding capacity**. Due to this hemoglobin the **shape of the red blood cells** is changed. The red blood cells become **crescents or sickles shaped.** These cells **deliver less oxygen to the body's tissues.**

Sickle cell anaemia is due to homozygous recessive gene which he or she may get from their both parents. (Fig.23.30)

Symptoms: The **painful Episodes** (called crises) which can last from hours to many days. These crises can cause pain in the bones of the back, the long bones, and the chest. When the anaemia becomes more severe, symptoms may include: fatigue, fever, paleness, Jaundice damage various organs. Rapid heart rate shortness of breath.

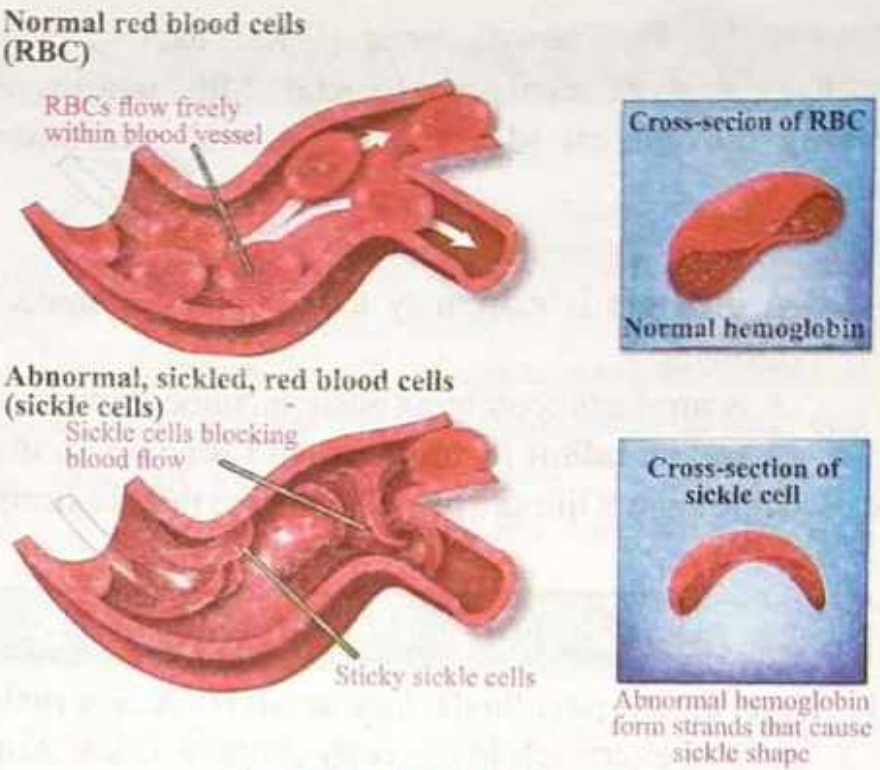


Fig. 23.30: Sickle Cell Anaemia

Treatment: The goal of treatment is to manage and control symptoms to limit the number of crises.

For A Sickle Cell Crises Includes

Blood transfusions (may also be given regularly to prevent stroke); **Medicines** to relieve crises and plenty of **Fluids**. **Bone marrow or Stem cell transplants** can cure sickle cell anaemia. **Folic acid** supplements should be taken.

Phenylketonuria (PKU)

A rare (Point mutation) condition in which a baby is born with the inability to properly break down an amino acid phenylalanine is called Phenylketonuria.

Cause: It is also due to **autosomal homologous recessive gene.** In a healthy baby phenylalanine is converted into tyrosine by the enzyme **phenylalanine hydroxylase**, while affected baby possess defective enzyme, which converts phenylalanine into toxic phenylketones, that accumulate and **damage central nervous system.** (Fig.23.31)

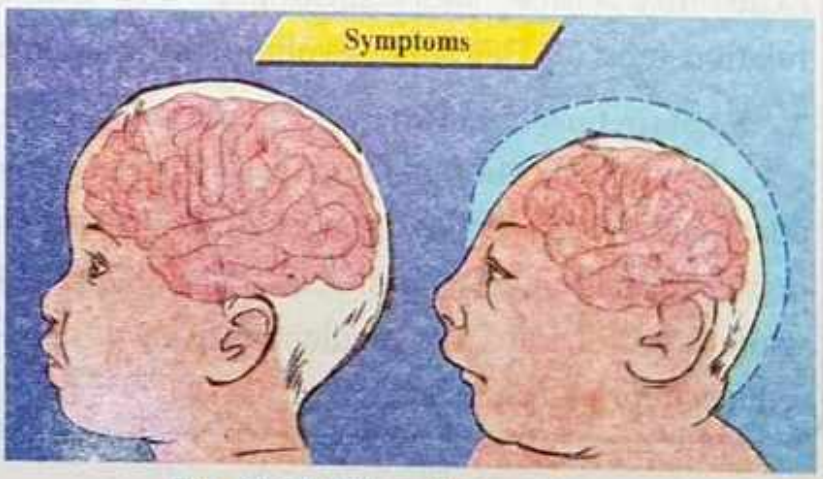


Fig. 23.31: Phenylketonuria

Symptoms: The Phenylketonuria (PKU) babies are characterized by lighter **skin, hair** and **eyes**, delayed **mental and social skills**, **head size** below normal, **hyperactivity, jerking movements of arm/legs**, **mental retardation**, **seizures**, **skin rashes** and **tremors**, *etc.*

Treatments: Treatment involves:

- A diet that is extremely low in phenylalanine, particularly when the child is growing.
- Any products containing phenylalanine should be avoided such as, milk, eggs.

A special **infant formula called Lofenalac** is made for infants with PKU. It can be used throughout life as a **protein sources** that is extremely low in phenylalanine.

Science, Technology and Society (STS)

1. Describe the paradoxical nature of DNA, as a tool of geneticists and forensics.

Almost every cell in our body contains DNA. Any two people share on average 99.9% of their DNA meaning that only 0.1% of your DNA is unique to you. Each human cell contains 3 billion DNA base pairs. Out of these 3 billion base pairs 3 million are different. That's more enough to provide a profile that accurately identifies a person. DNA is often left behind a crime scene in the form of hair, blood, saliva and semen. To identify individuals, forensic scientists have scanned 13 DNA regions or loci that vary from person to person and use the data to create a DNA profile of that individual (sometimes called a DNA fingerprint). Some examples of DNA uses for forensic identification: (1) Identify potential suspects whose DNA may match evidence left at crime scenes. (2) Exonerate persons wrongly accused of crimes. (3)Identify crime and catastrophe. (4) Establish paternity and other family relationships. (5) Determine evolutionary relationships, *etc.*

2. Explain how harmful mutations have been eradicated by nature.

Natural selection is the process through which populations of living organisms adapt and change. A harmful mutation is a mutation that decreases the fitness of the organisms. Through natural selection favourable traits are transmitted to generation while harmful traits are eradicated from the population due to premature death or reduced reproductive success.

SUMMARY

- The term "Chromosome" was proposed by Waldeyer.
- Each typical chromosome consists of two strands known as chromatids and both are attached with each other at a point known as centromere or primary constriction.
- Heterochromatin in highly condensed and unexpressed region while euchromatin is highly condensed during cell division while become non-condensed after cell division and the genes of this region are also expressed.
- Hershey and Chase claimed that the virus DNA, not the virus protein, was hereditary material.
- Replication bubble is formed when DNA helicase and topoisomerase enzyme work at origin of replication.
- The complete strand of DNA is known as antisense because mRNA is complementary to this strand.
- The genetic codes are almost same in all organisms thus known as universal.
- In translation mRNA is decoded by the ribosome to produce a specific polypeptide that will later fold into an active protein.
- The natural and automatic mutation occurs due to internal or external factors are called spontaneous mutations.
- Down syndrome is characterized by trisomy (2n+1) *i.e.* having an extra copy of 21st autosome.
- The strand of the DNA, which is transcribed is called coding or sense strand.
- The agents that cause mutations are called mutagens.
- Klinefelter's syndrome is characterized by 2n+1 (44+XXY), i.e., trisomy of sex chromosomes.
- Turner syndrome is characterized by 2n-1 (44+OX) or (44+OY).
- The gene mutation makes up a new allele in the population.
- Phenylketonuria and sickle cell anaemia are the examples of gene mutation.
- Organism or cell in which mutation is occurred is called mutant.

EXERCISE

SECTION-I: OBJECTIVE QUESTIONS

Multiple Choice Questions (MCQs)

A. Select the correct answer

1. Morphological characteristics of chromosomes are collectively called:
   (a) Holotype (b) Karyokinesis
   (c) Karyotype (d) Neotype
2. Mongolism is also known as:
   (a) Down's syndrome (b) Klinefelter's syndrome
   (c) Turner's syndrome (d) Jacob's syndrome
3. All are related to turner's syndrome, except:
   (a) Short stature (b) Webbed neck
   (c) Broad face (d) Without ovaries
4. The human chromosomes are composed of
   (a) DNA+RNA (b) DNA+Lipid
   (c) DNA+RNA+Protein (d) DNA only
5. Synthesis of a new DNA strand begins with
   (a) a DNA primer (b) an RNA primer
   (c) an Okazaki fragment (d) DNA polymerase I
6. The chromosomes were first discovered in 1882, by
   (a) Morgan (b) Walther Fleming
   (c) Carl Correns (d) Waldeyer
7. The number of chromosomes in Monkey is
   (a) 46 (b) 48
   (c) 50 (c) 44
8. The strand of DNA that elongate towards the replication fork
   (a) Lagging (b) Leading
   (c) Primer (d) Okazaki
9. The number of tRNA in human are
   (a) 45 (b) 60
   (c) 61 (d) 35
10. Anticodons are present on
    (a) mRNA (b) tRNA
    (c) DNA (d) rRNA

11. The initiation codon is
(a) UUA (b) ACC
(c) AUG (d) GCG

12. Down's syndrome is autosomal non-disjunction of chromosome number
(a) 21 (b) 22
(c) 13 (d) 18

13. Which condition appears due to point mutation
(a) Turner's syndrome (b) Klinefelter's syndrome
(c) Sickle cell anaemia (d) Down's syndrome

B. Fill in the blanks.

1. The name chromosome was assigned by .....
2. The number of chromosome in frog is .....
3. The copying of mRNA from DNA is called .....
4. The strand of DNA that runs from replication fork is called .....
5. The sequence of 3 nucleotides on mRNA is called .....
6. Both UUU and UVC are codon of ..... amino acid.
7. The syndrome having trisomy of chromosome No.21 is ..... syndrome.
8. Phenylketonuria is an example of ..... mutation.
9. If a person has 44 autosomes + XXY, he will suffer from .....
10. Change in DNA structure is called .....

SECTION-II: SHORT QUESTIONS

C. Give the short answers of the following questions.

1. Differentiate between heterochromatin and euchromatin.
2. Write any three parallel behaviors between genes and chromosome.
3. Explain types of chromosomes on the basis of centromeric position.
4. Differentiate between conservative model and dispersal model of DNA replication.
5. Define RNA primer, primase and ligase.
6. Write difference between leading strand and lagging strand.
7. Write any three characteristics of codons.
8. Describe importance of regulation of gene expression.
9. Write differences between physical and chemical mutagens.
10. Describe useful aspects of mutation.
11. Describe harmful aspects of mutation.

12. Write cause of sickle cell anaemia.
13. Write treatment of phenylketonuria is possible.
14. Write the symptoms of Down's Syndrome.
15. Write symptoms of Turner's syndrome.

SECTION-III: EXTENSIVE QUESTIONS

Give detailed answers of the following questions.

1. Explain structure of chromosome.
2. Describe in detail the composition of chromosome.
3. Illustrate the experiment performed by Hershey-Chase.
4. Describe elongation phase of DNA replication.
5. Describe molecular concept of a gene.
6. Describe the experiment of Fredric Griffith.
7. Explain gene and genetic code.
8. Describe post transcriptional modification of mRNA.
9. Explain how prokaryotic and eukaryotic protein synthesis differ from each other.
10. Write an essay on Down's syndrome.

UNIT 24

EVOLUTION

Major Concept

24.1 The Evolution of the concepts of Evolution
24.2 Evidences of Evolution
24.3 Evolution of Eukaryotes from Prokaryotes
24.4 Lamarckism
24.5 Darwinism
24.6 Neo-Darwinism

Learning Outcomes

Students will be able to:

- Describe creationism and the theory of evolution as two contradictory ideas.
- Relate Quranic injunctions to the process of the evolution of man.
- Explain how biogeography provides an evidence for evolution.
- Describe the evidences of evolution that come from palaeontology, comparative anatomy and molecular biology.
- Differentiate between convergent and divergent evolution on the basis of inheritance of the homologous and analogous structures.
- Describe the theories that have been put forwarded about the mechanism of evolution of eukaryotes from prokaryotes.
- Justify Lamarck as an early proponent of evolution.
- Describe the theory of inheritance of acquired characters, as proposed by Lamarck.
- Outline the steps of the evolution of the giraffe, as illustrated in Lamarckism.
- State the drawbacks in Lamarckism.
- Briefly describe the observations Darwin made during his voyage on HMS Beagle.
- Explain the theory of natural selection as proposed by Darwin.
- Describe the ideas of Charles Lyell, James Hutton and Thomas Malthus that contributed in the early development of Darwinism.
- Describe the role of Alfred Wallace in motivating Darwin to publish the theory of natural selection.
- Justify, on the grounds that both Wallace's and Darwin's papers were published in the *Journal of the proceedings of the Linnaean Society,* why the theory was attributed to Darwin.
- Describe the assumptions of the Hardy-Weinberg theorem and relate these to the factors that change the allelic frequencies of the population.
- Explain the concept of genetic drift (neutral selection).
- Define the concept of speciation and explain the mechanisms of speciation (allopatric, parapatric and sympatric speciation).

Introduction

The central idea of Biological evolution is that all life on earth share a common ancestor. Evolution can be defined as **descent with modification**, a phrase Darwin used in proposing that earth's many species and descendants of ancestral species that were different from present day species. **Evolution** can also be defined more narrowly as a change in the genetic composition of a population from generation to generation.

A brief description of main theories concerning the origin of life is presented in this chapter. Some evidences in support of evolution have also been provided. The Hardy-Weinberg principle and factor that change the allelic frequencies will also be discussed.

24.1 The Evolution of the Concept of Evolution

Understanding evolution is critical for understanding biology. Evolution is the only scientific explanation for **diversity of life**. It explains similarities among vast variety of life. There are many concepts about evolution. Two major and contradictory concepts of evolutionary thoughts are:

a) Special Creation b) Theory of eVolution

24.1.1 Concept of Special Creation

The belief that the origin and diversity of life result from super natural event at a particular time in the past, whereby each species was created separately (from the act of God) is called special creation. The supporter of special creation is called **creationists**. This theory is supported by most of the world's major religions and civilizations. This concept is based on the references of Holy books. According to their interpretations that Allah has created everything in the universe in **six days** and human was created at sixth day. In fact, the **faith** accepts things for which there is no evidence in the scientific sense. This means that logically there can be no intellectual conflict between scientific and theological account of creation, since they are mutually exclusive **realms of thoughts**. In most cases the **scientific truth** to the scientists is **tentative**, but **theological truth** to the believer is **absolute**.

Evolution rarely follow a straight line from species to species. Instead it is more like a tree with many bran-ches. Some branches lead to new branches, while other become dead ends.

24.1.2 Concept of Evolution

In biology, evolution is the change in the characteristics of a species over several generations and theory of evolution is based on the idea that all species are related and change over time. The supporters of evolution are called **evolutionists**. According to

their point of view, universe and man did not always exist in their present form but result of many changes from lower to higher order. They also reject the theory of special creation. According to **big bang theory** the life began on earth about **3.5 billion** years ago. The fossil record supports this hypothesis that life originated from simple **prokaryotic organism** and then **eukaryotic organisms** developed from this prokaryote about **1.9 – 2.1 billion** years ago. The present day biodiversity is the result of these continuous evolutionary changes. The concept of evolution did not begin by Darwin and publication of his book "Origin of Species". The evolutionary concepts were present at the time of **Aristotle** about (384-322BC).

24.1.3 The Process of the Evolution of Man in the Holy Quran

The Quran is clear in its support that humans came from lower beings and that creation had a process involving diverse successive stages.

Allah Almighty started the creation of life on Earth, and then left it to evolve as a result of learning from the adaptation to various environments, which intervention from Him to make His creation better. As far as origin of man is concerned.

Allah Says in Quran "O mankind! Be careful of your duty to your Lord Who created you from a single soul and from it created its mate and from them has spread a multitude of men and women". *(Surah Nisa, Verse-1)*

This verse tells us that the beginning of life was a single soul, then its mate came out of it. Biological science tells us that the earliest form of life was represented by single cell organisms found in water, then these multiplied by splitting themselves. With the course of time, reproduction started to be by mating pairs, instead of the archaic forms of splitting or dividing.

Allah Says in Quran "Allah is He) who has made everything He created better and He began the creation of the human (being) out of clay". *(Surah Sajda, Verse-7)*

In this verse, we are told that Allah (Praise to Him) began the creation of human beings out of clay, but that was the beginning, then He improved His creation making it better.

The most relevant word in this verse is "**began**" (bada-a), which tells us clearly that creation happened in a process that had a beginning, not just at once.

Allah Says in Quran "He has created you in diverse (and successive) stages". *(Surah Nooh, Verse-14)*

This verse may be interpreted to refer to the successive stages of the development of a foetus in its mother's womb. However, it can also be interpreted to refer to the successive stages of the human evolution.

Allah Says in Quran "We created the human being from stinking, smooth, and wet

clay". *(Surah Al-Hajar, Verse-28)*

This verse gives a very specific description of the environment where life started. It refers to swamps where still water in combined with the earth soil, which creates stinking but smooth clay easy to take different forms.

This is exactly what biologists have come up with to explain the beginning of life on Earth.

Allah Says in Quran "It is He Who created you, fashioned you perfectly, and made you with the right proportions (straightened you up, to walk in an upright position". *(Surah Infitar, Verse-7)*

This verse may refer to three main stages of the creation of human beings. The first was creation of a living cell (The Arabic verb Khlaqa, created). The second was the change from unicellular prokaryote organism to the multi-cellular eukaryote organism (the Arabic verb sawwa, fashioned you perfectly). The third was the human departure from the animal stage (The Arabic verb 'adala' made you walk in an upright way).

Allah Says in Quran "Roam the earth and observe how the creation was initiated". *(Surah Ankabut, Verse-20)*

This verse is a direct commandment to humans telling us to travel the earth and observe how creation was brought forth. Interesting thing is that Darwin followed this verse unknowingly and discovered how creation formed.

24.1.4 Origin of Life According to Concept of Evolution

The **vent hypothesis** suggests that life may have begun at **submarine hydrothermal vents**. The first sea **hydrothermal vent** was discovered in 1977 in Pacific Ocean. The fossil found in these vents are about 3.5 billion years old. These fossils belong to a group of prokaryotes, *e.g.* the archaeobacteria (now called archea). It is also believed that the early atmosphere of earth was oxygen free, hot and ozone less. Therefore, frequent exposure of ultra violet radiation was there. This primitive earth's atmosphere has very little nutrients and first prokaryotes were **absorptive heterotrophs**. Later chemoautotrophs were evolved. The **photosynthetic organism** evolved about 3.2 billion years ago. This first photosynthetic organism used hydrogen sulphide as source of hydrogen for sugar molecule instead of water. These prokaryotes still use hydrogen sulphide (H_2S) as source of hydrogen for carbohydrate and produce sulphur (S) as by-product. Later on when cyanobacteria evolved, these started using H_2O as source

Focus Concept of Evolution

The theory of evolution states that species change over time. The primary mechanism for this change is natural selection. The fossil record, morphology, biogeography, comparative anatomy, embryology and molecular biology all provide evidences for evolution.

of hydrogen in synthesizing carbohydrates and liberated O_2 as a by-product. This O_2 accumulated in atmosphere. Thus slowly and gradually **ozone layer** formed. This ozone layer acts as filter for ultraviolet radiations from the sun. When eukaryotic photosynthetic organism evolved about 1.9 – 2.1 billion years ago, the production of O_2 increased many folds and ozone layer got thicker and more protective for life on land. This increased the biodiversity on earth.

24.2 Evidences of Evolution

The evidences to support theory of evolution is provided by many sources. Some important evidences are discussed here.

i) Evidence from Biogeography

The study of the geographical distribution of fossils and living organisms is called biogeography. A comparison of recently formed fossil types of living organisms in the same geographic area shows that new organisms arise in area where similar forms already lived. Thus, **armadillos** appeared in North and South America where **glyptodonts**, lived in the past. Modern kangaroos appeared only in Australia, which evolved from extinct giant kangaroo. Darwin found 13 species of finches in Galapagos Islands, which are not found anywhere else in the world, as far as he knew. He concluded that the finches had evolved from a common ancestral group that probably reached the island many generations earlier. In the isolation of the **Galapagos island**, the original finches had probably evolved into the 13 species.

The study of biogeography supports the theory of evolution as it is found that closely related species are usually found in close physical proximity to one another. The fossils from these regions resemble modern organisms. This suggests that these species share a common lineage.

> ***Age of Earth***
>
> The most recent estimate of the age of the earth was published in the journal nature in August, 2005. The age of the earth as estimated from the age of meteorite is 4569 million years old.

ii) Evidence from Palaeontology

The study of past life with the help of fossils is called palaeontology. The study of forms of life existing in prehistoric or geologic times, as represented by the fossils (Lt = fosilium = something dug up) of plants, animals and other organisms.

Palaeontology supports the study of evolution because it shows a descent of modern organisms from common ancestors. Palaeontology indicates that fewer kinds of organisms existed in past eras, and organisms were probably less complex. **Palaeontologists** descend deeper and deeper into layers of rock, the variety and complexity of fossils decrease. The fossils from the upper most rock layers are most like current forms. The oldest known fossils are of prokaryotes. Therefore, prokaryotes are

considered as ancestors of all life forms on earth. The fossil record may allow us to trace the history of one particular organism, *e.g.* the fossil record of different genera and species of horses indicate that **earliest horses** had four toes. Then after a long period of time, the number of toes reduced to three. In modern day horses, the large central toe is present which ends in a hoof. Thus paleontology supports the theory of evolution. (Fig.24.1)

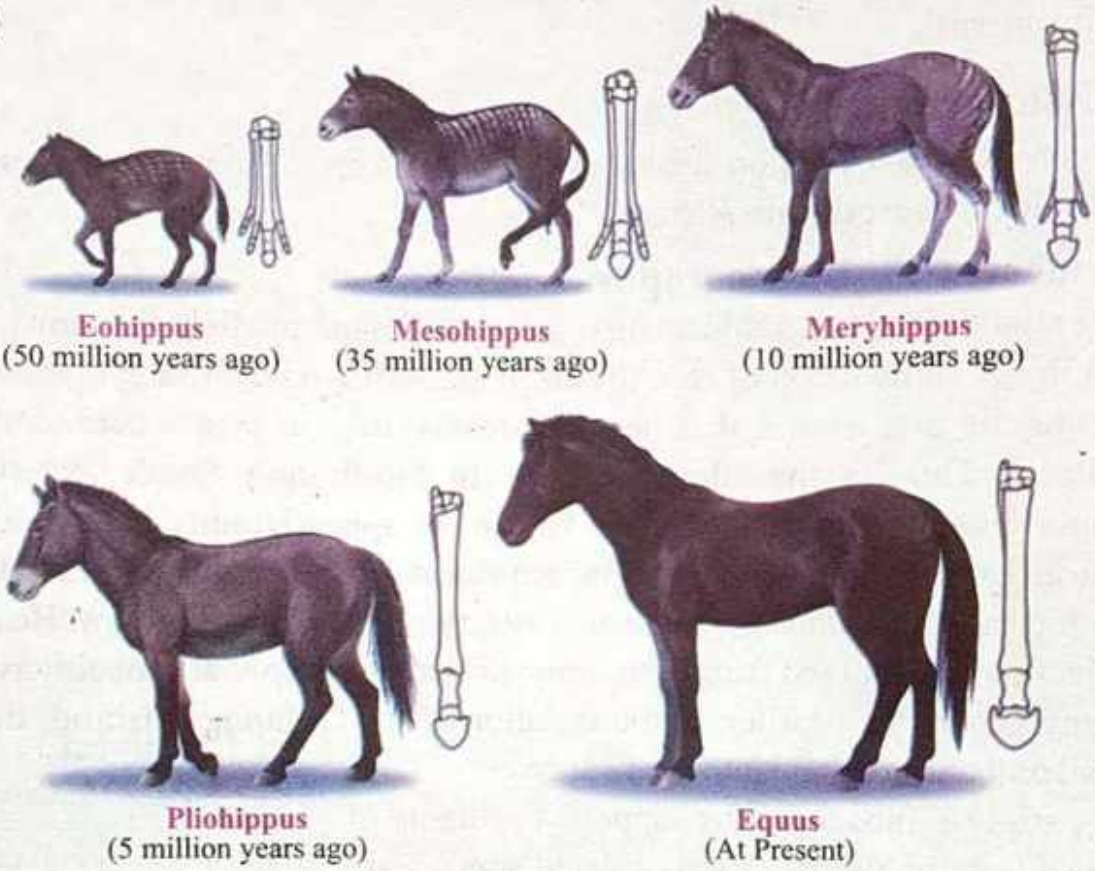


Fig. 24.1: Evolution of Horse

iii) Evidence from Comparative Anatomy

Anatomy is a field of biological sciences which is concerned with the identification and description of the internal body structures of living things.

The study of comparative anatomy predates the modern study of evolution. Early scientists like **Buffon and Lamarck** used comparative anatomy to determine relationship between species. They believed that organisms with similar structures have originated from common ancestor. Today, comparative anatomy can serve as the first line of reasoning in determining the relatedness of species. However, there are many hidden dangers that make it necessary to support evidence from comparative anatomy with evidence from other fields of study.

Homologous and Analogous Structures

Homologous are those structures which are similar in structure but may or may not have the same functions *e.g.* the forelimbs of different mammals like human, cat,

whale and bat have same basic pattern of bones: However, their fore limbs have different function. This indicates that these mammals have common ancestor. (Fig.24.2)

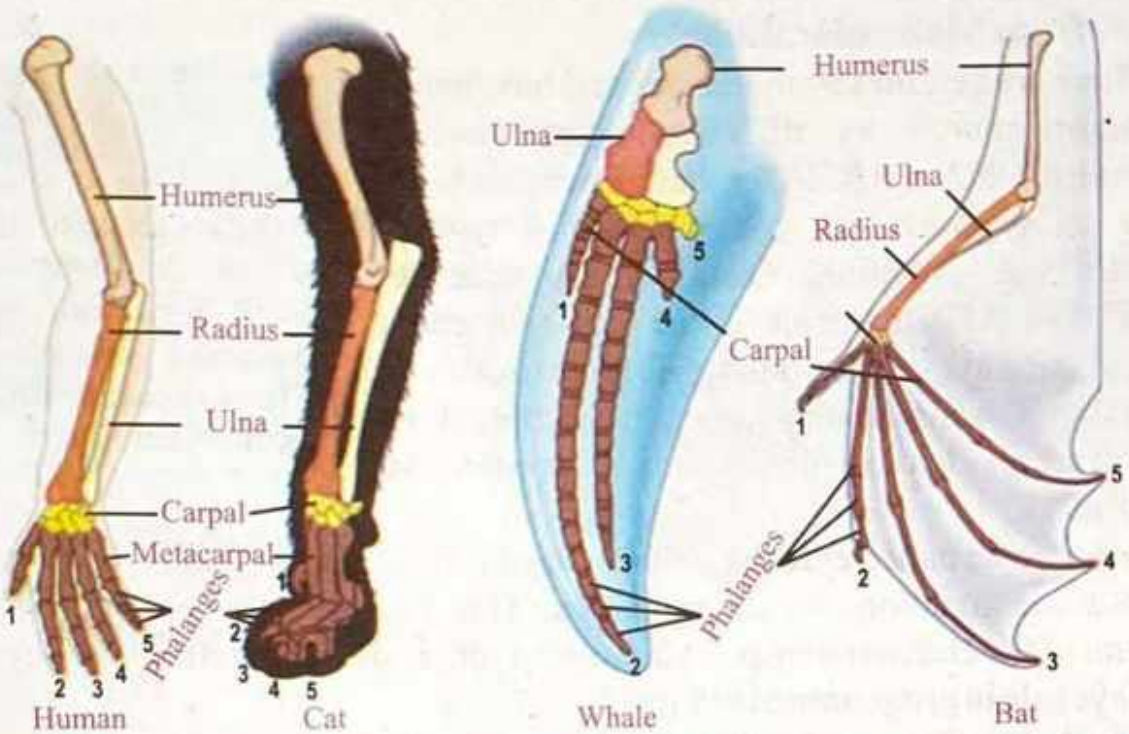


Fig. 24.2: The fore limbs of Human, Cat, Whale and Bat showing Homologous Structure

The homologues struct-ure shows **divergent evolution**.

Analogous structures are those structure which are different in structure but similar in function. These structures perform similar function but may be different in their basic pattern *e.g.* the wings of bats and birds look similar from outside. They also have the same function. However, wing evolved independently in two groups of animals.

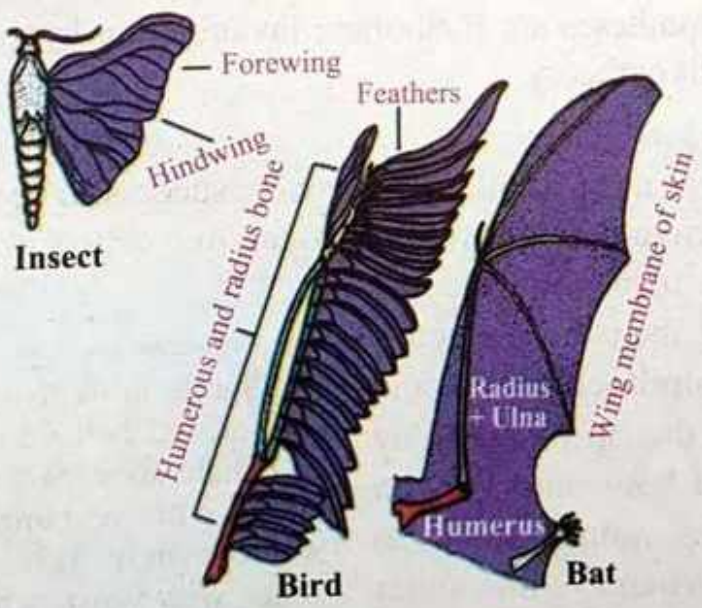


Fig. 24.3: Analogous Structure of Birds, Bat, Insects

Extra Information

Some snakes have hipbones, which show they once had four legs like lizards, their close cousins.

Moreover, the bird wings and insect wings are also analogous traits. This type of evolution is called **convergent evolution**. (Fig. 24.3)

Evidence from Molecular Biology

There are certain key molecules and biochemical mechanisms shared by different organisms. All organisms use DNA and RNA for their genetic code. The DNA in all organisms is composed of 4 types of nucleotides *i.e.* Adenine, Guanine, Cytosine and Thymine. The ATP molecule is the common energy currency in all organisms. The process of photosynthesis, cellular respiration, transcription and translation are all identical or very similar in various type of organisms.

> **Extra Information**
>
> Inside some whales and dolphins are small limb bones which show that once had back legs and that their ancestors walked on land. These occasion-ally reappear as tiny rear flippers.

A molecule called **cytochrome C**, which is found in all organisms. This molecule performs same functions in all organisms. This highly conserved protein is a key component of the electron transport chain (a part of cellular respiration). The cytochrome C also plays role in programmed cell death.

Similarity, these molecules make sense that these are important molecules and therefore, present in most of organisms. However, it would not make sense if each of these molecules appeared independently in each species. These shared biochemical molecules and pathways provide strong evidence for common descent and evolution.

24.3 Evolution of Eukaryote from Prokaryotes

Fossil records indicate that eukaryotes evolved from prokaryotes somewhere, between 1.9 - 2.1 billion years ago. Two hypothesis have been proposed to describe the evolution of eukaryotes. These hypotheses are membrane invagination hypothesis or theory and endosymbiotic hypothesis or theory.

24.3.1 Membrane Invagination Theory

The invasions of the host prokaryotes cell probably were successful because the host cell membrane infolded to surround both invading prokaryotic cells and there by transport them into the cell. The membrane did not dissolve but remained intact, and there by created a second membrane around the **promitochondria** and **prochloroplast.** It is also known that in modern day eukaryotes the inner membrane of both mitochondria and chloroplast contain structures more similar to prokaryotes than eukaryotes. Whereas the outer membrane retains eukaryote characteristics. It is also

> **Extra Information**
>
> You might think that you are special, but believe it or not you share about 50% of your DNA with a banana and approximately 31% of your genes with yeast, which is a single celled organism.

suggested that continued membrane infolding created the endomembrane system. It can be said that possibly the first eukaryotic cell type was born from prokaryotic, symbiotic, multi cell interactions. (Fig.24.4)

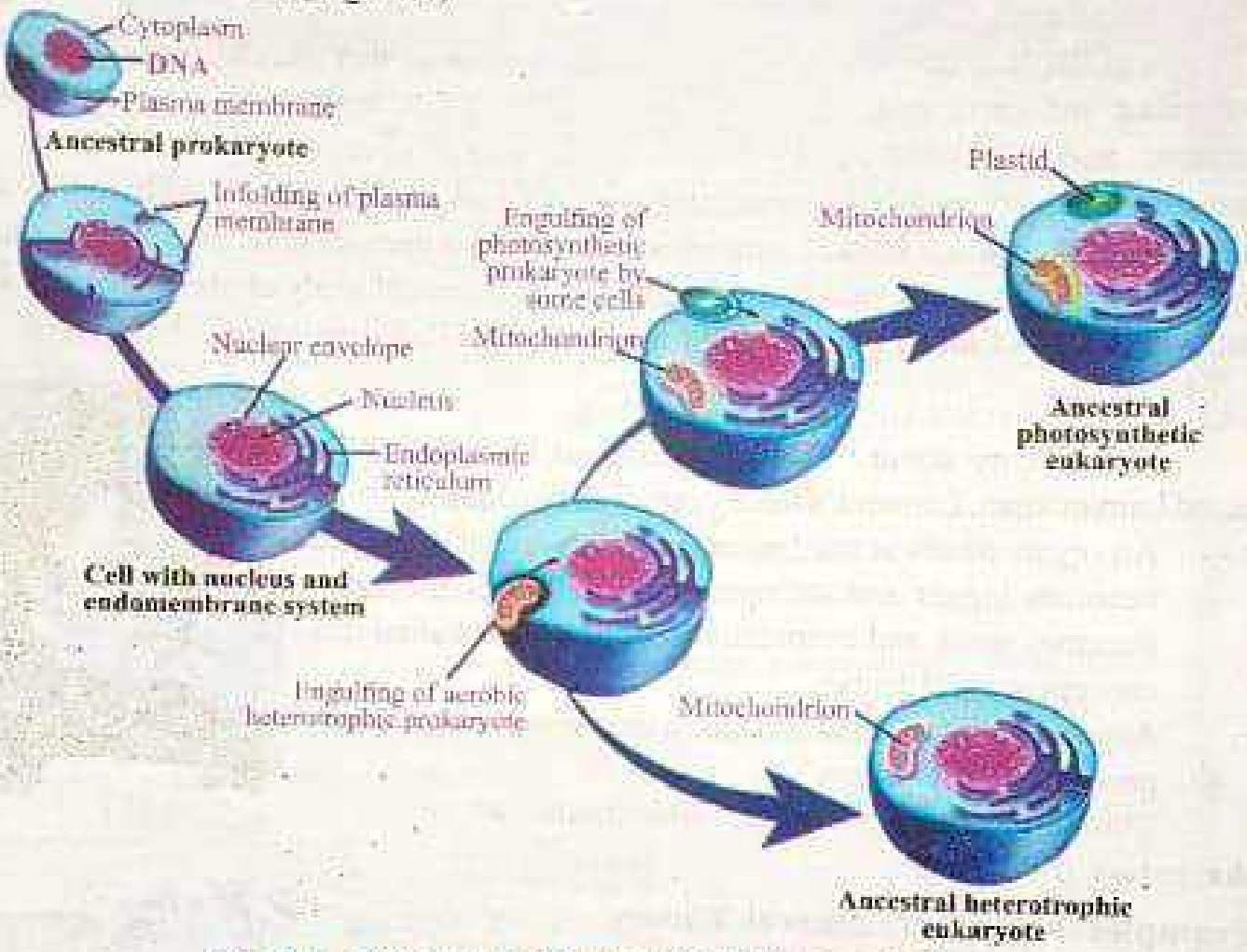


Fig. 24.4: Endosymbiotic Theory and Cell Invagination Theory

24.3.2 Endosymbiosis Theory

Research conducted by **Lynn Margulis** supports the hypothesis that two separate mutually beneficial invasions of a prokaryote cell produced the modern day mitochondria and chloroplast as eukaryotic organelles. In this model, ancestral mitochondria were small heterotrophs capable of using oxygen to perform cellular respiration and thereby create useful energy. They become part of a large cell either by direct invasion as an internal parasite or as an indigestible food source. Later a second invasion brought ancestral chloroplasts, which are thought to be small photosynthetic cyanobacteria. Modern day supporting evidence for endosymbiosis shows that both mitochondria and chloroplasts have their own genes,

Interesting Information

Monkey is different from ape. Monkeys have tails and narrow chest. Apes are tailless and have broad chests.

circular DNA and RNA, and reproduced by binary fission independent of the host's cell cycle. They therefore, appear to be more similar to prokaryotes than eukaryotes.

24.4 Lamarckism

Jean Baptiste de La Marck (August 1, 1744 – December 28, 1829) was a **French naturalist** and early proponent of idea that evolution (descent with modification) occurred and proceeded in accordance with natural laws. Lamarck, however, is remembered today mainly in connection with his now rejected theory of heredity, the inheritance of acquired traits. Lamarck is regarded as a premier authority of plants and invertebrate zoology and well known **toponymist** (Expert of study of places names). He also wrote a book **Philosophie Zoologique** (Zoological Philosophy) in 1809.

24.4.1 Lamarck's theory of Evolution

The theory about evolution presented by Lamarck is called Lamarckism. Lamarck's theory involved two ideas.

i) An organ which is used more and more by an organism becomes bigger and stronger, and one that is not used, becomes weak and eventually disappears. He called this concept use and disuse.

ii) Any feature of an organism that is improved through use is passed to its offsprings.

This concept was called **inheritance of acquired characters**. (Fig.24.5)



Fig. 24.5: Jean Baptiste de La Marck

Examples to Support Lamarck Theory

Evolution of Giraffe

According to Lamarck, the ancestors of giraffe looked like horses with small neck and forelimbs. They lived in areas where there was no surface vegetation. Therefore, they had to stretch their neck and forelimbs to eat leaves from tall plants. Consequently, these parts got elongated. This trait was transmitted in the succe-ssive generations. (Fig.24.6)

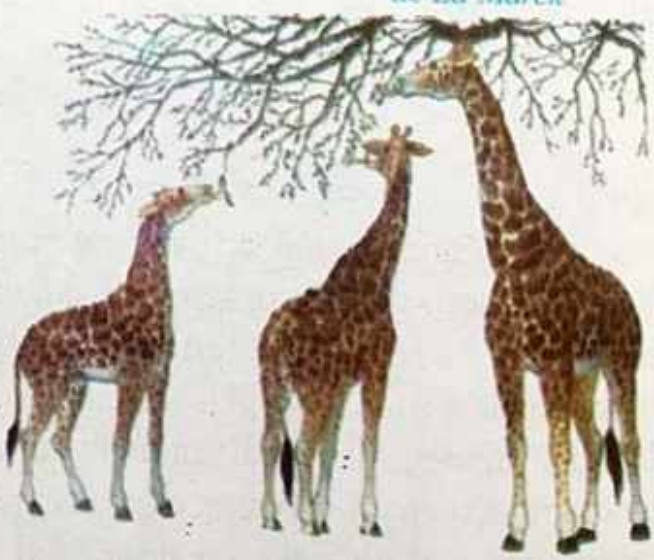


Fig. 24.6: Evolution of Giraffe Neck

Extinction of Limbs in Snakes

The snakes are believed to have evolved from lizard like ancestors that had two pairs of limbs. Due to disuse of the limbs, the limbs got weaker and shorter and eventually disappeared.

Flightless Birds

It is believed that the ancestors of birds such as Ostrich were able to fly. Due to some environmental changes, they had a lot of food and well protected. They did not use wings and as a result the wings became **vestigial**.

24.4.2 Drawbacks of Lamarckism

Lamarck's theory of acquired characters couldn't gain popularity and acceptance due to following drawbacks.

i) There is no experimental proof of his theory.
ii) New organs are not formed in organisms by requirement.
iii) It is not necessary that the acquired character transmits into new generation.

Moreover, a German biologist **August Weisman,** in 1880s disproved the Lamarck's theory of inheritance by giving experimental proof. He removed tails of 68 mice, repeatedly for many generations, and reported that no mice were born without a tail or even with shorter tail. This rejects the theory of inheritance of acquired characters.

24.5 Darwinism

Charles Darwin was born on February 12, 1809 in **Shrewsbury,** England and died at **"Down House"** in Kent on April 19, 1882. He is known as father of evolution. He was selected as naturalist on **HMS Beagle** (A British naval ship about to sail around the world to expand the navy's knowledge of natural resources). He wrote the book **"Origin of species by means of natural selection".** In his book, he has given the idea of evolution by means of natural selection. (Fig.24.7)



Fig. 24.7: Charles Darwin

24.5.1 Darwin's Observations During his Voyage

In 1831, when Darwin was just 22 years old, he set sail on scientific expedition on a ship called the HMS Beagle. He was the naturalist on the voyage. As a naturalist, it was his job to observe and collect the specimens of plants, animals, rocks and fossils wherever the expedition went ashore. During this long journey Darwin made observations.

Darwin Finches

One of the most famous species that Darwin observed were finches that lived on Galapagos Islands. He found 13 different species of finches and noted the main differences amongst the finches on each island which were their beak shape. He observed that finches on each island had beak shapes that were applicable for the type of food that was available on the island. (Fig.24.8)

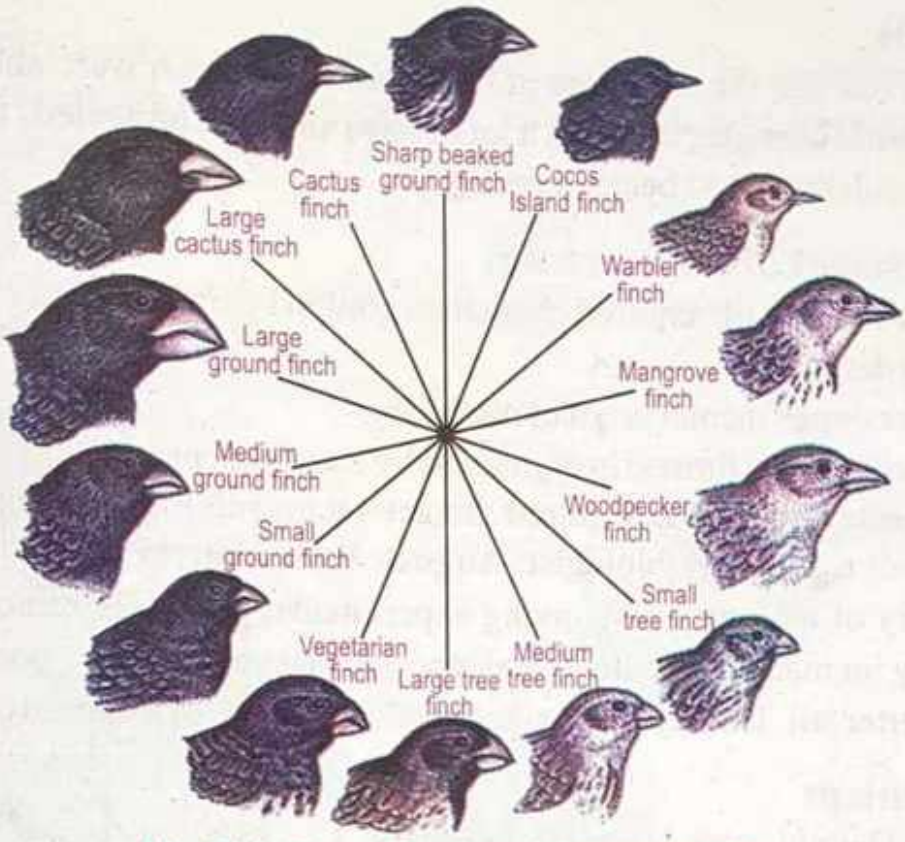
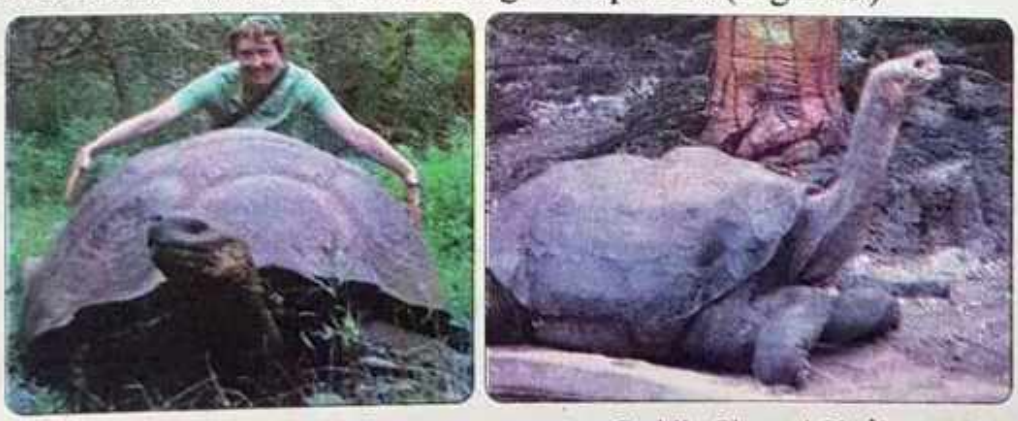


Fig. 24.8: Darwin Finches of Galapagos Island

Giant Tortoise

Darwin also observed giant tortoises in Galapagos Islands. The **Galapagos Islands** were named for their giant tortoises. Darwin noticed that tortoise on one island had **saddle-shaped shell**, while those on another island had **dome shaped shell**. This observation made Darwin to think about origin of species. (Fig.24.9)



Dome Shaped Shell Saddle Shaped Shell

Fig. 24.9: Tortoises of Galapagos

Fossils of South America

In South America, Darwin found fossils that resembled modern animals however, they had differences is size and adaptations. It made him realize that living things had ancestors and that species change over time.

24.5.2 Development of the theory of Evolution

Although Darwin presented his theory of **natural selection** in 1859 in his famous book "origin of species" but he started his work in 1836 after return from 5 years trip of HMS Beagle. In the meanwhile, he collected the data to support his idea. His theory of evolution is not only based on his observations, but he was also inspired by the work of many other scientists of his time. Therefore, he also shared the ideas of these scientists in the development of his theory.

Contribution of Charles Lyell

He was well known English **geologist**. He wrote a book **"Principles of Geology"**, in his book Lyell argued that gradual geological processes have gradually shaped Earth's surface. Darwin was impressed and he took his book with him on the Beagle voyage.

Extra Information

The size of Galapagos tortoise is about 4 feet, weight 475 pounds, average life span is 100 years and it feeds on plants.

James Hutton (1726 - 1797)

He was Scottish geologist, chemist and naturalist. He has given the concept of **uniformitarianism**, which explains the features of the earth's crust by means of natural processes over geological time. He was also the first person to propose a mechanism of natural selection to account for evolutionary change over time. Darwin was also inspired by Hutton's work.

Thomas R. Malthus (1766 – 1834)

He was an English **economist**. He wrote an **essay on population**. In the essay, he argued that human populations grow faster than the resources they depend on. When populations become too large, famine and disease breakout. In the end, this keeps populations in check by killing off the weakest members. Darwin read the article during his journey and influenced by his thoughts.

Alfred Russell Wallace (1823 – 1913)

Wallace lived at about the same time as Darwin. He also travelled to different places to study nature. However, he developed basically the same theory of evolution while working on distant lands, Wallace sent Darwin a paper he had written. In the paper, Wallace explained his evolutionary theory. This served to confirm what Darwin already thought.

Interesting Information

The phrase "survival of the fittest" associated with Darwin was coined by biologist Herbert Spencer after reading Darwin's work.

Why the theory was attributed to Darwin?

Although the Wallace developed basically the same theory of evolution as described by Darwin. Moreover, Hutton was the first person to propose a mechanism of

natural selection. The Alfred Russell Wallace also motivated Darwin to publish his book about the origin of species by means of natural selection. However, Darwin came up with great supporting evidences from a wide variety of scientific disciplines, including palaeontology, geology, vestigial organ, biogeography and comparative anatomy. Darwin spent more than 30 years in studying and observing nature before concluding his ideas. Therefore, this theory was attributed to Darwin.

Extra Information

At the time of Darwin's death in 1882 his book had been published. The origin of species has been translated into 29 languages including, Turkish, Hindi *etc.*

24.5.3 Darwin's Theory of Natural Selection

According to this theory various types of plants, animals and other living things on earth have their origin in other pre-existing types and that the distinguishable differences are due to modifications in successive generations. There are two main points of Darwin's theory of evolution *i.e.*

- Descent with modification
- Natural selection.

Descent with Modification

Descent with modification means passing on the traits from parent organism to their offsprings. According to Charles Darwin, all species descended from only a few life forms that had been modified over time. This descent with modification as he called it, forms the backbone of his theory of evolution.

Natural Selection

Natural selection is the process in nature by which organisms better adapted to their environment tend to survive and reproduce more than those less adapted to their environment. There are four observations about natural selection.

a) Over Production

Each species has the capacity to produce more offsprings that can possibly obtain food and survival. If all offsprings of any species remained alive and reproduce, they will soon over crowd the earth and could destroy all other species. For example if each breeding pair of elephants produces six offspring during its 90 year life span, in 750 years a single pair of elephants will give rise to a population of 19 million. Yet elephants have not overrun the planet.

b) Struggle for Existence

The individuals increase enormously in number but the space and food available remain almost constant. There is always an active competition and three- fold struggle to ensure living, to obtain the maximum amount of food and better place. The struggle for

existence may be:

1. **Intra Specific:** Competition among the organisms of same species.
2. **Inter Specific:** Competition among the organisms of different species living together.
3. **Environmental Struggle:** Struggle against various environmental conditions.

c) Variations

The individuals in a population exhibit variation in their traits. Some of these traits improve the chances of an individual's survival and reproductive success, whereas other traits do not. Variation necessary for evolution by natural selection must be heritable.

d) Survival of the fittest

As a result of competition among the organisms, the stronger win and survive (variant) while the weaker less variant are rooted out. *e.g.* if there is flood only those organisms that can swim or respire in water, have a better chance to survive and other will die. Darwin called it natural selection. It is also called survival of the fittest.

The process of natural selection thus causes an increase in favorable alleles and decrease in unfavorable alleles with in the population. Over succeeding generations, individual members become better adapted to local, conditions, thus leading to the evolution of new species.

24.6 Neo-Darwinism

Neo-Darwinism also called the **modern evolutionary synthesis**, generally denotes the integration of Charles Darwin's theory of evolution by natural selection, Gregor Mendel's theory of genetics as a basis of biological inheritance, and mathematical population genetics. **Neo-Darwinism** has been one of the most significant, overall developments in evolutionary biology, since the time of Darwin, Neo-Darwinism introduced the connection between two important discoveries: the unit of evolution (gene) with the mechanism of evolution (natural selection).

24.6.1 Hardy-Weinberg Theorem

Godfrey Hardy and **Wilhelm Weinberg** developed relationship between the frequencies of alleles and genotypes in 1908. They pointed out that the frequencies of various genotypes in a population can be described mathematically which is known as Hardy-Weinberg principle; it states that "Both the ratios of genotypes and frequency of alleles remain constant from generation to generation in a sexually reproducing population provided other conditions are stable".

Conditions/assumptions for stability

Hardy-Weinberg principle describes how a population can remain at genetic

equilibrium. **Genetic equilibrium** occurs when there is no evolution within the population. At genetic equilibrium, the gene or allele frequencies are stable. They do not change. There are following conditions that must be met for genetic equilibrium to occur:

1. No mutation (change) in DNA sequence.
2. No migration (moving into or out of a population).
3. Random mating.
4. No natural selection.

These conditions rarely occur in nature. If one or more of the above conditions do not exist, then evolution can occur. As a result, allele frequencies are constantly changing, and populations are constantly evolving.

Problem of Gene Frequency

The allele for grey body B is dominant to black body color b. There are 30% recessive alleles in the gene pool having population of 1000 individuals. Calculate the number of grey body individuals and black body individuals in a population.

Factors that change allele frequencies

There are number of factors which may lead to change in allele frequencies. These factors include.

a) Mutation: It is the change in genome of an organism. It is major source of variations and natural selection.

b) Migration or gene flow: It is the movement of individuals from one population to another. If a foreign individual migrates (comes) into the population is called **emigration**. If an individual migrates (goes out) of the population is called **immigration**. In both cases, allele frequencies will change accordingly.

c) Non-random mating: It is the mating among specific group of individuals in a large population. Individuals will mate more frequently with close individuals than more distant ones. Although new alleles cannot be developed by non-random mating but it can cause an increase in homozygous genotypes.

Hardy-Weinberg Equation

It is not only important in population genetics; public health scientists also use it to estimate the percentage of people carrying alleles for certain diseases. Estimating the frequency of harmful allele is useful for the public health programs dealing with genetic diseases.

d) Natural Selection: Populations vary in the type of individuals and their reproductive success. Those individuals who leave more offsprings behind than others, pass on more of their alleles and have a better success rate in dominating the population. The selection may be artificial in which breeder select for the desirable traits.

Hardy-Weinberg Equation

It is a mathematical equation that can be used to calculate the genetic variation of a population at equilibrium. This equation is an expression of the principle known as

Hardy-Weinberg equilibrium, which states that the amount of genetic variation in a population will remain constant from one generation to the next in the absence of disturbing factors *e.g.* mutation genetic drift etc.

To explore Hardy Weinberg equation, we can examine a simple genetic locus at which there are two alleles, 'A' and 'a'. The Hardy-Weinberg equation is expressed as $\mathbf{p^2 + 2pq + q^2 = 1}$ where 'p' is frequency of 'A' allele and 'q' is the frequency of the 'a' allele in the population. In the equation 'p^2' represents the frequency of the homozygous genotype 'AA', while 'q^2' represents the frequency of homozygous genotype 'aa' and '2pq' represents the frequency of heterozygous genotype 'Aa'. In addition, the sum of the allele frequencies for all the alleles at a locus must be '1', so $p + q = 1$. If the 'p' and 'q' allele frequencies are known, then the frequencies of the genotypes may be calculated using the Hardy-Weinberg equation. In population genetics studies, the Hardy-Weinberg equation can be used to measure whether the observed genotype frequencies in a population differ from the frequencies predicted by the equation. (Fig.24.10)

p = frequency of allele A in population
q = frequency of allele a in population
if there are only 2 alleles for a gene then:
p + q = 1 or 100%
Allele frequencies can be used to
Determine genotype frequencies too!
$\mathbf{p^2 + 2pq + q^2 = 1}$

Example: If there are 200 M alleles in the gene pool and 800 m alleles, the

$0.2 + 0.8 = 1$

M m

and $(0.2)^2 + 2(0.2\ \ 0.8) + (0.8)^2 = 1$ or 100%

MM	**Mm**	**mm**
0.04	0.32	0.64

The Hard-Weinberg equilibrium is never achieved in nature, but it's very useful in studying populations.

Fig. 24.10: Hardy Weinberg Equation

24.6.2 Genetic Drift

Genetic Drift is a change in allele frequency in a population due to a random selection of certain genes. Mostly mutation within the DNA can have no effect on the fitness of an organism. These changes in genetics can increase or decrease in a population simply due to chance.

In largest populations, the allele frequency of each gene stays relatively stable. This happens because the genes are not affecting fitness and thus do not have natural selection pressure against or for the allele. In the smallest populations, the frequency of these genes can fluctuate greatly, some become fix with the population, while others disappear. These events which lead to changes in allele frequency are called genetic drift.

Types of Genetic Drift

There are two important causes of genetic drift. These are:

i) Bottleneck Effect ii) Founder Effect

i) Bottleneck Effect

It is a type of genetic drift in which a population's size severely decrease due to any natural disaster like disease, predation and competition.

Example: A population of 100 rabbits lives in the woods (Forest). The rabbits have many different coat colors: black, brown, tan, white, grey and red. In the population, the different alleles that create coat colors are equally distributed. A disease come into the rabbit population and kills 98% of rabbits. The only rabbits that are left are red and grey rabbits, simple by chance. The other alleles are disappeared. (Fig. 24.11)

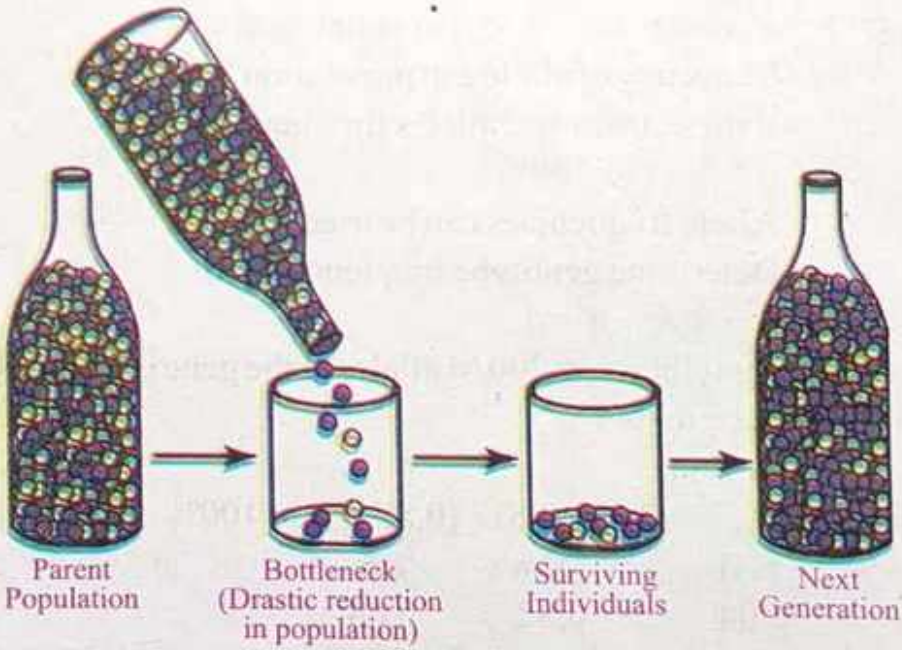


Fig. 24.11: Bottleneck Effect

ii) Founder Effect

In this type of genetic drift, population's size decreases as well as genetic variability. It happens when a few individuals in a population colonize a new location that's separate from the old population.

Example: If only two birds of a species land on island, their allele alone will account for diversity present. While these alleles will dominate at first, mutations will arise in the population that will lead to new adaptations. These new adaptations stay with the founding population. With enough time, the two populations can diverge to a point where they can no longer interbreed, species often separate in this way.

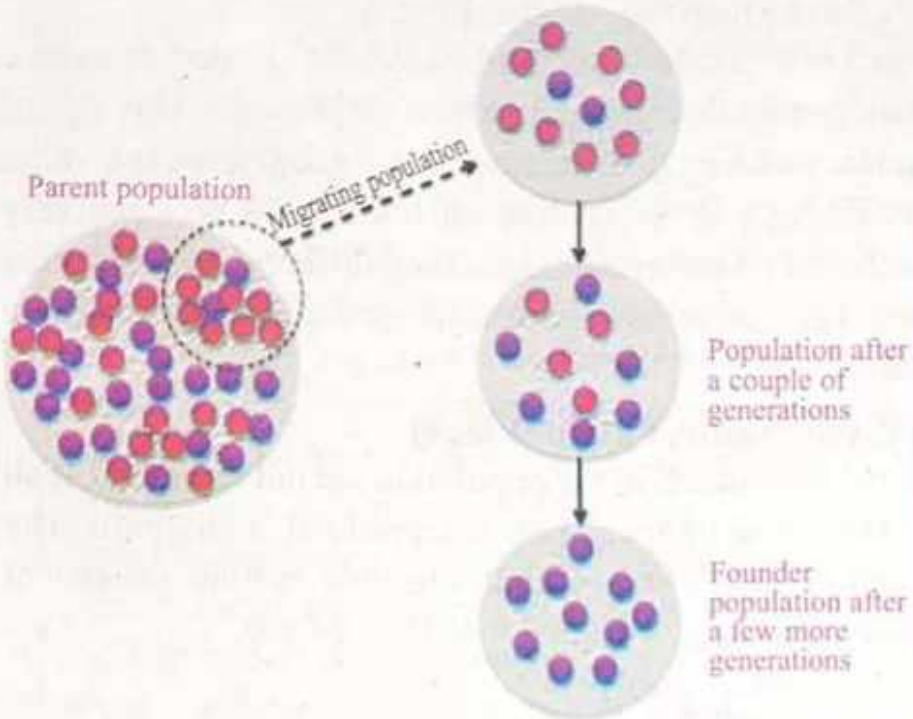


Fig. 24.12: Founder Effect

Recent Research

Scientists developed a model to predict how the number of geographically isolated populations in a species affects the rate of speciation. The model predicts that speciation occurs more rapidly when natural selection acts on two large subpopulations than when it acts on many small sub populations.

24.6.3 Speciation

Speciation is an evolutionary process by which individuals within a population undergo change to such a degree that they become a new and distinct species. This most often occurs due to geographic isolation or reproductive isolation of individual within the population. As the species evolve and branch off, they can no longer interbreed with members of the original species. There are three types of natural speciation's which can occur. The other type is artificial speciation which occurs when scientists create new species for the purposes of experiment.

Recent Research

Scientists have found that human females show a distinct preference for particular male body colors. They found that major histocompatibility complex (MHC) gene confer specific order and that females have a preference for male whose MHC genes are unlike their own. Offsprings of such couple have strong immune system.

i) Allopatric Speciation (Allo=other, Patric=Place)

It is a type of speciation which is caused by geographic isolation. The most common mechanism for geographic isolation is an actual physical barrier that gets between members of a population. This can be something as small as a fallen tree for small organisms or as large as being split by oceans.

There is a special type of allopatric speciation known as peripatric speciation. There is still some geographic isolation but there is also some **sort of instance** that causes very few individuals to survive in the isolated population, compare to allopatric speciation.

ii) Parapatric Speciation (Para=Beside, Patric=Place)

It is a type of speciation in which two subpopulations of a species evolve reproductive isolation from one another while continuing to exchange genes. This type of speciation is very rare. Reproductive isolation in these cases is not geographic but rather temporal or behavioural. For example, plants that live on boundaries between very distinct climates may flower at different times in response to their different environments making them unable to interbreed. The examples of parapatirc speciation of animals are mormyrid fish, tropical cave snail *etc*.

iii) Sympatric Speciation (Sym=Same, Patric=Place)

In this type of speciation, the individuals in the population are not separated at all and all live in the same place. The cause of speciation is reproductive isolation. The reproduction isolation may be due to individual coming into their mating seasons at different time or preference to mate with a selected individual. (Fig. 24.13)

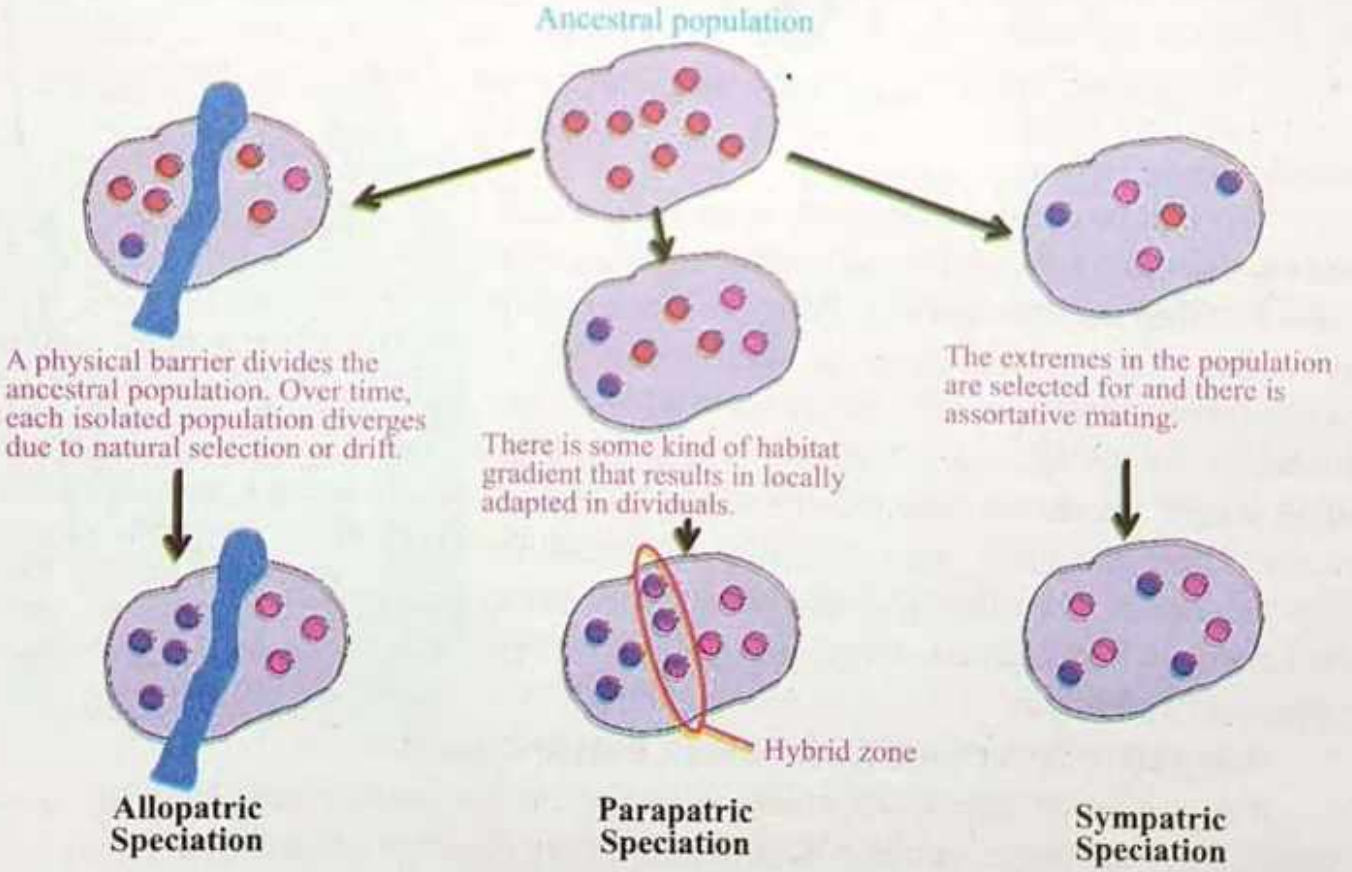


Fig. 24.13: Different Types of Speciation

Science, Technology and Society (STS)

1. The contribution of radiometric dating to the palaeontological analysis of fossils.

There are several techniques that are used by geologists and palaeontologists, to determine the actual ages of rocks and the fossils they contain. The most common method is called radiometric dating or often called radioactive dating, is based on the fact that living organisms contain certain radioactive isotopes in certain ratios. For example, living organisms have the same constant ratio of ^{14}C, a radioactive isotope to ^{12}C, a stable isotope, as does Earth's atmosphere. However, when an organism dies, its ratio of ^{14}C to ^{12}C starts to drop, because ^{14}C decays to other chemical elements, and the organisms no longer obtains any ^{14}C from the atmosphere. Each radioactive isotope has a fixed rate of decay known as half-life. The half-life is the amount of time it takes for one half of the initial amount of the parent radioactive isotope, to decay to the daughter isotope. For example, ^{14}C has a half-life of 5600 years. Knowing both the half-life of a radioactive isotope and the ratio of radioactive to stable isotope in a fossil enables us to tell how old the fossil is. For instance, if a fossil has a ^{14}C to ^{12}C ratio half that of atmosphere, it is about 5600 years old, a fossil with one fourth the atmospheres ratio is about 11,200 years old.

2. List the vestigial structures found in man and categorize them in homologous or analogous structures.

Human vestigial organs are those organs that have lost all or most of their original functions through evolution. There are about 90 such structures present in our body.

- Vermiform appendix is a vestige of the cecum.
- Coccyx or tailbone is the remnant of a lost tail.
- The wisdom teeth are vestigial third molars that human ancestors used to help in grinding down plant tissue.
- Humans have ear muscles that are minimally developed and non-functional, but some people are able to move their ears in various directions.
- Tonsil are also one of the removed part from human body.
- The fifth toe in the foot is nothing to do in foot.

SUMMARY

- The central idea of biological evolution is that all life on earth share common ancestor.
- The belief that the origin of life and diversity of life result from the act of God is

called special creation.

- The evidences to support evolution is provided by many sources.
- Analogous structures are similar in unrelated organisms.
- Fossils record indicates that eukaryotes evolved from prokaryotes about 2 billion years ago.
- Lamarck theory has two ideas *i.e.* use and disuse of organs.
- In 1831, Darwin was just 22 years old he set sail on scientific expedition on a ship called HMS Beagle.
- James Hutton has given the concept of uniformitarianism,
- Malthus argued that human population grow faster than the resources they depend on.
- Alfred Russell lived at about the same time as Darwin.
- Hardy Weinberg principle describes how a population can remain at Genetic equilibrium.
- Genetic drift represents random changes in small gene pools due to sampling errors in propagation of alleles.
- Speciation is an evolution process by which a population undergo change to such a degree that they become new species.

EXERCISE

SECTION-I: OBJECTIVE QUESTIONS

Multiple Choice Questions (MCQs)

A. Select the correct answer.

1. Endosymbiont hypothesis explains origin of:
   (a) Eukaryotes (b) Prokaryotes
   (c) Armadillo (d) Fish
2. The armoured mammal that live only in America is:
   (a) Echidna (b) Pangolin
   (c) Porcupine (d) Armadillo
3. Hardy-Weinberg theorem describes the frequencies of genotype of non-evolving:
   (a) Family (b) Population
   (c) Species (d) Community
4. Emigration and immigration of members of a population, cause disturbance in the:
   (a) Genotype (b) Phenotype
   (c) Gene pool (d) Genetic drift

5. Analogous structure are:
   (a) Anatomically similar and functioning similarly
   (b) Anatomically similar but functioning differently
   (c) Anatomically different but functioning similarly
   (d) Anatomically different and functionally differently

6. The theory of use and disuse was given by
   (a) Darwin (b) Lamarck
   (c) Aristotle (d) Mendel

7. Book "The origin of species" was written by
   (a) Linnaeus (b) Cuvier
   (c) Lyell (d) Darwin

8. Lamarck theory of natural selection is usually known as
   (a) Natural selection (b) Inheritance of acquired characters
   (c) Descent with change (d) Mutation

9. The first eukaryotic organism appeared on earth about
   (a) 1 billion years ago (b) One and half billion years ago
   (c) Three million years ago (d) 2 billion years ago

10. Who figured out the mechanics of evolution known as natural selection?
   (a) Charles Darwin (b) Alfred Russell
   (c) Lamarck (d) Buffen

11. Genetic drift is change of gene frequency in
   (a) Same generation (b) One generation to next
   (c) By chance (d) Appearance of recessive allele

12. Species occurring in different geographical area are called as
   (a) Sympatric (b) Allopatric
   (c) Peripatric (d) Parapatric

13. Which of the following is most important for speciation?
   (a) Seasonal isolation (b) Reproductive isolation
   (c) Behavior isolation (d) Tropical isolation

14. In the Hardy Weinberg equation, the frequency of dominant allele is represented by
   (a) q^2 (b) q (c) p^2 (d) p

B. Fill in the blank.

1. The Vent hypothesis suggests that life may have begun at submarine ..... Vent.
2. The study of the geographical distribution of fossil and living organisms is called .....

3. The fossil record of horse indicates that earliest horses had ..... toes.
4. There are two hypotheses about the evolution of eukaryotes from prokaryotes (i) membrane invagination theory and (ii) .....
5. Darwin presented his theory of natural selection in ..... in his famous book .....
6. Thomas Malthus was an English .....
7. Neo-Darwinism also called modern .....
8. Hardy Weinberg principle describes how a population can remain at genetic .....
9. Genetic drift is a change in allele .....
10. In parapatric speciation, the populations are not ..... by a physical barrier.

SECTION-II: SHORT QUESTIONS

C. Give the short answers of the following questions.

1. Define concept of special creation.
2. Briefly describe evidence of evolution from anatomy.
3. Illustrate membrane invagination theory.
4. Describe the drawback of Lamarckism.
5. Write the influence of Finches to Darwin.
6. Write the reasons for attributing theory of natural selection to Darwin.
7. Write factors that change allele frequency, briefly explain any one.
8. Illustrate about bottleneck effect.
9. Differentiate between allopatric and parapatric speciation.
10. Describe the survival of the fittest.

SECTION-III: EXTENSIVE QUESTIONS

D. Give detailed answers of the following questions.

1. Describe Lamarck theory of evolution.
2. Explain the observations of Darwin during voyage, summarize them.
3. Explain Darwin's theory of natural selection.
4. Describe Hardy Weinberg theorem and its conditions for stability?
5. Define speciation and explain its types.

UNIT 25

MAN AND HIS ENVIRONMENT

Major Concept

25.1 Biogeochemical Cycles
25.2 The Flow of Energy
25.3 Ecological Succession
25.4 Population Dynamics
25.5 Human Impact on Environment
25.6 Environmental Resources and their Depletion

Learning Outcomes

Students will be able to:

- Define biogeochemical cycles and locate the primary reservoirs of the chemicals in these cycles.
- Describe water cycle in detail.
- Define the terms aquifers and water table.
- Describe nitrogen cycle in detail.
- Define the terms of nitrogen-fixation, nitrification, de-nitrification and ammonification.
- Describe productivity in terms of gross primary productivity and net primary productivity.
- Explain the flow of energy in successive trophic levels.
- Interpret the pyramids of number, biomass and energy.
- Define ecological succession as the process through which ecosystems change from simple to complex.
- Describe primary and secondary succession.
- Differentiate between xerarch and hydrarch succession.
- Explain the xerarch succession on a bare rock starting from the small pockets of lichens to the vegetation of flowering plants.
- Describe characteristics of a population, such as growth, density, distribution, carrying capacity, minimum/viable size.
- Explain, using demographic principles, problems related to the rapid growth of human populations and the effects of that growth on future generations (*e.g.* relate the carrying capacity of the Earth to the growth of populations and their consumption of resources).
- Analyze the role of the department of population welfare, government of Pakistan in controlling the growing population of Pakistan.
- Relate the need of the nuclear power to the scarcity of fossil fuels.
- State the problems of using nuclear power (surety of safe operation and safe disposal of the wastes).

- Describe the causes of the increasing concentration of carbon dioxide in the world's atmosphere.
- Correlate the increasing CO_2 concentration with the global warming and describe its long term effects.
- Explain the causes and effects of acid rain.
- Describe the composition of the ozone layer and its role in protecting the life on earth.
- State the sources of chlorofluorocarbons and their role in the depletion of ozone.
- Explain the effects of Ultraviolet radiation as a serious human health concern.
- Narrate the incidence when one of the four reactors of the Chernobyl nuclear power plant blew up in 1986.
- Distinguish between renewable and non-renewable environmental resources.
- Describe how man is responsible for the depletion of environmental resources.
- Describe the conventional and non-conventional energy resources.
- Analyze the efforts of various government departments and NGOs to educate people for the protection of environmental resources.

Introduction

The purpose of study of this unit is to enhance the level of under-standing about the ecology and human interaction with his environment. This will help to understand effects of rapidly growing human population and his activities threatening the stability of ecosystem. How biogeochemical cycles are important for flow of chemical elements and compounds between living organisms and their physical environment. This unit also deals with ecological succession, utilization of **renewable** and **non-renewable environmental resources** and their conservation. However, we will begin with discussing how elements are essential for life and how these elements are recycled between living and non-living environment.

25.1 Biogeochemical Cycle

The flow of chemical elements and compounds between living organisms and their physical environment is known as **biogeochemical cycle**. Chemicals absorbed or ingested by organisms are passed through the food chain and returned to the soil, air and water by such as respiration, excretion and decomposition. As an element moves through this cycle, it often forms

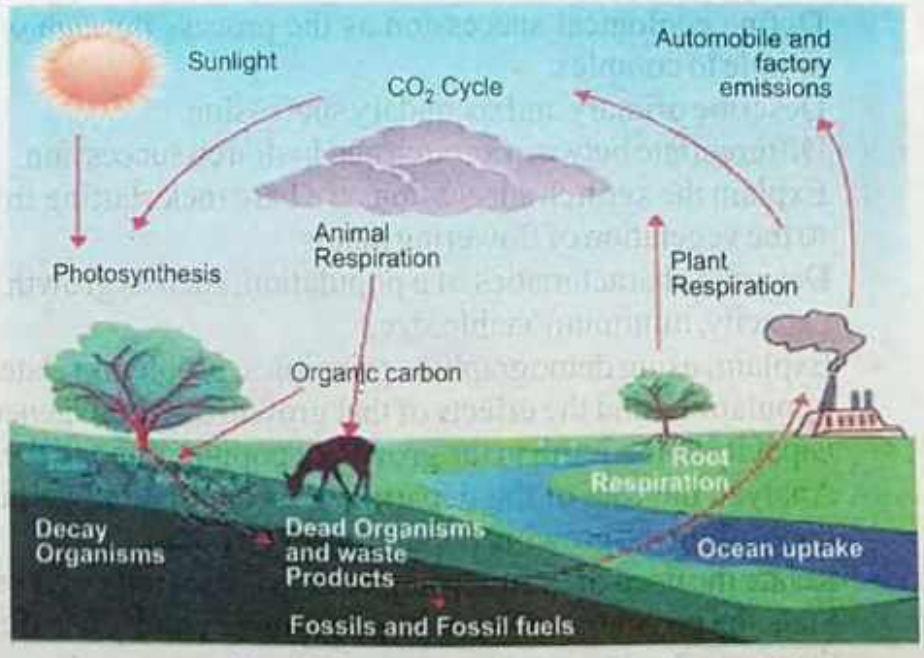


Fig. 25.1: Biogeochemical Cycles

compound with other elements as a result of metabolic processes in living tissues or by natural reactions in the atmosphere (air), hydrosphere (water) or lithosphere (outer rigid strong layer of earth). (Fig.25.1)

25.1.1 Primary Reservoirs of Nutrients

The chemicals are sometimes held for long periods of time in one place. This place is called a **reservoir** *e.g.* coal deposits that are storing carbon for a long period of time. When chemicals are held for only short period of time, they are being held in **exchange pools**. Examples of exchange pools include plants and animals.

Plants and animals utilize carbon to produce carbohydrates, fats, and proteins, which can then be used to build their internal structure or to obtain energy. Plants and animals temporarily use carbon in their systems and release it back into the air or surrounding medium. Generally, reservoirs are **abiotic factors**. Carbon is held for relatively short time in plants and animals in comparison to coal deposits. The period of time that a chemical is held in one place is called its **residence time** (the length of time a substance remains in the adsorbed, suspended, or dissolved state).

Extra Information

Two thirds of the world's population are projected to face water scarcity by 2025 according to United Nations.

Water Cycle

Do you know there is as much water today as there was 1000's of years ago? This is possible due to amazing water cycle. Ocean is the major source of water, which contains about 97% of the total water. The water cycle is driven by solar energy which evaporates water and by gravity which draws the water back to earth in the form of precipitation *i.e.* rain, snow, dew, or hail. (Fig.25.2)

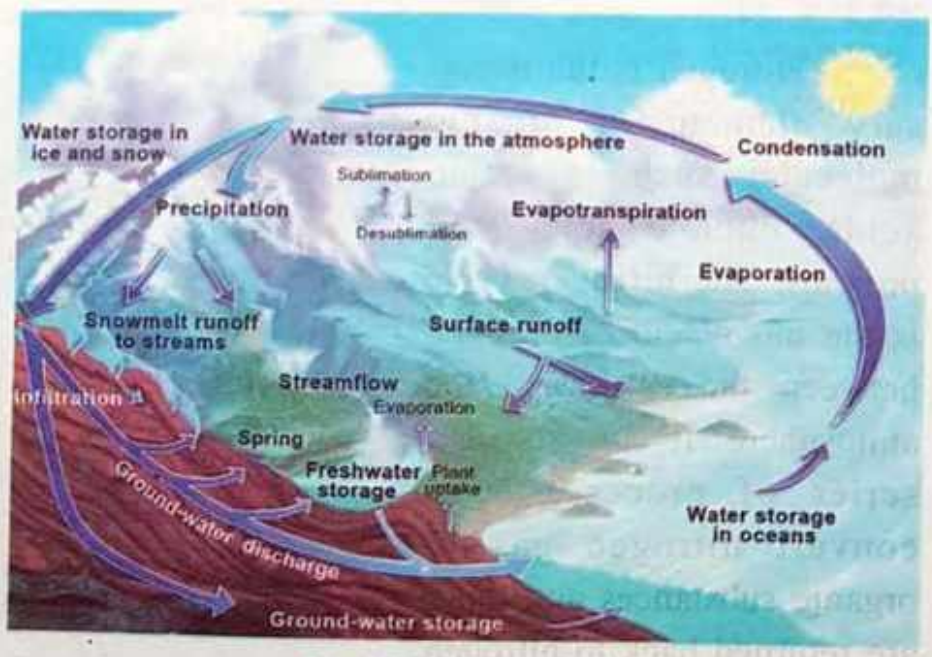


Fig. 25.2: Water Cycle

Water in Environment

Water falling on land takes different paths. Some water is evaporated from the soil, lakes and streams. A portion of water runs off the land back to the oceans.

When rain water falls, some of the **water sinks** or **percolates** into the ground and saturates the earth to a certain level. The top of the saturation zone is called **water table**. Wherever the earth contains **basin** or **channels**, water will appear to the level of the water table. The water within the basins is called **lakes** and **ponds** and water within the channels is called **streams** or **rivers**. Sometimes ground water is also located in underground rivers called **aquifers**. An aquifer is an underground layer where the material contains water, that supplies the water for wells, springs, *etc.*

Abiotic and Biotic Factors

Abiotic factors are the non-living part of environment. These include light temperature, water, wind, soil, etc. Biotic factors are living parts of an environment such as plants animals and micro-organisms.

Water in living bodies

The bodies of living things contain roughly 70% water, some of the water in the water cycle enters the **living communities** of ecosystems. It is absorbed by the roots of plants and much of this is evaporated back to the atmosphere from their leaves. A small amount is combined with carbon dioxide during photosynthesis to produce **high-energy molecules**. Eventually these are broken down during **cellular respiration**, releasing back to the environment. Heterotrophs get water from their food or by drinking. Some of this water is released back to environment by **vaporization**.

25.1.2 Nitrogen Cycle

Nitrogen is the necessary element of organic molecules such as amino acids, nucleic acids and proteins. The **nitrogen cycle** is the movement of nitrogen between the earth and the atmosphere. It consists of a series of processes that convert nitrogen gas to organic substances and these are returned back to nitrogen in atmosphere. It is a continuous cycle maintained by the decomposers and other bacteria. The nitrogen cycle can be explained in four types of reactions *i.e.* decomposition. Nitrogen fixation, assimilation and de-nitrification. (Fig.25.3)

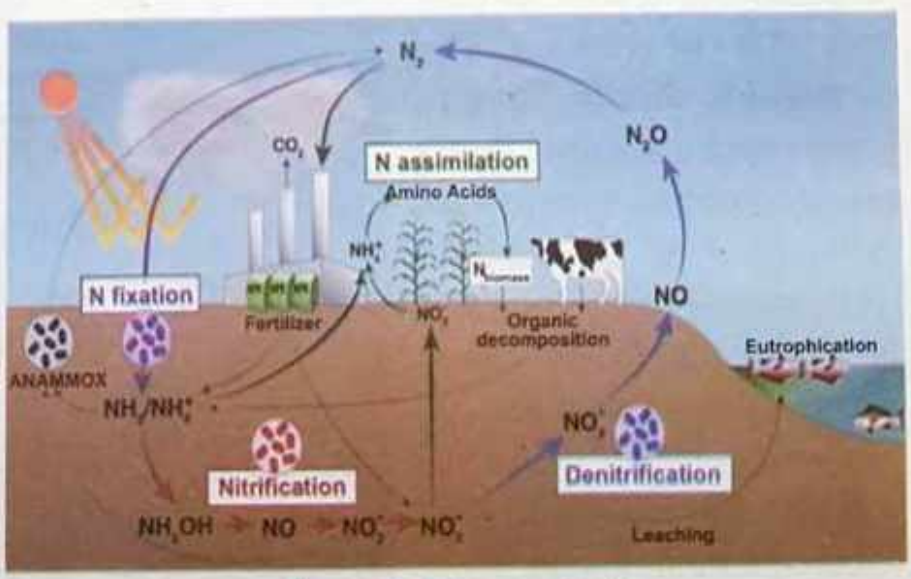


Fig. 25.3: Nitrogen Cycle

1. Decomposition

Decomposition is the process of breakdown of complex substance into its components. Decomposition of organic nitrogen compounds is the first source of soil nitrates. It occurs in two steps: (i) ammonification (ii) nitrification

a) Ammonification

The nitrogenous wastes of animals and nitrogenous compounds of dead organisms are decomposed by **saprophytic soil bacteria** and **fungi** to form simple substances like water, carbon dioxide, amino acid and energy. The amino acids are converted into ammonia or ammonium ions. Production of ammonia or ammonium compounds during the decomposition of organic matter by microorganisms (**ammonifying bacteria**) is called **ammonification**.

b) Nitrification

Some ammonia escapes into the soil but much of it and ammonium ions are converted into nitrates by **nitrifying bacteria**. It is accomplished by two groups of nitrifying bacteria. The first group of bacteria *e.g.* ***Nitrosomonas*** converts ammonia to nitrites and the second group of bacteria *e.g.* ***Nitrobacter*** converts nitrites to nitrates. This process is called **nitrification**. Nitrification takes place only in well aerated soils because the bacteria are aerobic in nature.

2. Nitrogen Fixation

Any process of combining atmospheric nitrogen with other elements, either by chemical means or by bacterial action is called **nitrogen fixation**.

Nitrogen gas (N_2) is composed of two atoms of nitrogen linked by a very strong triple bond (N≡N). This makes it chemically unreactive and large amount of energy is required to break the bond. Nitrogen gas can be fixed in three ways.

a) Atmospheric Fixation

The nitrogen fixation that occurs spontaneously by lightning is called atmospheric fixation; a small amount (5-8%) is fixed in this way. **Lightning** allows nitrogen and oxygen to combine and produce various oxides of nitrogen. These are carried by the rain into the soil where they can be used by plants.

Extra Information

Nitrogen is the basic element for many fertilizers. Ammonia (46%) remains the most important fertilizer till date since it was first manufactured artificially.

b) Industrial Fixation

The synthesis of nitrogen containing **fertilizers** is called industrial fixation.

c) Biological Fixation

Nitrogen-fixing bacteria fix about 60% of nitrogen gas in the atmosphere. The reduction of nitrogen gas to ammonia is energy intensive. It requires 16

molecules of ATP and a complex set of enzymes to break the bonds so that the nitrogen can combine with hydrogen. Its reduction can be written as:

$$N_2 + 3H_2 \longrightarrow 2NH_3$$

Only a relatively few bacteria (the nitrogen-fixing bacteria) are able to carry out this reaction. Fixed nitrogen is made available to plants by the death and lysis of free living nitrogen fixing bacteria *e.g.* ***Azotobacter*** (aerobic) and ***Clostridium*** (anaerobic) or from the symbiotic association of some nitrogen fixing bacteria with plants *e.g.* ***Rhizobium.***

3. Assimilation

The formation of organic nitrogen compounds like amino acid from inorganic nitrogen compounds present in the environment is called **nitrogen assimilation**. Many microorganisms are able to utilize free nitrogen directly from atmosphere but plants obtain nitrogen in the form of inorganic nitrogenous compounds like ammonia and nitrates from the soil, whereas animals take their nitrogen from the eating of plants or other animals.

4. Denitrification

The process in which a nitrate becomes molecular nitrogen, especially by the action of bacteria. Such bacteria are called de-nitrifying bacteria *e.g.* ***Pseudomonas*** reduces nitrates in the soil to gaseous state.

$$\underset{\text{(Nitrate)}}{NO_3} \longrightarrow \underset{\text{(Nitrite)}}{NO_2} \longrightarrow \underset{\text{(Nitrogen Oxide)}}{NO} \longrightarrow \underset{}{N_2O} \longrightarrow \underset{\text{(Nitrogen Gas)}}{N_2}$$

25.2 The Flow of Energy in Ecosystem

Energy moves life. The cycle of energy is based on the flow of energy through different trophic levels in an ecosystem. Species are classified to trophic levels on the basis of their main source of nutrition and energy.

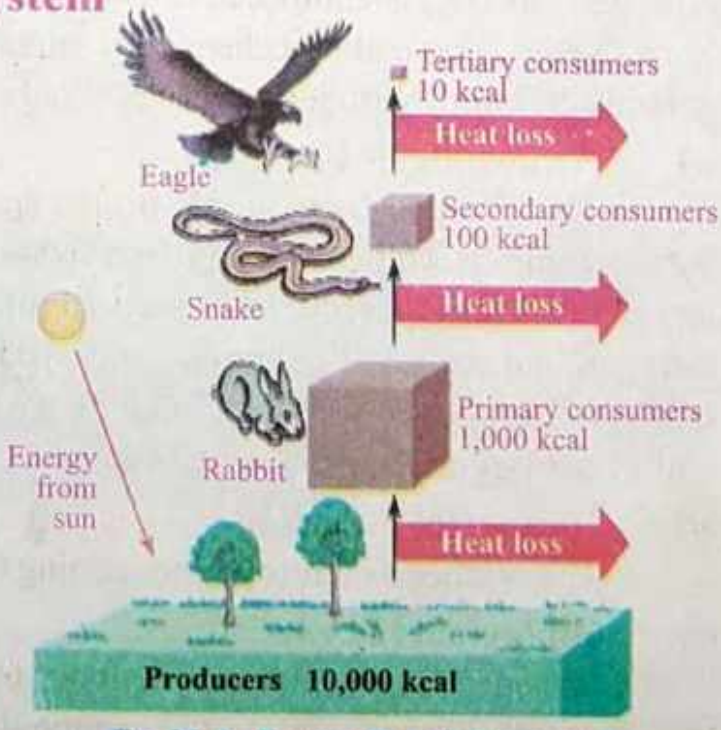


Fig.25.4: Energy flow in Ecosystem

25.2.1 Concept of Trophic Levels

In an ecosystem the organisms are arranged in different feeding groups, each is known as trophic level. There are following trophic levels.

First Trophic Level

At the first trophic level (T_1), **primary producers** (plants, algae and

some bacteria) use solar energy to produce organic plant material through photosynthesis.

Second Trophic Level: Herbivores or primary consumers make up the second trophic level (T_2).

Third Trophic Level

Predators, the **secondary consumers** that eat herbivores comprise the third trophic level (T_3); If larger predator *i.e.* tertiary consumers are present; they represent still higher trophic levels.

Fourth Trophic Level

Organisms that feed at several trophic levels or predator (Carnivore eat another carnivore) and (**omnivores**) are classified at the highest of the trophic levels (T_4), at which they feed.

Fifth Trophic Level

Decomposers, which include **bacteria, fungi, molds**, and **detritivores** such as worms, and insects, break down wastes and dead organisms and return nutrients to the soil, occupy the fifth trophic level (T_5). (Fig.25.5)

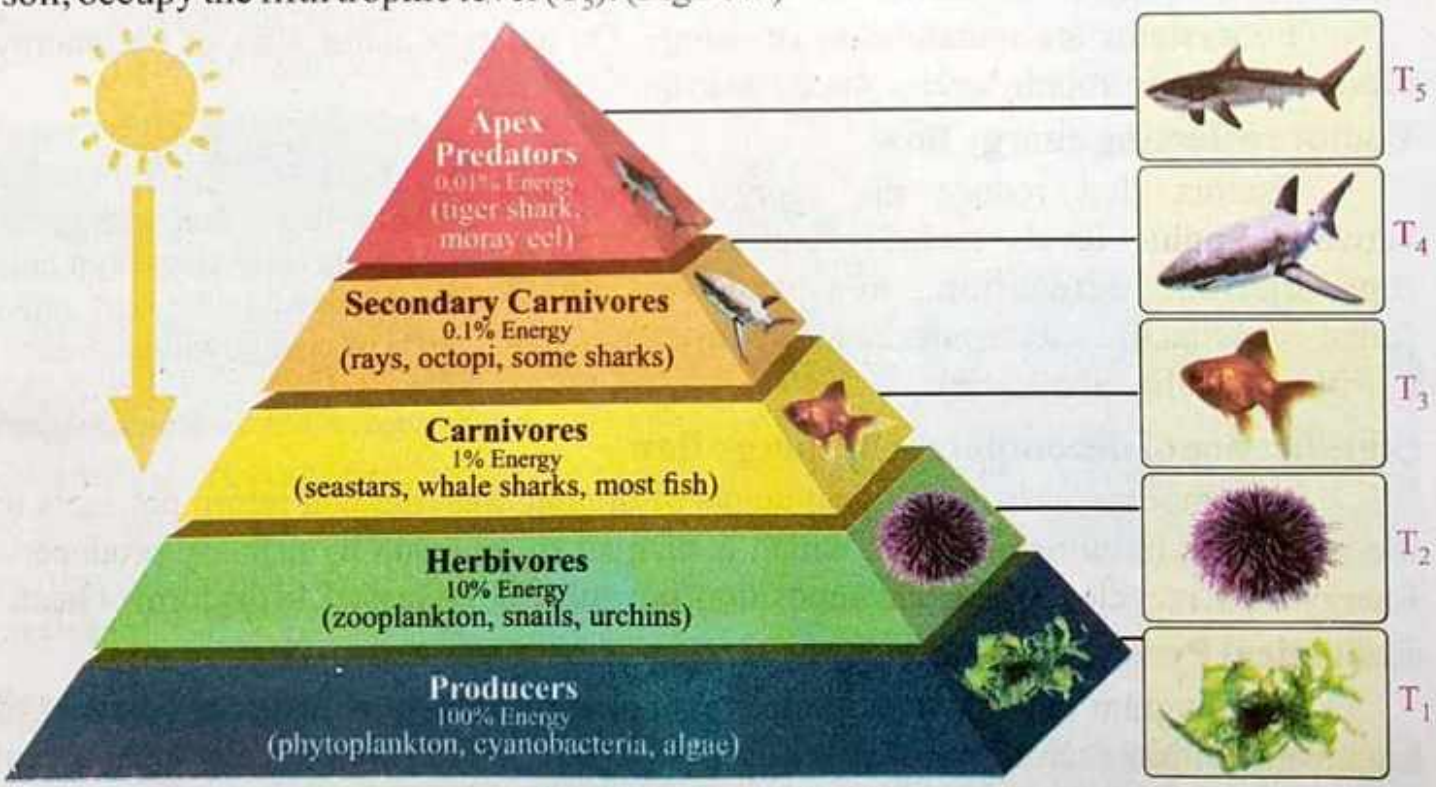


Fig. 25.5: Trophic Levels

25.2.2 Concept of Productivity

The **ultimate source of energy** for ecosystems is sun (solar energy). Only 1% of solar energy is incorporated into the ecosystem. The total amount of solar energy which is fixed by the producers during photosynthesis is called **gross primary productivity**

(GPP). On the other hand, the amount of energy that remains available for plant growth after subtracting the fraction that plants use for respiration is termed as **Net primary productivity** (NPP) or **biomass**.

Productivity in Land Ecosystems

Productivity in ecosystem depends on Temperature and moisture. It generally rises with temperature up to about 30°C, after which it declines and is positively correlated with moisture. On land primary productivity thus is highest in warm, wet zones in the tropics where tropical forest biomes are located. In contrast, desert shrub ecosystems have the lowest productivity because their climates are extremely hot and dry.

Productivity in Aquatic Ecosystems

Light and nutrients are important controlling factors for productivity in aquatic ecosystems. In oceans, light penetrates only up to **500m** of the oceans. Marine primary productivity is high near coastlines. Among aquatic ecosystems, **algal beds and coral reefs** have the highest net primary production while the lowest rates occur in the open due to a lack of nutrients in the illuminated surface layers.

25.2.3 Energy Flow between the Trophic Levels

Ecosystems are transformers of energy. On average about 10% of net energy production at one trophic level is passed on to the next level.

Factors affecting energy flow

Factors that reduce the energy transferred between trophic levels include respiration, growth, reproduction, defecation, non-predatory death (organisms that die but are not eaten by consumers), and nutritional quality of material.

10% Rule

Means that when energy is passed in ecosystem from one trophic level to the next, only 10% of energy will be passed on.

Significance of decomposers in energy flow

Decomposers process large amounts of organic material and return nutrients to the ecosystem in inorganic form, which is then taken up again by primary producers. Energy is not recycled during decomposition, but rather it is released, in the form of heat.

Ecological Pyramids

The diagram that shows the relative amount of energy or matter or numbers of organisms within each trophic level in a food chain or food web is called ecological pyramids. **Ecological pyramids** are, therefore, graphical representation of ecological data.

Pyramids of Energy

A lot of energy is lost to the environment as food is transferred from one trophic level to the next. Energy may be lost to the environment in following ways. (Fig.25.6)

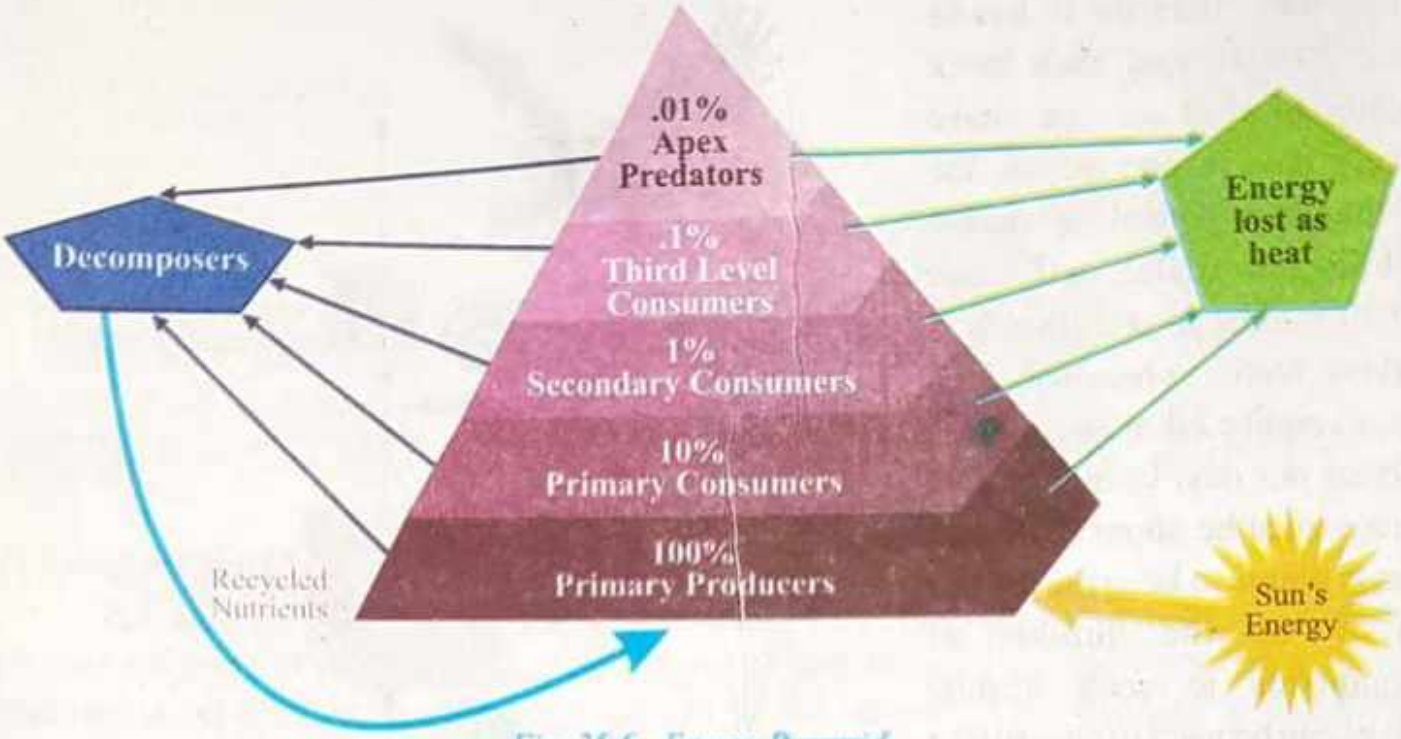


Fig. 25.6: Energy Pyramid

- As heat during respiration at every trophic level.
- Through undigested matter egested by consumers.
- Through excretory products *e.g.* urea, from consumers.

The total energy level decreases progressively along the food chain. Therefore, the pyramid of energy is always broad at the base and narrow towards the apex. Normally we can assume that 90% of energy is lost when it is transferred from one trophic level to the next. The progressive loss of energy explains why food chains are generally short. A shorter food chain means more energy is available to the **final consumer**. Therefore, more energy will be available to human if he feeds directly on crop plants rather that to eat cattle that feeds on plants.

Extra Information

It is estimated that there are more than 100,000 different types of decomposers in existence.

Pyramid of Biomass

Biomass is the total mass of living matter in each trophic level at any one time. For the food chain we have just considered, the pyramid of biomass has a similar shape to that of pyramid of number. The mass of all grasses is together having a larger biomass than the snakes. Three hundred snakes are heavier than the ten **hawks**.

Pyramid of Numbers

Consider a **simple food chain** consisting of grass, rabbits, snakes and hawks.

Supposing there are 10 hawks in a habitat, and each hawk needs to feed on one snake every day. In one month, the 10 hawks will need 300 snakes while 300 snakes will need 4500 rabbits in one month. A rabbit feeds voraciously and may require 20 or more grass plants per day. In one month, there must be about 2700,000 grass plants to keep the rabbits alive. So the number of organisms at each trophic level can be used to construct a pyramid of numbers. For this food chain, the pyramid will be **broad at the base** and **narrow towards the top**. (Fig.25.7)

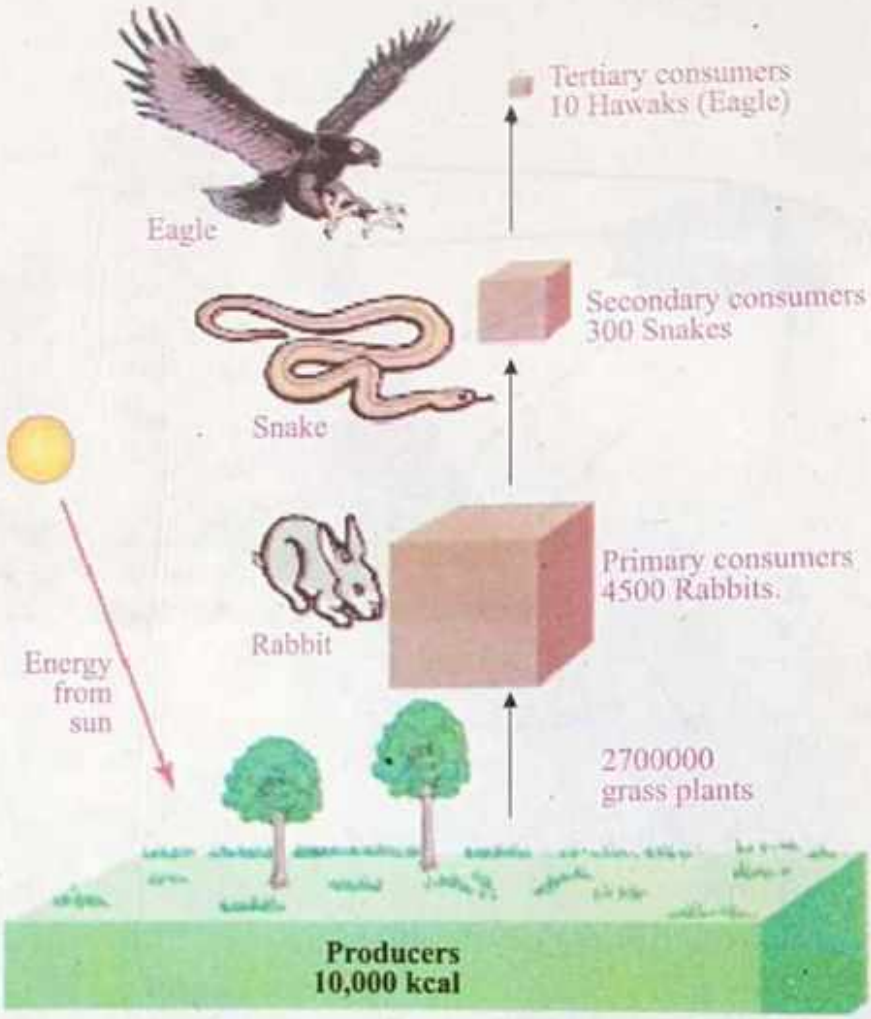


Fig. 25.7: Pyramid of Number

25.3 Ecological Succession

Ecological succession is the gradual process by which ecosystem change and develop overtime.

Kinds of Ecological Succession on the Basis of Origin

There are two main types of succession.

1- Primary Succession

2- Secondary Succession

1) Primary Succession

It is the start of vegetation on bare or newly exposed area such as land exposed as a result of soil erosion, melting of glaciers, *etc.* The newly exposed land surface is unsuitable for a large number of species; only few species are capable of growing in such areas. The **first entrants** are known as **pioneer species** or **primary invaders**.

The primary succession modifies the habitat as a reaction of the plants to environment and results in the creation of conditions suitable for the growth of other species. (Fig.25.8)

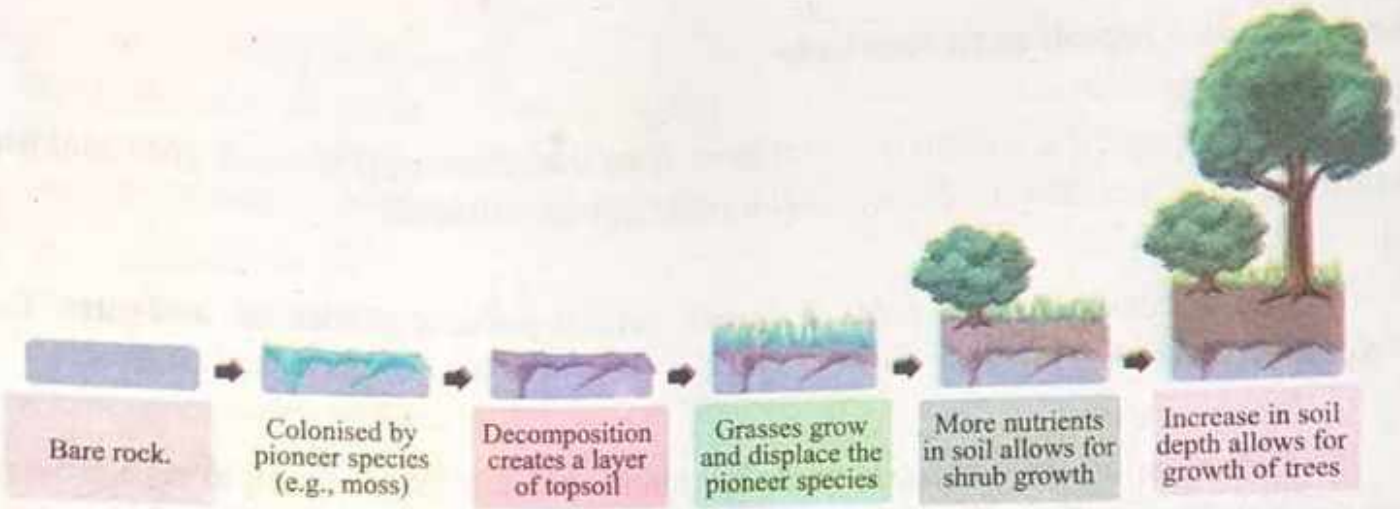


Fig. 25.8: Primary Succession

2) Secondary Succession

It takes place in the areas where the established or **normal succession** is disturbed by such factors as fire, grazing, *etc.* the degree of resemblance to the original succession depends upon the degree of damage caused by the factors. If the damage is slight the secondary succession will soon become primary like. In case of severe damage the secondary succession may remain different. (Fig.25.9)



Fig. 25.9: Comparison between Primary and Secondary Succession

Successions According to Habitats

a) Hydroseres

This type of succession is initiated in **open water** where plants can grow and the pattern of this succession is almost similar in all aquatic habitats.

b) Mesoseres

The succession, that starts in areas, which possess **sufficient moisture** for vegetation to develop.

c) Xeroseres

Colonization of the **bare rock** by plants is very good example of xerosere succession. The rock surface is extremely **xeric** except for short periods of rain when moisture is available.

Hydrach and Xerarch

Ecological succession which beings in pond, lakes, marshes or elsewhere water, are termed as hydrach and different stages are called hydrosere, while succession initiated as bare rocks, sand dunes, rocky slopes, *etc.* (dry areas) are termed as xerarch and different stages are called xerosere.

Stages Involved in the Development of Xeroseres (Xerarch Succession)

A xerosere comprises the following stages.

i) Crusticose Lichen stage

The pioneer species are always **lichens**, *e.g. Rindodina* and *Lecidea*, *Licarnora*, which flourish during short moist periods but can withstand long periods of drought. These pioneers cause the accumulation of some organic matter and dust, thus providing a base for the growth of higher lichens.

ii) Foliose Lichen Stage

The **crusticose-lichens** are gradually replaced by **foliose lichens** such as *Parmelia*, *Umbilicaria*, *dermatocarpon, etc.* The foliose lichens absorb more and lose less water. More organic matter is accumulated and a base for the growth of mosses is provided.

iii) Moss Stage

Xerophytic mosses like *Polytrichum* and *Tortula* occupy the soil formed by the lichens of the previous stages. The mosses absorb much more water and nutrients owing to their longer rhizoids. They can also withstand desiccation. Further accumulation of organic matter results in the formation of a thick layer of humus capable of supporting other herbs and grasses.

iv) Herbaceous Stage

Annual herbs invade the area for a few generations, their growth is poor. As dead

parts of these herbs decay and form humus which riches the soil, *biennial* and **perennial herbs** appear. These plants reduce evaporation and increase temperature, thus cause increase in the moisture of the soil. Gradually a soil layer few inches thick and rich in organic contents is produced which can support the growth of shrubs.

v) Shrub Stage

Shrubs then invade the soil formed by the inhabitants of the previous stages. These over shadow the herbs. More organic matter is accumulated, soil becomes richer and its water retaining capacity is increased.

vi) Three and Climax stage

Among the first invaders are xerophytic trees, which are widely spaced. The trees increase in number and become stronger and wide spread as the soil becomes deeper. Mesophytic ones replace the xerophytic shrubs. New herbs develop in the humid air and the richer soil. The interaction between species and environment continues for generations and the result is a **climax forest** with thick growth of mesophytic trees associated with characteristic under shrubs and herbs.

25.4 Population Dynamics

Population dynamics is the branch of life sciences which deals with the studies of long term and short term changes in size, age, composition of population and biological and environmental processes influencing those changes. **Population dynamics** deal with the way populations are affected by birth and death rates and by **immigration** and **emigration**.

25.4.1 Characteristics of a Population

A population is a group of individuals of a single species, living in the specific area at a specific time. Members of a population rely on the same resources, are influenced by similar environmental factors and have a high likelihood of interacting with and breeding with one another. The characteristics of a population are: growth, density, distribution, carrying capacity and viable size.

Growth

Increase in the number of individuals of a population is called **population growth**. Consider what happens if a few individuals enter an unoccupied area. Assuming there is enough food and that predation and disease are not too severe, reproduction will occur and the number of individuals will increase. At first, there may be a **lag phase** as the individuals settle into their new environment. As reproduction gets underway, the population shows exponential growth. The population size doubles at regular intervals. During exponential phase the population is said to grow geometrically.

Density

Density is the number of individuals per unit area or volume *e.g.* the number of apple trees per square kilometer in Zairat or the number of *E. coli* bacteria per milliliter in a test tube.

Distribution

The way a population is spatially distributed across an area, is driven largely by food supply or other resources, is called **distribution**. There are three distribution patterns found in different populations like clumped (individuals aggregate in patches), uniform (individuals are evenly spaced) or random distribution (unpredictable spacing among individuals).

Carrying capacity

There is a limit to the number of individuals that can occupy a habitat. The **carrying capacity** is defined as the maximum population size that a particular environment can support. Ecosystems cannot exceed their carrying capacity for a long period of time. Otherwise species will deplete sources of food, water, *etc.*

Health Services through various programmes

The department of population welfare is providing Family Planning and Reproductive Health Services. These include:

1. Family Welfare Centres
2. Mobile Service Units
3. Reproductive Health Services (RHS)

These centres are being run by various NGOs with assistance of the Population Welfare Department.

25.5 Human Impacts on Environment

Human activity has been affecting the environment for thousands of years. Population growth leads to the loss of natural habitat. **Deforestation** causes loss of species of fauna and flora, oxygen production and carbon dioxide elimination. Ozone layer depletion, water pollution, global warming, desertification, increased erosion of land, is directly caused by human activities such as use of nuclear fuel, industrialization, urbanization, transportation, *etc.*

25.5.1 Nuclear Power

Nuclear power is the use of nuclear reaction that releases nuclear energy to generate heat. This heat is used in **steam turbines** to produce electricity in a nuclear power plant, generates heat and electricity. The scarcity of fossil fuels which is not available in all the countries is the reason for the development nuclear power stations.

Advantages of nuclear power

There are number of advantages of nuclear power *e.g.*

i) 15% of the world electricity provided by nuclear power.
ii) Nuclear power costs about the same as coal, so it's not expensive to make electricity.
iii) Does not produce smoke or carbon dioxide, so it does not contribute to the **greenhouse effect**.
iv) Produces huge amounts of energy from small amounts of fuel.
v) Produces small amounts of waste.
vi) Nuclear power is reliable and **un-exhaustible source of energy**.

Disadvantages of using nuclear power

Some disadvantages of nuclear power are as under.

i) Release **radioactive wastes** in environment, so disposal and safety is important
ii) Incurs heavy **initial cost** to construct a power plant.
iii) Threat to aquatic marine life due to the **traces of oxygen**.
iv) **Hazardous implications** on human lives and technology can be misused especially by **terrorists**.
v) Nuclear weapons can **destroy humanity**.

Chernobyl Nuclear Power Incidence

The Chernobyl disaster was a nuclear accident. It occurred on 26 April, 1986 at the **Chernobyl Nuclear Power Plant in Ukraine**. An explosion and fire released large quantities of radioactive contamination into the atmosphere which spread over much of the **Union of Soviet Socialist Republics (USSR)** and Europe. Approximately over 500,000 workers were affected apart from the 57 direct deaths in the accident itself. United Nations Scientific Committee on the Effects of Atomic Radiation predicted in 2005 that up to 4,000 additional cancer deaths related to the accident would appear among the 600,000 persons receiving more significant exposures.

What happened in Japan in 2011?

On March 11, 2011 an earthquake of magnitude of 9.00. It ruptured a 500 kilometres long fault zone off the northeast coast of Japan, killing 513 people.

25.5.2 Carbon Dioxide and Global Warming

Due to burning of fossil fuel in motor vehicles and industrial processes, the amount of CO_2 is increased in atmosphere. CO_2 absorb high energy radiations and thus result is increase the atmospheric temperature. This rise in temperature is known as **global warming**. CO_2 is also injurious to human health as it decreases the oxygen

carrying capacity of blood.

Causes of Increasing Concentration of CO_2 in Atmosphere

The main causes of CO_2 in the atmosphere are burning of fossil fuels, such as coal, oil and natural gas for industry, driving our transport, heating our homes, generating electricity, the burning of wild, forests are increasing CO_2 in the atmosphere. There has been a marked increase in the CO_2 percentage in the atmosphere since industrial revolution. In addition, **eruption of volcanoes** off and on, is another cause to increase of CO_2 in the world atmosphere.

CO_2 Concentration and the Global Warming

The amount of CO_2 in the air is increasing day by day. Itmakes up about 0.04% of the air now, compared with 0.03% in the mid-twentieth century. It is very likely that the raised atmospheric CO_2 levels are causing the average temperatures on Earth to increase, a process called global warming or green-house effect. (Fig.25.12)

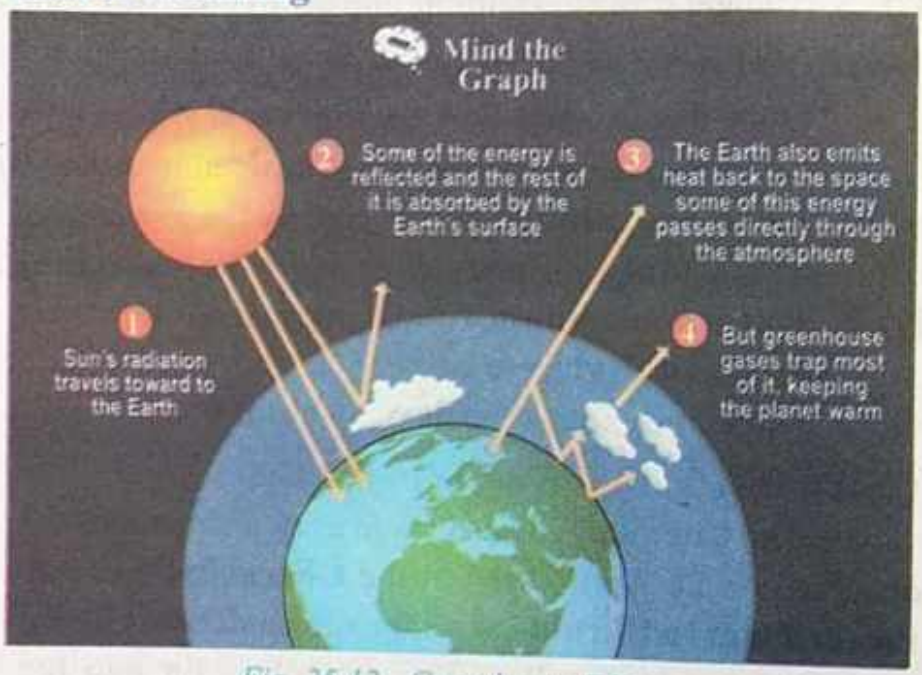


Fig. 25.12: Greenhouse Effect

Long term effects of Global Warming

CO_2 increase in atmosphere prevents reflection of infra-red radiation which warms earth. A worst-case scenario suggests that the warming would be great near the poles. The resultant melting polar ice might raise sea level by an estimated 100 m, gradually flooding areas 150 km (or more) inland from the current coastline. A warming trend would also alter the geographical distribution of precipitation, making major agricultural areas drier.

25.5.3 Acid Rain

Acid rain, or **acid deposition**, is a broad term that includes any form of precipitation that contains acidic components such as **sulphuric acid** or **nitric acid**. The precipitation is not necessarily wet or liquid; the definition includes snow, fog and hail. The type of acid rain that contains water is called wet deposition while the acid rain that contains dust or gases is called dry deposition. (Fig.25.13)

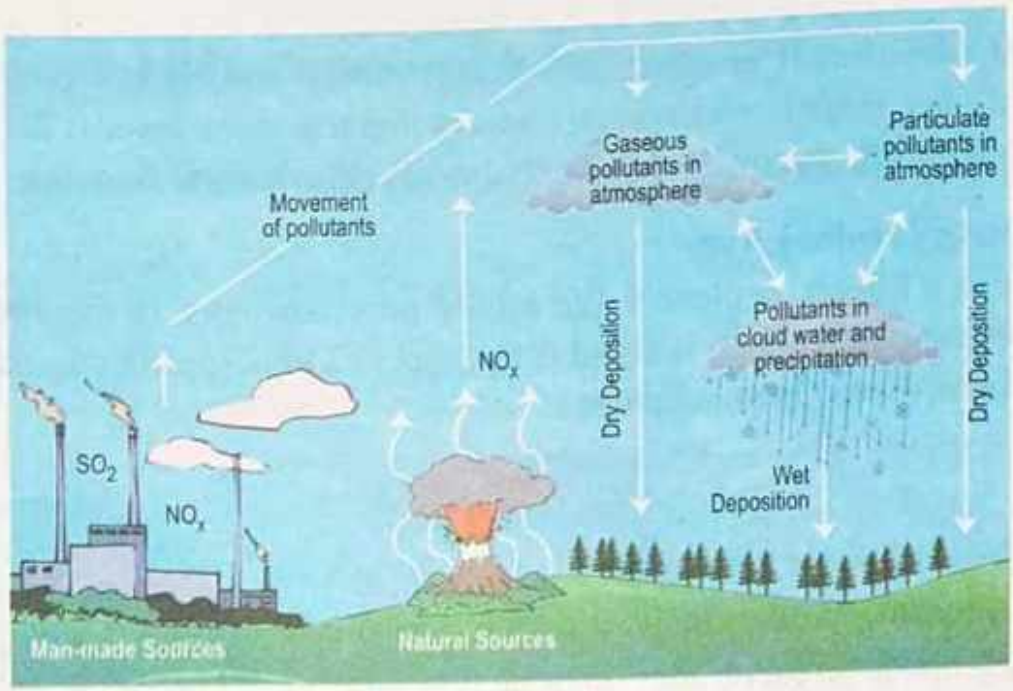


Fig. 25.13: Acid Rain

The Causes of Acid Rain

The acid rain may fall hundreds of miles away from the source of pollution. It is a natural phenomenon caused by chemicals emitted during volcanic eruption and forest fires. However, majority of acid rain is caused by human activity such as burning of coal by electricity generating plants, industrial boilers and large smelters that obtain metals from ores. In addition, nitrogen oxides are emitted by automobiles. The causes of acid rain due to human activities are called **anthropogenic sources**.

Effects of Acid Rain

The acid rain is harmful in number of ways. These include:

i) It increases soil acidity.
ii) Acid rain damages life in farms and forests.
iii) It kills aquatic organisms and prevents their successful reproduction.
iv) It also increases the quantity of certain metals such as **Aluminium** that may prove toxic to many organisms in the ecosystem.
v) Acid rain causes extensive damage to buildings and stone structures, which is known as **stone cancer**.
vi) Acid rain adversely affects the nervous, respiratory and digestive system of man.

25.5.4 Ozone Depletion

The ozone layer protects all life from sun's harmful radiations. The earth's atmosphere is composed of several layers. The lower layer is called **troposphere** (10 km altitude). The next layer is **stratosphere** which is 10-50 km. The ozone layer is concentrated in 15-30 km, above the earth's surface in stratosphere. The ozone layer

contains O_3 molecules. It is constantly being formed and broken down in the high atmosphere. Today, there is widespread concern that the ozone layer is deteriorating due to the release of pollution, containing the chemicals **chlorine** and **fluorine**.

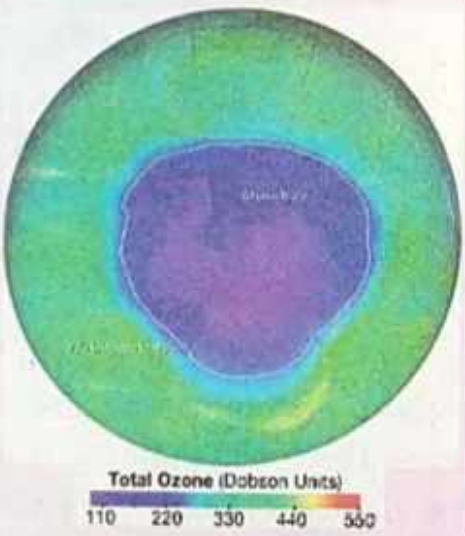
Composition of Ozone Layer

Ozone is a bluish, explosive and highly poisonous gas. In the stratosphere, the normal concentration of ozone is about 0.1 part per million (ppm), compared with 0.02 part per million in the lower atmosphere.

Ozone Hole

The ozone hole is not technically a "hole" where no ozone is present, but is actually a region of depleted ozone in the stratosphere over the Antarctic that happens at the beginning of Southern Hemisphere spring (August-October).

The average concentration of ozone in the atmosphere is about 300 Dobson Unit; any area where the concentration drops below 220 Dobson Units is considered part of the ozone hole.



Formation of Ozone Layer

Ozone is formed in the atmosphere when ultraviolet radiation from the sun splits one oxygen molecule into two oxygen atoms. The atomic oxygen then combines with another oxygen molecule to form ozone (O_3).

Causes of Ozone Layer Depletion

Ozone molecules splits into one oxygen atomic form and two oxygen in molecular form. In the stratosphere, there is a group of commercially important compounds called **chlorofluorocarbons (CFCs)**. These have been used as **propellants** in **aerosol cans**, **coolants** (*e.g.* Freon) in air conditioners and refrigerators, foam (*e.g.* Styrofoam) for insulation and packing and cleaners in the electronic industry. Ultraviolet radiation breaks CFCs and similar compounds into chlorine, fluorine and carbon. Under certain stratospheric conditions, chlorine and fluorine are capable of reacting with ozone, converting it into molecular oxygen (O_2) and atomic oxygen (O).

Interesting Information

Pollution is one of the biggest global killer affecting over 100 million people. That's comparable to global diseases like malaria and HIV.

Role of Ozone Layer in Protecting the Life on Earth

Ozone molecules in the stratosphere absorb incoming solar ultraviolet radiations and this protects life on Earth from harmful UV rays.

Extra Information

In 1985, it was discovered that the springtime levels of stratospheric separate ozone over Antarctica had declined by over 40% since 1977. A hole had been punctured in Earth's protective shield.

Effects of Ultra Violet Radiation on Human Health

With depletion of the ozone layer, UV radiations reach to the Earth's surface. Excessive exposure to UV radiation is linked to a number of human health problems, including sunburn, premature aging of skin, skin cancer and **cataracts**. Photosynthesis by phytoplankton is also affected and reduced by ultraviolet radiation.

25.6 Environmental Resources and their Depletion

Wherever humans have gone, they have altered the environment according to their needs. Living organisms are important natural resources. Earth is a self-contained unit. The future of the mankind depends on protection and conservation of environmental resources.

25.6.1 Kinds of Natural Resources

Environment is full of resources. All resources of environment can be divided into two groups *i.e.* renewable and non-renewable resources.

Renewable Resources

Renewable resources are un-exhaustible resources that replace themselves quickly enough to keep pace with consumptions. Examples are air, water, land and wild life. Living organisms use these resources continuously but these are constantly replaced by natural cycles *e.g.* water cycle, carbon cycle, oxygen cycle, nitrogen cycle, *etc.*

Non-renewable Resources

Non-renewable resources are formed at a rate much slower than their environmental consumption. These are exhaustible and cannot be replaced if destroyed. Examples are various metals, non-metallic minerals, coal, oil and natural gas, *etc.*

Interesting Information

27,000 trees are cut down each day so we can have toilet paper.

25.6.2 Conventional and Non-Conventional Energy sources

There are plenty of energy resources to get energy. These resources can be classified as conventional and non-conventional sources.

Conventional Energy Sources

The energy source that has been used for long time is called conventional sources

of energy. The examples of conventional energy sources are fossil fuels (coal, natural gas, oil), firewood and sources of energy *i.e.* electricity, coal, oil, wood, peat and uranium.

Extra Information

Fóssil fuels include coal, oil and gas. They provide 95% of the energy requirement. They are non-renewable. They are called fossil fuels because they are remains of plants and animal that lived millions of years ago.

Human prefer to use conventional sources of energy because these are **inexpensive** and require established technologies that can produce energy around the clock *e.g.* fossil fuel. The disadvantages of conventional sources of energy are that they have a limited supply because eventually these sources (fossil fuels) will be used up. In addition, burning fossil fuels release significant amounts of greenhouse gases (carbon dioxide, methane, nitrous oxide, *etc.*) and contribute to acid rain and rain Pollution.

Non-conventional Energy Sources

These resources of energy are continuously replenished by natural processes. These are not commonly used, so called non-conventional resources. These include solar energy, **Hydro-electric energy** (dams in rivers), Wind energy, Tidal energy, Ocean wave energy, **Geothermal** energy (heat from deep under the ground), **Ocean thermal power** (the difference in heat between shallow and deep water), **Biomass** (burning of vegetation to stop it producing methane), **Bio-fuel** producing ethanol (petroleum) from plants, Bio-gas. It is also known as renewal energy sources.

Interesting Information

The conventional energy sources are the non-renewable resources in Pakistan that includes: thermal energy and nuclear energy. Thermal sources in Pakistan are coal, oil, natural gas. The non-conventional sources of energy in Pakistan are wind energy, hydroelectric power, solar energy and biogas.

The **advantages** of non-conventional source of energy are that these are abundant in nature. Solar and wind energy is great source of energy but so for these sources are not used abundantly. There are pollution free and eco- friendly. These sources can be renewed with minimum effort and less energy, consumption for their renewable. The disadvantages of nonconventional energy sources include inconsistent, high operating cost, harmful to wild life and environment, *etc.*

Depletion of Resources

Resource depletion is a term referring to the exhaustion of raw materials within a region. Use of resources beyond their rate of replacement is considered to be resource

depletion.

Causes of resource depletion

There are many causes of depletion of natural resources. These include over consumption/ excessive or unnecessary use of resources, non-equitable distribution of resources, overpopulation, slash and burn agricultural practices, technological and industrial development, erosion, irrigation, mining for oil minerals and pollution or contamination of resources.

25.6.3 Protection of Environmental Resources

Environmental resources are very important for our existence. Our health and well- being are closely linked to the quality of our air, water, soil and biological resources. There are many things we can do to protect these resources *e.g.* reuse and recycle, educate common masses, conserve resources, and use renewable resources for energy production, planting trees.

Role of Government

In protecting the environmental resources, government can play very important role. The governments control and develop forests, dams, major irrigation system, power stations, railways, ports, roads, mines and industries of the country. The ministry of environment is entrusted with planning, protection and coordination of environment and forestry programmes. The ministry is involved in conservation and survey of flora, fauna, forests and wildlife, prevention and control of pollution, afforestation, and regeneration of degraded areas and protection of overall environments. The assessment of environmental impact prior to implementing any project which can damage environment is taken up by ministry of environment. To educate the people every year, earth day on 22nd of April and tree plantation week are observed. However, Government should take steps like protection of key ecosystems, promote small agricultural producers, promote green energy, protect wild life, ban on hunting, *etc.*

Extra Information

Tsunami Billion Tree Scheme was launched in 2014 by the Government of Khyber Pakhtunkhwa (KPK), Pakistan as a response to the challenge of global warming. This scheme restores 350000 hectares of forests and degraded land to suppress its Bonn challenge commitment.

Role of Non-Governmental Organizations (NGOs)

NGOs are playing a very important role in environmental protection and management and creating mass awareness towards environment. They have made people aware of the environmental problems, which are caused due to neglect and uncontrolled

exploitation of natural resources. Some of the NGOs are working for environmental awareness while some are working in research field. Pakistan is facing number of environmental problems like deforestation, air pollution, climate changes, pesticide misuse, and desertification. Pakistan is a developing country and government alone cannot tackle these problems efficiently, so NGOs should play their role to overcome these environmental issues.

Activity

Draw a concept map that shows how population grows. Include the following terms: exponential growth, logistic growth, birth rate, death rate, immigration, emigration. Add any other terms that you think are useful to complete the map.

Extra Reading Material

Control of Population Growth in Pakistan

The Ministry of Population Welfare, Government of Pakistan is responsible for the control of population growth in Pakistan. Population welfare program is an on-going program launched by the ministry of population of Pakistan since 1960. The first ever population policy in Pakistan was announced on 11th July, 2002. The population policy is wide in scope. It states a commitment to reduce the incidence of unwanted fertility, promote small family norm, make an investment in youthful population and focus on male involvement. The overall vision of population policy is to achieve population stabilization replacement level. A total fertility rate of 2:1 child per woman by 2020. Thus increase awareness of adverse consequences of rapid population growth at the national, provincial, district and community level. Promote family planning as an entitlement based on informed and voluntary choice and attain reduction in infertility.

Science, Technology and Society (STS)

Investigate the careers related to the study of environmental resources.

- Aquarium Director of Education
- Desert Ecologist
- Environmental Attorney
- Environmental Planner
- Environmental Organizing Consultant
- Forest Ranger
- Natural Resource Specialist
- Outdoor Adventure Educator
- State Park Resources Ecologist
- Wildlife Biologist
- Professor
- Ecologist

- Director in Antipollution Department
- Legal consultant
- Act of Wild Life
- Implication of Environment Acts
- Role of Forest and Forest Department
- International Union for Conversation of Nature (IUCN)
- World Wild Fund for Nature (WWF)

SUMMARY

- The flow of chemical elements and compounds between living organisms and their physical environment is known as biogeochemical cycle.
- A lot of energy is lost to the environment as food is transferred from one trophic level to the next.
- Nitrogen is the necessary element of some organic molecules such as protein and nucleic acid.
- The cycle of energy is based on the flow of energy through different trophic levels in an ecosystem.
- Productivity in ecosystem depends on temperature and moisture.
- The diagram that shows the relative amount of energy or matter or number of organisms within each trophic level in a food chain or food web is called pyramid.
- Ecological Succession is the gradual process by which ecosystem changes and develops over time.
- Population dynamics is the branch of life science concerned with the long term and short term changes in size, age and composition of population.
- The carrying capacity is defined as the maximum population size that a particular environment can support.
- Nuclear power is the release of nuclear energy to generate electricity and heat.
- Human activities have been affecting the environment for thousands of years.
- The amount of CO_2 is increasing in the air day by day.
- Acid rain or acid deposition is a broad term that includes any form of precipitation that contains acidic components.
- In the stratosphere, there is a group of commercially important compounds called chlorofluorocarbons.
- Non-renewable resources form at much slower than their environmental consumption.
- Pakistan is facing number of environmental problems like deforestation, air pollution, climate change, pesticides misuse, desertification, *etc.*

EXERCISE

SECTION-I: OBJECTIVE QUESTIONS

Multiple Choice Questions (MCQs)

1. Change in community structure of an ecosystem over a period of time:
   (a) Niche (b) Unstable ecosystem
   (c) Succession (d) Pioneer
2. Herbaceous stage in xerosere is the:
   (a) First stage (b) Third stage
   (c) Fourth stage (d) Last stage
3. The ozone layer has developed a hole over the:
   (a) Arctic (b) Equator
   (c) Antarctica (d) Tropics
4. As CFCs rise to the atmosphere, the ultraviolet rays release:
   (a) Fluorine (b) Chlorine
   (c) Carbon (d) Nitrogen
5. The group of organisms that fix atmospheric nitrogen are
   (a) Plants (b) Bacteria
   (c) Fungi (d) Insects
6. The producers of ecosystem are
   (a) Decomposers (b) Absorptive heterotrophs
   (c) Ingestive heterotrophs (d) Autotrophs
7. Ozone layer is found in
   (a) Troposphere (b) Stratosphere
   (c) Hydrosphere (d) Mesophere
8. The cause of greenhouse effect is
   (a) CO_2 (b) Hydrogen
   (c) Nitrogen (d) Oxygen
9. The graphical representation of ecological data of an ecosystem is called
   (a) Succession (b) Niche
   (c) Habitat (d) Pyramid
10. Which of these levels of ecological study involves both abiotic and biotic components
    (a) Organisms (b) Population
    (c) Ecosystem (d) Community

11. Which of the following is renewable resource?
(a) Oil and natural gas (b) Water and oil
(c) Air and water (d) Oil and coal

12. About 95% of our daily energy requirements are fulfilled by
(a) Atomic energy (b) Hydroelectric power
(c) Fossil fuel (d) Wind energy

13. The ozone molecule is made up of by building of three atoms of
(a) Nitrogen (b) Hydrogen
(c) Oxygen (d) Carbon

B. Fill in the Blanks.

1. Every organism must get nutrients for its .....
2. The water cycle is driven by ..... energy.
3. The total amount of solar energy which is fixed by the producers during photosynthesis is called .....
4. Ecological succession which begins in water is called .....
5. Increase in the number of individuals of a population is called ..... growth.
6. The maximum population size that a particular environment can store is called ..... capacity.
7. The energy resources that have been used from long time is called ..... source of energy.
8. Acid rain may fall hundreds of miles away from the source of .....
9. The Chernobyl disaster incidence took place on 26, April .....

SECTION-II: SHORT QUESTIONS

C. Give the short answers of the following questions.

1. Describe trophic level.
2. Define nitrification and role of bacteria in this process.
3. Differentiate between denitrification and nitrification.
4. Illustrate ecological pyramids.
5. Write the reasons why food chains are shorter?
6. Write some causes of acid rain.
7. Describe briefly greenhouse effect.
8. Differentiate between industrial and biological fixation of nitrogen.
9. Differentiate between hydrosere and xerosere.

10. Define the following terms.
    i) Aquifers
    ii) Net primary production
    iii) Climax community
11. Briefly describe role of NGOs to tackle environmental problems.
12. Differentiate between renewable and non-renewable energy resources.
13. Describe effects of ozone layer depletion.

SECTION-III: EXTENSIVE QUESTIONS

D. Give detailed answers of the following questions.

1. Describe water cycle.
2. Describe different components of ecosystem.
3. Define ecological pyramid and explain pyramid of energy biomass and number.
4. Define succession. Explain two types of ecological succession
5. Explain the characteristics of population dynamics?
6. Define nuclear energy and explain its advantages and disadvantages.
7. Define ozone layer and describe its composition, formation, role and causes of its depletion.
8. Differentiate between conventional and non-conventional energy resources, Discuss them in detail.
9. Explain different stages of xerosere succession.

UNIT 26

BIOTECHNOLOGY

Major Concept

26.1 Cloning of Genes
26.2 DNA Sequencing
26.3 DNA Analysis
26.4 Genome Maps
26.5 Tissue Culture
26.6 Transgenic Bacteria, Plants and animals
26.7 Biotechnology and Healthcare
26.8 Scope and importance of Biotechnology

Learning Outcomes

Students will be able to:

- Define gene cloning and state the steps in gene cloning.
- Describe the techniques of gene cloning through recombinant DNA technology.
- Explain the role of restriction endonucleases and DNA ligases in gene cloning.
- Describe the selection and isolation of the gene of interest.
- Explain the properties and the role of vectors in recombinant DNA technology.
- State the steps for the integration of DNA insert into the vector.
- Briefly state the technique applied for the selection of the vectors that take up the DNA insert.
- Describe the steps involved in gene amplification through polymerase chain reaction.
- Describe the procedure for the construction of genomic library.
- Explain the Maxam *I* Gilbert procedure and the Sanger-Coulson method of DNA sequencing.
- Describe the principles of Gel Electrophoresis as being used in gene sequencing.
- Introduce the automated DNA sequencing as based on the Sanger-Coulson method.
- Describe the purposes and mechanism of DNA analysis.
- Describe the terms of genome analysis, genome map and genetic markers.
- State the history of the human genome project admiring James Watson as its first director.
- Describe the goals of the human genome project.
- Predict some of the possible benefits that can be derived after the completion of the human genome project.
- Define following terms related to plant tissue culture; explants, callus, micro-propagation, plantlets, somatic embryogenesis, soma clonal variation.
- Explain tissue culture and differentiate between the organ culture and cell culture.
- Differentiate between the callus culture and suspension culture techniques.

- Describe the anther culture, ovary culture, meristem culture and embryo culture techniques.
- Briefly describe the techniques used for, applications and limitations of animal tissue culture.
- State the objectives of the production of transgenic bacteria, transgenic plants and transgenic animals.
- Describe different methods applied for the introduction of DNA into plant and animals cells / embryos.
- Describe the role of biotechnology in the production of insect, virus and herbicide resistant plants.
- State the notable human gene transfers in different animal species and describe their potential applications and future prospects.
- State the role of transgenic bacteria in making biotechnology products.
- List some of the ecological concerns surrounding transgenic bacteria.
- Describe the ways in which genetic engineering improves farm animals.
- Describe how biotechnologists are able to combat health problems by producing vaccines.
- State the role played by biotechnology in disease diagnosis (DNA/RNA probes, monoclonal antibodies).
- Describe what products biotechnologists obtain for use in disease treatment.
- Explain the current methods employed for gene therapy (*ex-vivo* and *in-vivo* methods).
- Explain with example gene therapies in the detection and treatment of some genetic diseases.
- Explain the role of successful gene therapy for cystic fibrosis.
- Explain the scope and importance of biotechnology in promoting human welfare.
- List the hazards and social/ethical implications of using gene technology in human.

Introduction

Biotechnology is any technique that uses living organisms to make products. As far back in recorded history as biblical times, biotechnology was used; *e.g.* yeast was used to bake bread and for the fermentation of wine and the production of cheese. In 1862, Louis Pasteur discovered that fermentation is caused by micro-organisms and is not an inorganic chemical process. The people became aware that they were using living things to make everyday products. Since Mendel's work was rediscovered in 1900, geneticists made startling advances which have led to new era of DNA technology. Modern techniques and technologies enable us to remove genes from one organism and insert them into another in order to produce desired substances, such as insulin, growth hormone, drugs and vaccines. This knowledge is being used to clean up environmental pollutants, kill insect pests, increase fertility of soil, *etc.*

Nowadays the field of biotechnology as has become a vast field, but this unit deals with a brief introduction of biotechnology, called **Genetic Engineering** (deals with manipulation or alteration in genetic material of an organism).

26.1 Cloning of Genes

Cloning of genes produces many identical copies (clones) of a single gene. The clones of genes are used in many chemical processes. There are two possible ways of cloning of gene *i.e.* recombinant DNA technology and polymerase chain reaction (PCR). The recombinant DNA technology is used when a very large quantity of a gene is required while PCR is used to create an optimum number of copies within a laboratory in a test tube.

26.1.1 Gene Cloning through Recombinant DNA Technology

Recombinant DNA technology is popularly known as genetic engineering, which is a series of procedures that are used to join together (recombine) two or more segments of DNA from different sources. The recombinant DNA (rDNA) is also called **Chimeric DNA**.

Cloning

It is a technique for developing a large number of genes, identical cells, tissues or organisms.

In order to produce recombinant DNA, following components are required:

- To get gene of interest (desired gene), which is to be cloned.
- **Molecular scissors (restriction endonuclease)** to cut out the gene of interest.
- Vector or molecular carriers are needed to carry gene of interest.
- The enzyme (ligase), which is responsible for the formation of phosphodiester linkage between two adjacent nucleotides.
- Expression system, (such as bacteria) in which gene of interest along with vector is inserted, to get large number of desired genes or specific chemical products.

26.1.2 Role of Molecular Scissors and DNA Ligase

Molecular scissors are also called **restriction endonucleases**. These natural enzymes of bacteria were first isolated by **Hamilton D. Smith** (1970), at **John Hopkin University** in Baltimore, Maryland, USA. He observed that this enzyme has property to cut the DNA of virus to prevent replication of viral DNA in bacteria, different species of bacteria produce different restriction endonucleases, which cut the DNA at very specific sequence of **four to eight nucleotides** arranged symmetrically in reverse order. Such sequences are called **palindromic sequence** and their cutting points are called **restriction site**. So far over **3,000 restriction enzymes** have been studied in detail and more than 600 of these are available commercially (230 different DNA sequences). These enzymes are routinely used for DNA modification in laboratories, and they are a vital tool in molecular cloning, twenty enzymes are frequently used in recombinant DNA technology. (Fig.26.1)

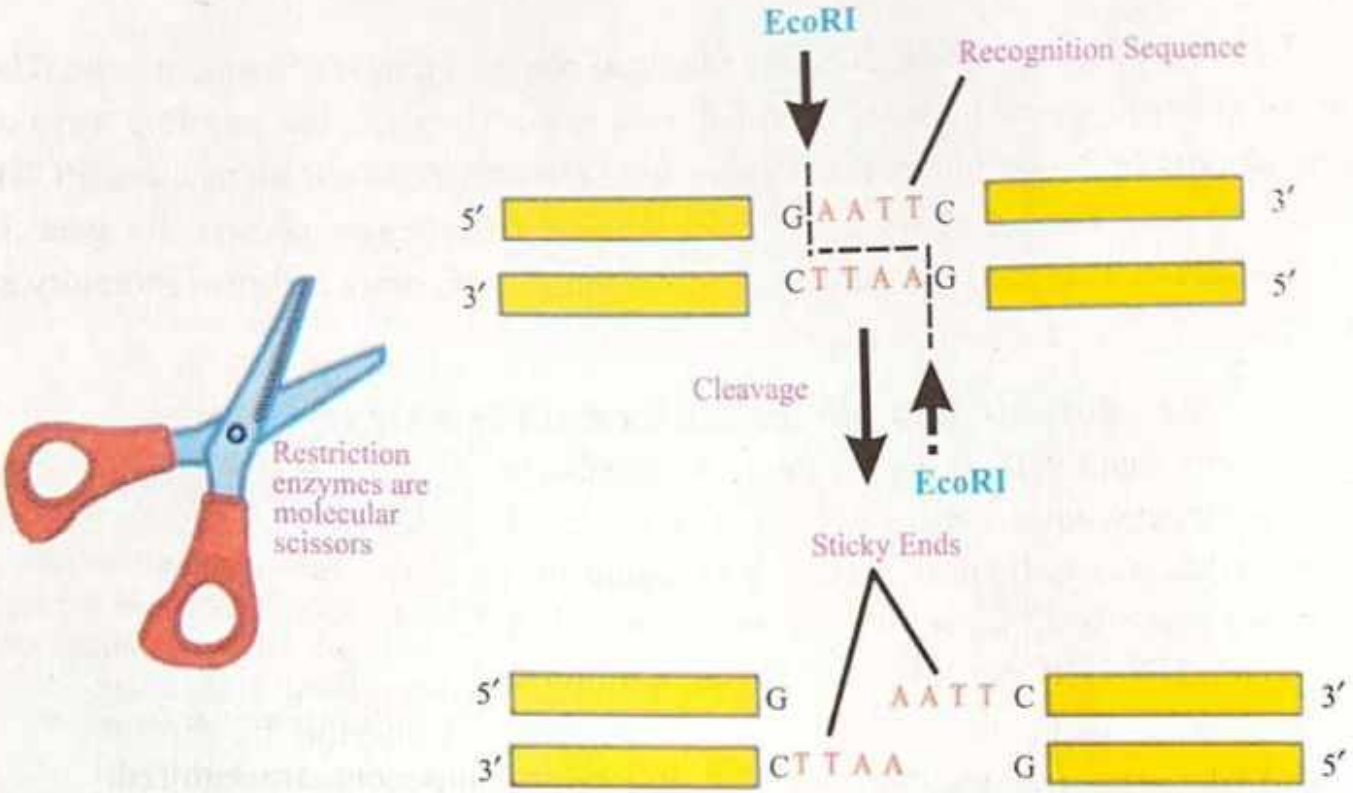


Fig. 26.1: Molecular Scissors

EcoRI (isolated from ***Escherichia coli***) is most commonly used restriction enzyme, which cut double stranded DNA into single stranded complementary ends, whose palindromic sequence has (AATT) bases at the cleavage site.

The complementary ends of the two DNA molecules are called **sticky ends** (a staggered cut) because these can bind by complementary base pairing. Thus foreign DNA with same palindromic sequence is easily inserted into vector DNA.

Extra Information

Restriction enzymes are named after their host of origin. *e.g.* xhal from Xanthomonas holcicola, hind II and III from Haemophilus influenzae.

Gene of Interest

The desired genes can be acquired by three possible ways.

- Genes can be isolated from the chromosomes by cutting the chromosomes on the flanking sites of the gene. For this purpose, restriction endonucleases are used. (These enzymes are obtained from bacteria, which they use for their own protection against viruses. The restriction enzyme cut down the viral DNA, but does not harm to the bacterial chromosome).
- The gene of interest can also be synthesized in the laboratory from mRNA, using reverse transcriptase, which are naturally found in retro viruses. This DNA molecule (gene) is called complementary DNA (cDNA).
- If the genes of interest are small, then they can be synthesized artificially by a

machine called DNA synthesizer. This machine can create specific DNA molecules of desired sequence of nucleotides.

Role of Molecular Carriers or Vectors

Vectors are another major component required to make a rDNA molecule for gene cloning. It acts as a vehicle for carrying foreign DNA into a host cell for multiplication. One common type of vector is a **plasmid** (small extra chromosomal circular DNA molecules in bacteria, contain genes for antibiotic resistance and fertility, *etc.*). The commonly used vectors are plasmids, **Lambda phage** DNA), yeast artificial chromosomes (YACs), bacterial artificial chromosomes (BACs).

DNA Ligase: It acts as **molecular glue** that assists to seal the foreign pieces of DNA into the vector to form recombinant or chimeric DNA. The complimentary ends of two DNA molecules are joined by hydrogen bonding and ligase is responsible for the formation of the phosphodiester linkage between adjacent nucleotides.

Expression of Recombinant DNA / Expression system

The most suitable organism which acts as vector to multiply and express the recombinant DNA, is bacteria, because they have short generation time and simplicity of its genetic system. The bacterial cells easily take up recombinant plasmid, especially if they are treated with calcium chloride to make them more permeable. Therefore, as the bacterium reproduces, each daughter bacterium contains the gene of interest, which will express itself and make a product *e.g. Agrobacterium, tumefaciens*.

Steps for creation of Recombinant DNA (Plasmid)

The simplified steps outlining how to create a recombinant DNA and

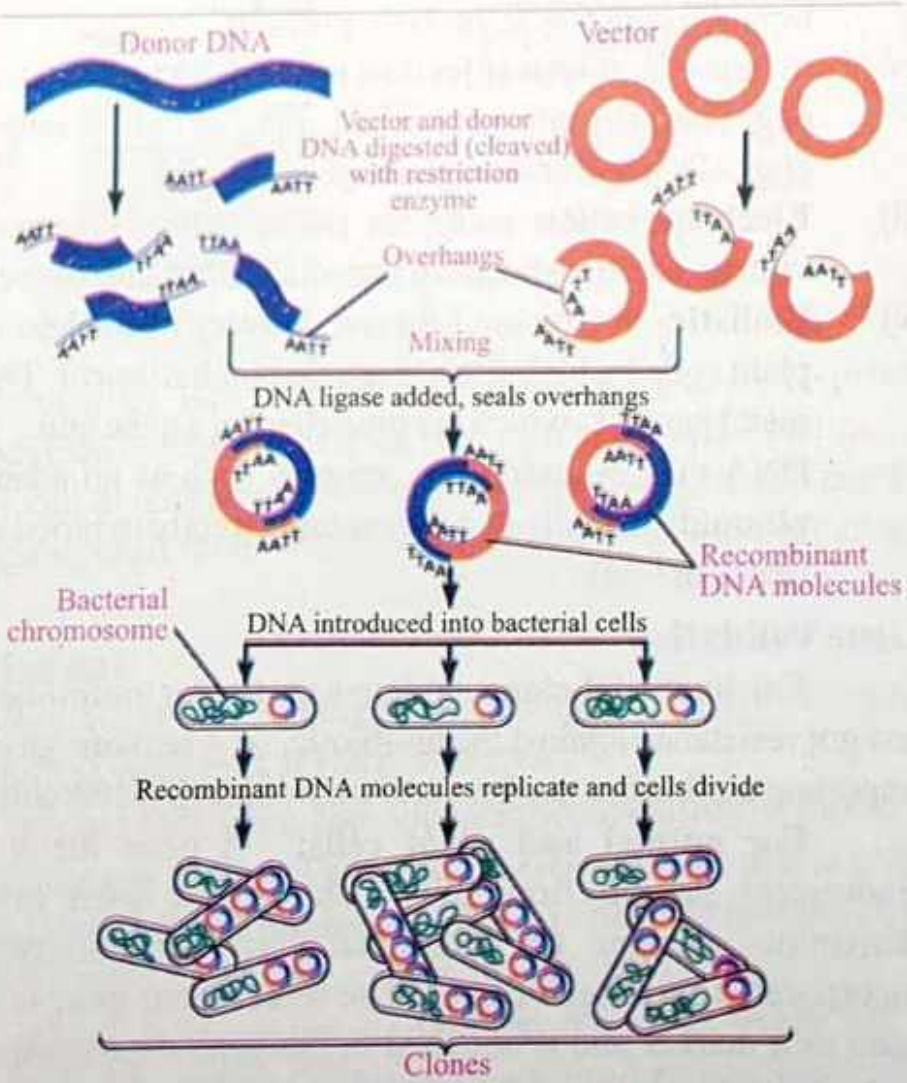


Fig.26.2: Formation of Recombinant DNA in Bacteria

transgenic species is cut, copy and paste.

1. **Cut:** A gene of interest is removed from the cell of an organism, using molecular scissors.
2. **Copy:** Now multiple copies are made (known as gene cloning). This step is usually carried in bacteria (some time phage) *e.g. Escheria coli* is the regulating system.
3. **Paste:** The genes are inserted (Pasted) into a bacterium or an egg cell or a plant cell of another species. And (after fertilization in case of animal) become part of the newly formed transgenic organism's DNA.
4. The transgenic organism develops into a mature organism with the new gene "Switched on" to function. (Fig.26.2)

Transformation of Expressing system/ Gene delivery Techniques

i) **Agrobacterium mediated transformation** take up recombinant plasmid, especially, if they are treated with calcium chloride to make them more permeable. Thereafter, as the cell reproduces, a bacterium clone forms and each new cell contains at least one plasmid.

ii) In animals, **micro-injection of DNA** directly injects DNA into the nucleus of an egg. This is usually performed under an optical microscope to introduce DNA into egg cells when creating transgenic species.

iii) **Electroporation** increases the membrane permeability by applying a high-voltage electric shocks to introduce DNA into the cells.

iv) **Biolistics** is a method for the delivery of nucleic acid (recombinant genes) into plant cells by high speed particle bombardment. The technique uses DNA-coated metal particles which are propelled by a gene gun.

v) DNA may be carried by **vectors** such as an adenovirus, liposome or bacterial plasmid into cells. It either enters directly to blood or may be delivered by aerosol (nasal or oral).

Gene Validation

For bacterial clone, adding a particular antibiotic to transformed clone, if clone has got resistance against the antibiotic, so it remains alive and continues to grow, some important antibiotics markers are Ampiciline, Kalamycine, Streptomycine, *etc.*

For animal and plant cells: A gene for a fluorescent protein from jelly fish is now used to determine whether an individual has successfully incorporated a transgenic gene. The **fluorescent gene** is used as a marker and is attached to the gene of interest that will be inserted into prospective transgenic

Liposomes are minute spherical sacs of molecule enclosing water droplet, carrying genes or drugs.

organism. Thus resulting offspring (cell) gives fluorescence under certain lightening conditions.

26.1.3 Polymerase Chain Reaction (PCR)

The Polymerase Chain Reaction "PCR" is a type of reaction which can create millions of copies of a single gene or any specific small piece of DNA quickly in a test tube. (Fig.26.3)

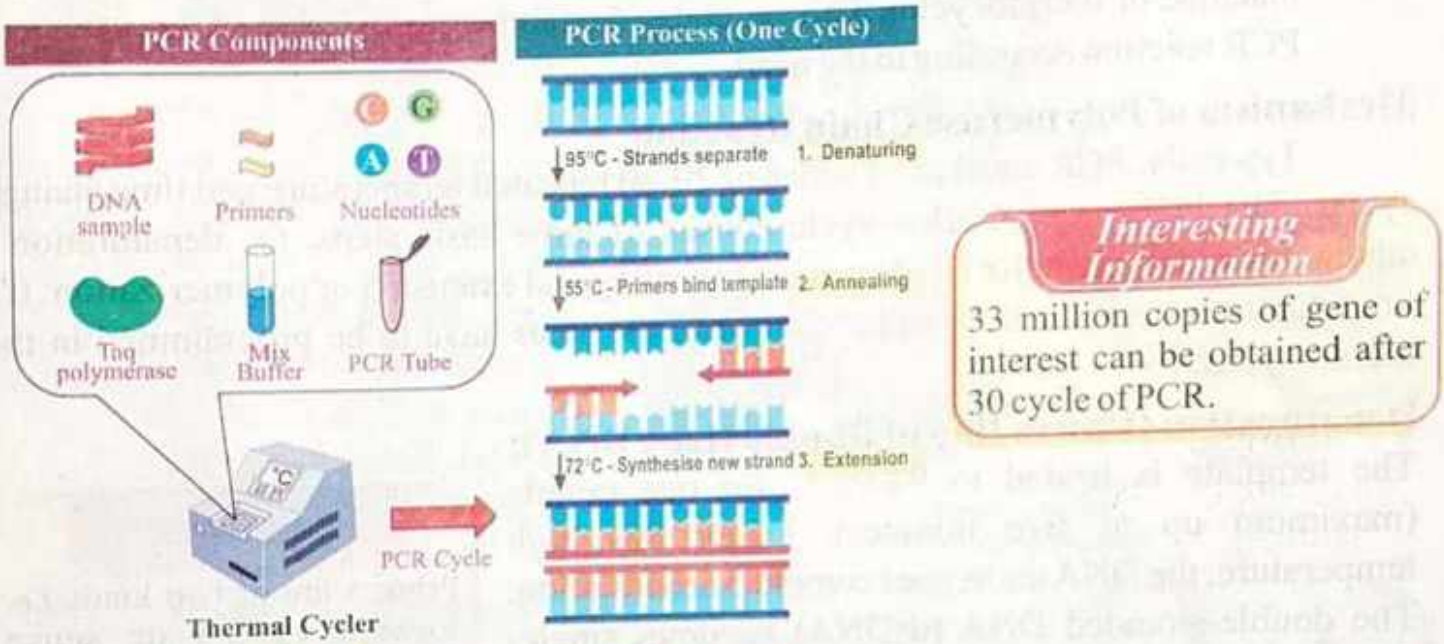


Fig. 26.3: Polymerase Chain Reaction

It was originally invented by **Kary Mullis** in 1983, who got noble prize in chemistry in 1993. It is based upon *in vitro* replication process. PCR takes its name from DNA replication enzyme in a cell. It is a chain reaction because polymerase will carry out replication over and over again, until there are millions of copies of the desired gene (DNA).

Components of PCR Technique

The components, required for PCR technique are template DNA, deoxyribo-nucleoside triphosphates (dNTPs), primers and Taq polymerase.

i) **Template DNA or Target DNA** is a copy of specific DNA from a mixture of DNA molecules which is to be copied. The template DNA may be useful gene or piece of DNA of infected organisms or pieces of DNA to be used for DNA finger printing.

ii) **Deoxyribo-Nucleoside triphosphates (dNTPs)** are four types of free nucleotides *i.e.* dATP, dGTP, dTTP, dCTP which are used as raw material for replication of new DNA pieces.

iii) **Primers:** Before carrying out PCR, primers sequence of about 15-20 bases are needed because DNA polymerase does not start the replication process. These primers are complementary to the base on either side of the target DNA.

iv) **Taq Polymerase:** The basic components required to copy template DNA is **thermocycler** and temperature tolerant (thermostable) enzyme. This enzyme is extracted from the bacterium ***Thermus aquaticus*** which lives in hot springs, it can withstand high temperature up to 115C. PCR is done in an automatic PCR machine or thermocycler. This regulates the temperature during various steps of PCR reaction according to the need.

Mechanism of Polymerase Chain Reaction

Typically, PCR consists of series of 20-40 repeated temperature and time change cycles. The PCR amplification cycle consist of three basic steps, *i.e.* denaturation / unwinding of double helix DNA, primer annealing and extension or polymerization. It's time duration, temperatures and sequence of the steps have to be programmed in the thermocycler.

Denaturation (Unwinding of Double Helix DNA):

The template is heated to 94-95°C for one minute (maximum up to five minutes). Under this high temperature, the DNA undergoes complete denaturation. The double-stranded DNA (dsDNA) becomes single-stranded (ssDNA). Thus each single ssDNA can act as the template for the *in vitro* DNA synthesis.

Interesting Information

Primers are of two kinds *i.e.* forward (3′-5′) or sense primers. Reverse primer (5′-3′) or Anti sense primer.

Primer annealing (Hybridize): In this step the two primers, the forward primers (3′-5′) and the backward primers (5′-3′), anneal or hybridize to the single-stranded template DNA at its complementary regions. This step is usually carried out at a lower temperature depending on the length and sequence of the primers. (In standard case 54-55°C) for approximately 1-2 minutes.

Interesting Information

Polymerase chain reaction is the reaction which is used for production of number of desired gene copies within test tube.

Extension of Polymerization

It is final step of PCR, in which the Taq DNA polymerase synthesizes new DNA strands to the 3′ ends of primers using dNTPs. The optimum temperature for carrying out the primer extension reaction or polymerization of dNTPs is standardized at 72°C and take one minute to be completed.

At the end of first cycle one target DNA molecule is converted into two daughter molecules. The second cycle immediately starts with the denaturation by heating at 94°C.

As a result all the newly synthesized. DNA are also denatured to single strands, which again act as templates. It will again be followed by the primer annealing and extension continues resulting in the amplification of the selected DNA sequence at an exponential rate *i.e.* the number of existing DNA molecules become doubled after each cycle.

The Application of Polymerase Chain Reaction

- To diagnose viral infections, genetic disorders and cancer.
- To identify criminals in forensic laboratories (DNA finger Printing).
- To determine the evolutionary history of human population. It has been possible to sequence DNA taken from a 76,000 year's old **mummified human brain** and from a 17 to 20 million years old plant fossil following PCR amplification.
- Detection of micro-organisms in food samples, water and in the environment with the help of species-specific primers.
- Reactions substances for DNA sequencing.

26.1.4 Genomic Library

A **genome** is a full set of genes or chromosomes of an individual. (Fig.26.4)

Genomic Library

A genomic library is a collection of bacterial or bacteriophage clones, each clone containing a particular

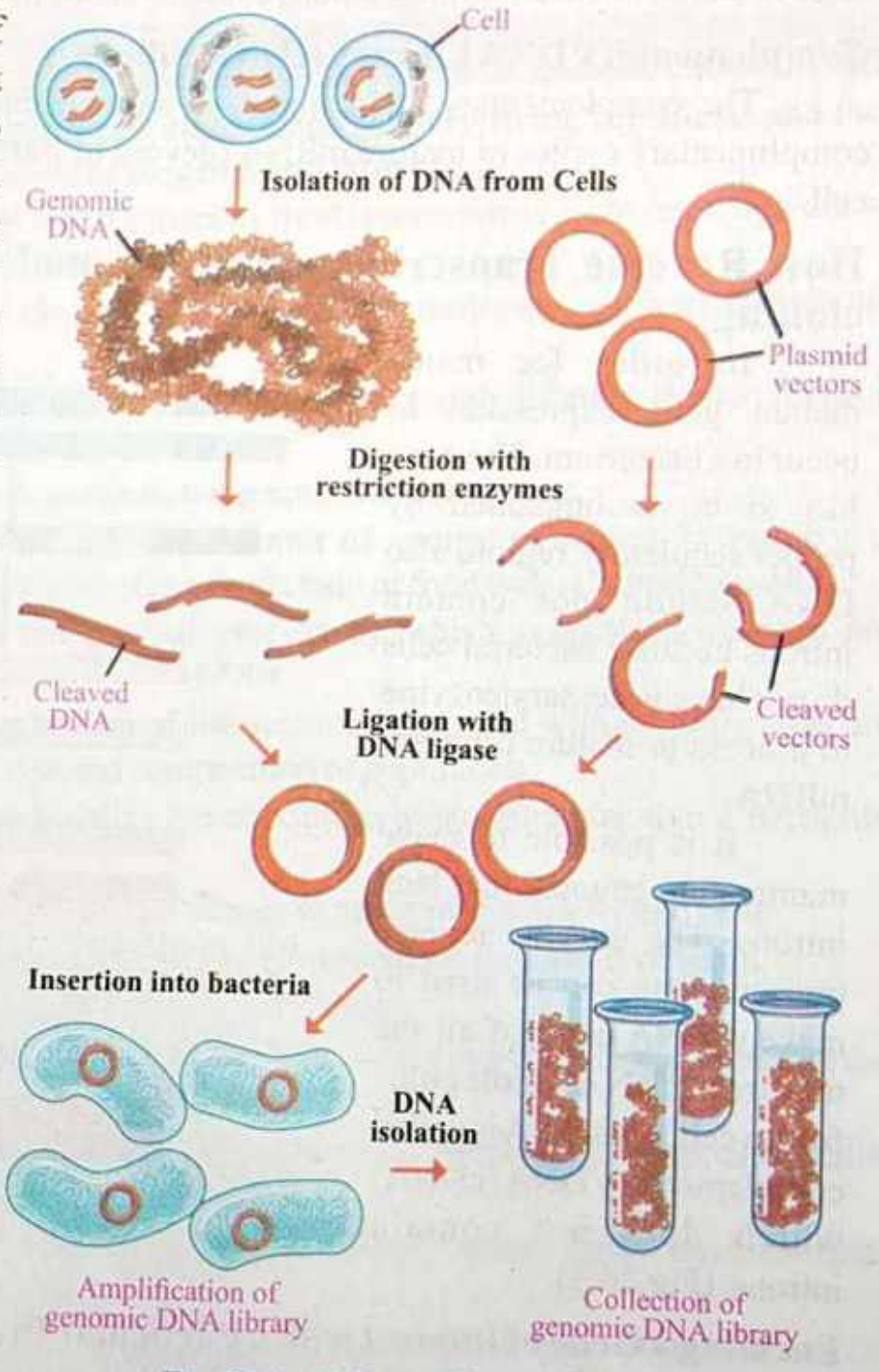


Fig. 26.4: Making a Genomic Library

segment of DNA from the source cell. The collection of genomic libraries of different organisms is called **gene bank**.

Making a Genomic Library

For making a genomic library, an organism's DNA is simply sliced into pieces by a molecular scissor and pieces are put into vectors (cut with the same molecular scissor *i.e.* plasmids or viruses) that are taken up by host bacteria. The ligase enzyme connects DNA pieces which is now called recombinant DNA. The entire collection of these bacterial or bacteriophage clones contains all the genes of that organism.

Complementary DNA Library (cDNA Library)

The complementary DNA library is the collection of clone of DNA, which is complimentary copies of mature mRNA (devoid of introns) separated from a particular cell.

How Reverse Transcriptase helps to make Mammalian Gene for cloning

In order for mammalian gene expression to occur in a bacterium. The gene has to be accompanied by proper regulatory region, also DNA should not contain introns because bacterial cells do not have necessary enzyme to process or mature prim-ary mRNA.

It is possible to make mammalian genome that lack introns. The enzyme reverse transcript-ase can be used to make a DNA copy of all the mature mRNA molecules from a cell. This DNA is called complementary DNA (cDNA) which does not contain introns. (Fig.26.5)

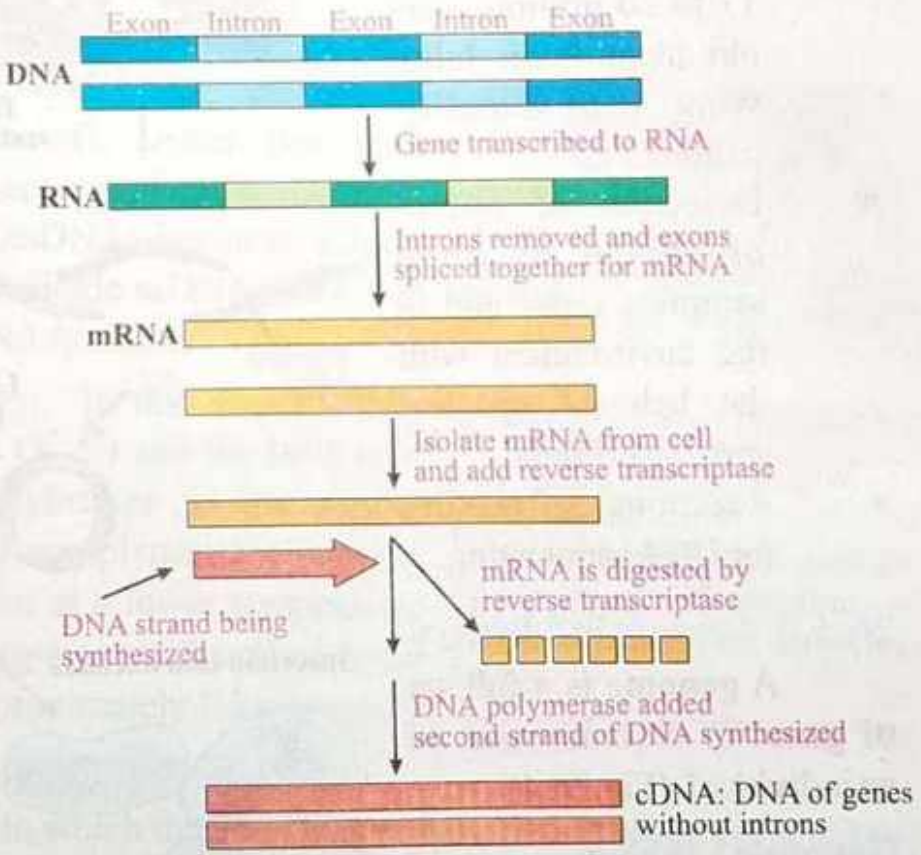


Fig. 26.5: Formation of cDNA

Locating a Gene of Interest with a Particular Probe

A **particular probe** is a single stranded nucleotide sequence that will hybridize

(pair) into a certain piece of DNA, it is used to search a genetic library for a certain gene.

Location of the probe is possible because the probe is either radioactive isotopes of phosphorous or fluorescent dye. To search gene from genomic library, following steps are taken.

- Bacterial cells, each carrying a particular DNA fragment, can be plated onto agar in a petri dish.
- Now probe is placed on these petridishes, probe is made of nine or more nucleotides.
- The probe hybridizes (form pairing) into the gene of interest.
- The genes can be isolated from the fragment.
- Now this particular fragment can be cloned further or even analyzed for its particular DNA sequence.

26.2 DNA Sequencing

DNA sequencing is the process of determining the order of the four chemical building blocks known as "bases" that make up the DNA molecule. The sequence tells scientist the kind of genetic information that is carried in a particular segment.
One of the important tools used in various DNA sequencing techniques is gel electrophoresis.

26.2.1 Gel Electrophoresis

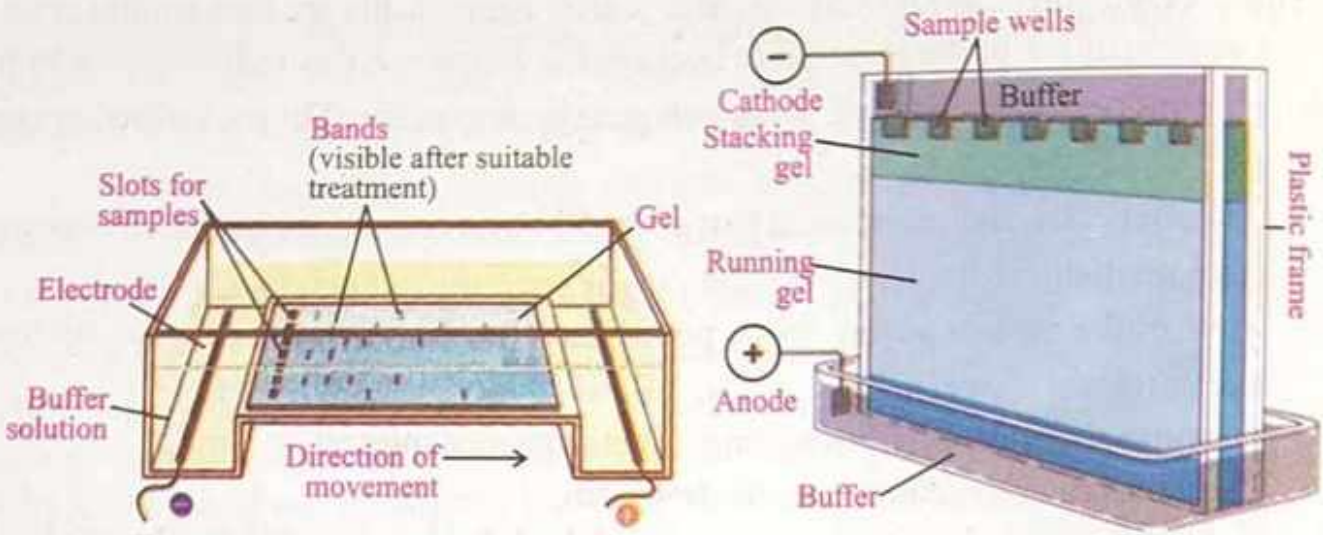
This laboratory technique is used to separate fragments of DNA, RNA and proteins in an effort to identify its origin.

Enzymes are used to chop up the long filaments of DNA into varying size of fragments. The DNA fragments are placed into small wells (holes) in the gel made of agarose or polyacrylamide, which are aligned along one end.

Interesting Information

Agarose is used for relatively large DNA molecules (more than 50 nucleotides) and **poly acrylamides** for high resolution of short DNA fragments (less than 50 nucleotides).

The gel is exposed to an electric current, positive on one side and negative on the other. DNA fragment travel is inversely proportional to its length. The effect is that the biggest, heaviest, and light charged particles do not move easily through the gel. They get stuck very close to the wells they were in at the beginning and most charged particles pass through the gel to the other side with less difficulty. Intermediate particles are distributed in between. In the end, the fragments of the different size leave a banded pattern of DNA on the gel. (Fig.26.6)



Horizontal Gel Electrophoresis *Vertical Gel Electrophoresis*

Fig.26.6:

Visualization of Fragments

To visualize DNA fragments, the gel can be stained by DNA binding florescent dyes that bind to the DNA molecules and are typically viewed under ultraviolet trans-illuminator. DNA bands can also be transferred from gel to nitrocellulose membrane for auto radiography (x-ray imaging).

Now we can observe that some bands are appeared thick and some are thin. The thick represent the high concentration of same size fragments where as thin bands exhibit low concentration. If a particular sized fragment is to be used for further analysis then the piece of gel containing that band can be cut and its DNA can be purified again.

26.2.2 DNA sequencing Techniques

In the late 1970s, methods were developing that allowed the nucleotide sequence any purified DNA fragment to be determined simply and quickly. These methods are based upon three steps.

i) To generate piece of DNA of different sizes. All starting from the same point and ending at different point.

ii) Separation of these different pieces of DNA on agarose gel.

iii) Reading of sequence from the gel.

26.2.3 Methods of DNA sequencing

Three methods are generally used to generate DNA fragments (which are of different sized).

i) Sanger-Coulson Method

ii) Maxam Gilbert Method

iii) Automated DNA Sequencing / Next generation sequencing

i) Sanger-Coulson Method / Dideoxy method

In this method **dideoxyribonucleoside triphosphates (dd NTP's)** are used to terminate DNA synthesis at different sites. Therefore, this method is also called as dideoxy method. (Fig.26.7)

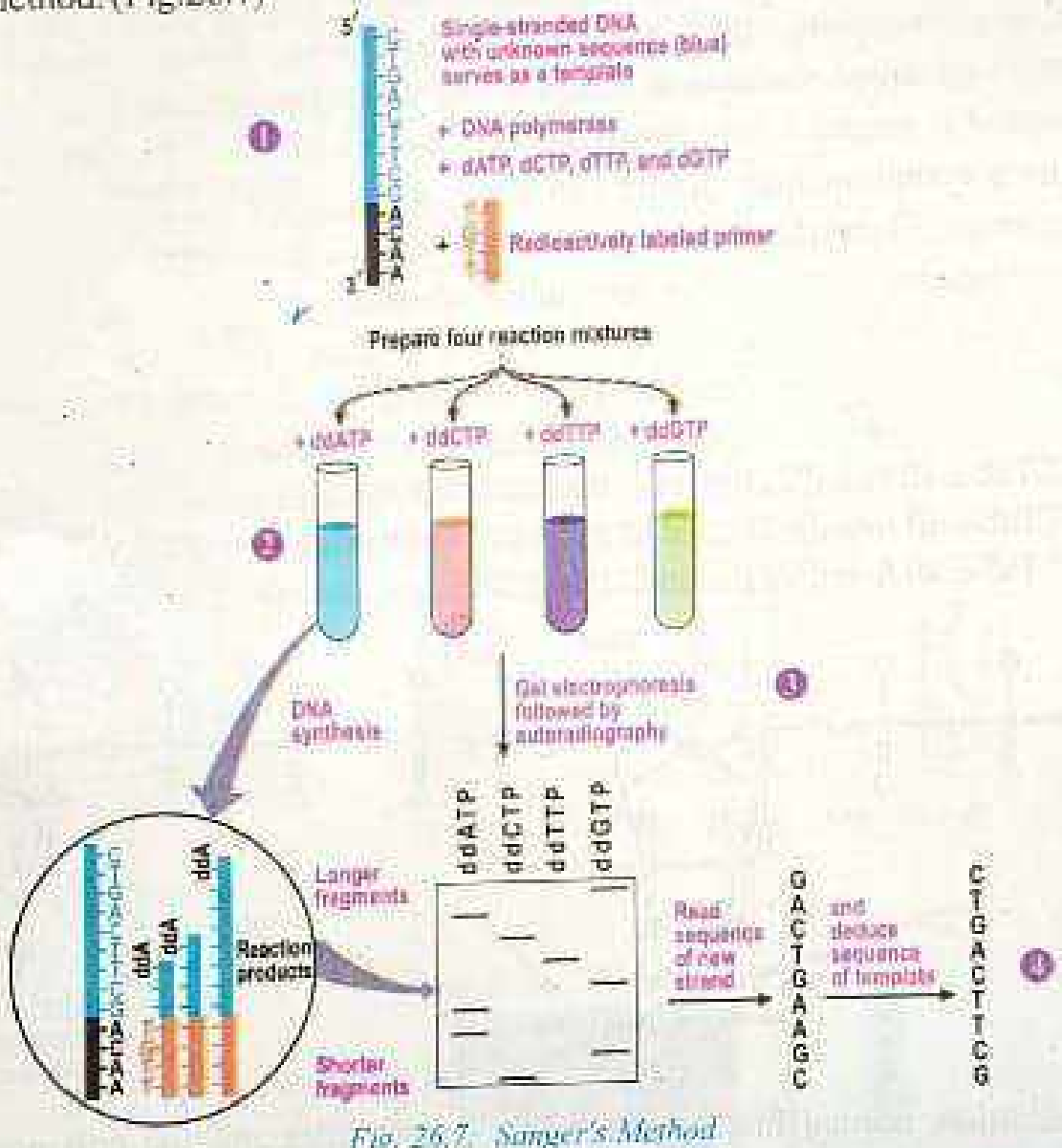


Fig. 26.7 Sanger's Method

It was developed by Frederick Sanger along with Andrew Coulson in 1977. They were awarded Nobel Prize in 1980 on this achievement. Sanger's method now has become the standard because of its practicality thus called Sanger's method. Sanger method is widely used and similar to the natural process of DNA synthesis.

Procedure:- The modified dideoxyribonucleotides are used which are same as deoxyribonucleotides except, they contain a hydrogen group on the 3′ carbon instead of a hydroxyl group (OH^-). When dideoxyribonucleotide integrated to sequence, it prevents

the addition of further nucleotides. This occurs because a phosphodiester bond cannot form between dideoxynucleotides and the next incoming nucleotides. Therefore, the DNA chain is terminated and replication ceased. For the sequencing of DNA, their double strand has to be denatured into single strands, using heat because only one strand that acts as template. Now the template strand is tagged with a known sequence at 3′ end, so that a complimentary primer can bind on the known sequence. Once the primer is attached to the DNA, the solution is divided into four tubes labelled "G", "A", "T" and "C".

Dideoxyribonucleotide triphosphate

Is a chain terminating precursor of DNA synthesis that block further polymerization when added to the end of DNA strand by DNA polymerase. These nucleotides lack 3′-OH⁻ hydroxyl group necessary for continued 5′-3′ DNA synthesis.

Then reagents are added to these samples as follows:

"G" Tube: all four dNTP's, ddGTP and DNA polymerase

"A" Tube: all four dNTP's, ddATP and DNA polymerase

"T" Tube: all four dNTP's, ddTTP and DNA polymerase

"C" Tube: all four dNTP's, ddCTP and DNA polymerase

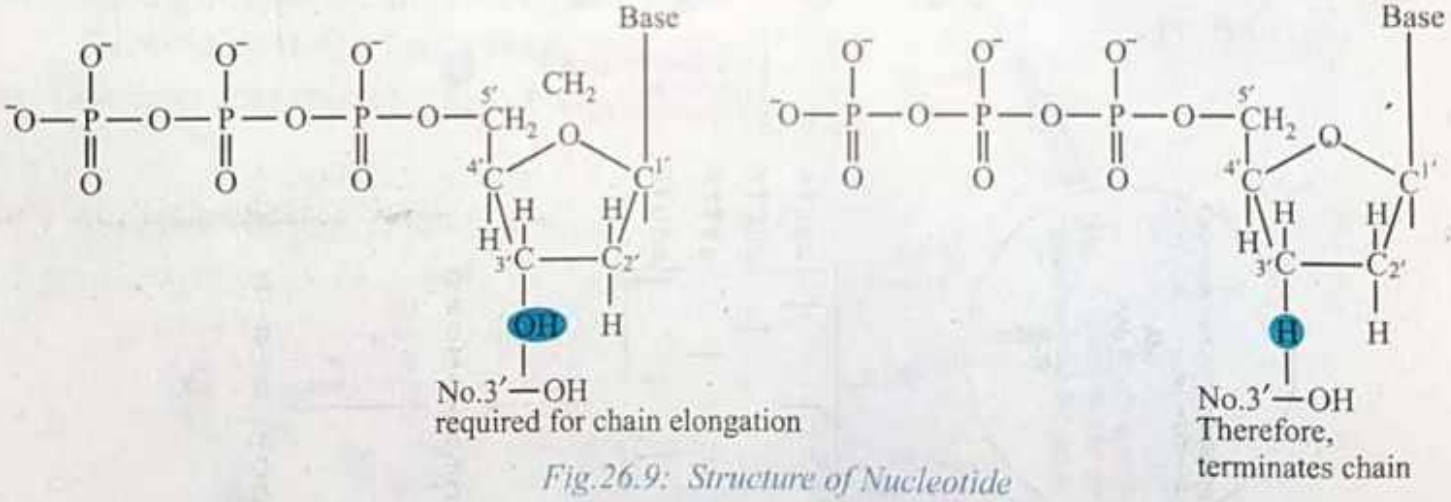


Fig.26.9: Structure of Nucleotide

In addition, normal free A, T, G, and C nucleotides and Taq polymerases are dissolved in these tubes. Now all tubes are placed in PCR machine so that sequencing reaction can start. As the DNA is synthesized, nucleotides are added on to the growing chain by the DNA polymerase. However, on this occasion a dideoxynucleotide is incorporated into the chain in place of a normal nucleotide, which results in a chain terminating event. For example, if the tube is containing ddTTP then only those fragments will be produced that will terminate on "T", same mechanism takes place in other tubes.

Importance: - The key to this method is that all the reactions start from the same

nucleotide and end with a specific base. Thus in a solution where the same chain of DNA is being synthesized over and over again, the new chain will terminate at all positions where the nucleotide has the potential to be added because of the integration of the dideoxynucleotides. In this way, bands of all different lengths are produced. Once these reactions are completed, the DNA is once again denatured in preparation for electrophoresis. The contents of each of the four tubes are run in separate lanes on a polyacrylamide gel in order to separate the different sized bands from one another. After the contents have been run across the gel, the gel is then exposed to either UV light or X-rays, depending on the method used for labelling the DNA.

ii) Maxam-Gilbert Method

This DNA sequencing method was developed by Allan Maxam and Walter Gilbert (1976-77). It is also known as chemical cleavage method because it is based on chemical modification of DNA and subsequent cleavage at specific bases.

Procedure: - The DNA to be sequenced must denature so that the two strands can be separated from each other, one strand is purified and divided into four samples (G, A + G, T + C and C). Each sample is treated with one of the modified chemical reagents and cleavage reagents. The former cause a chemical modification in the nucleotides they are

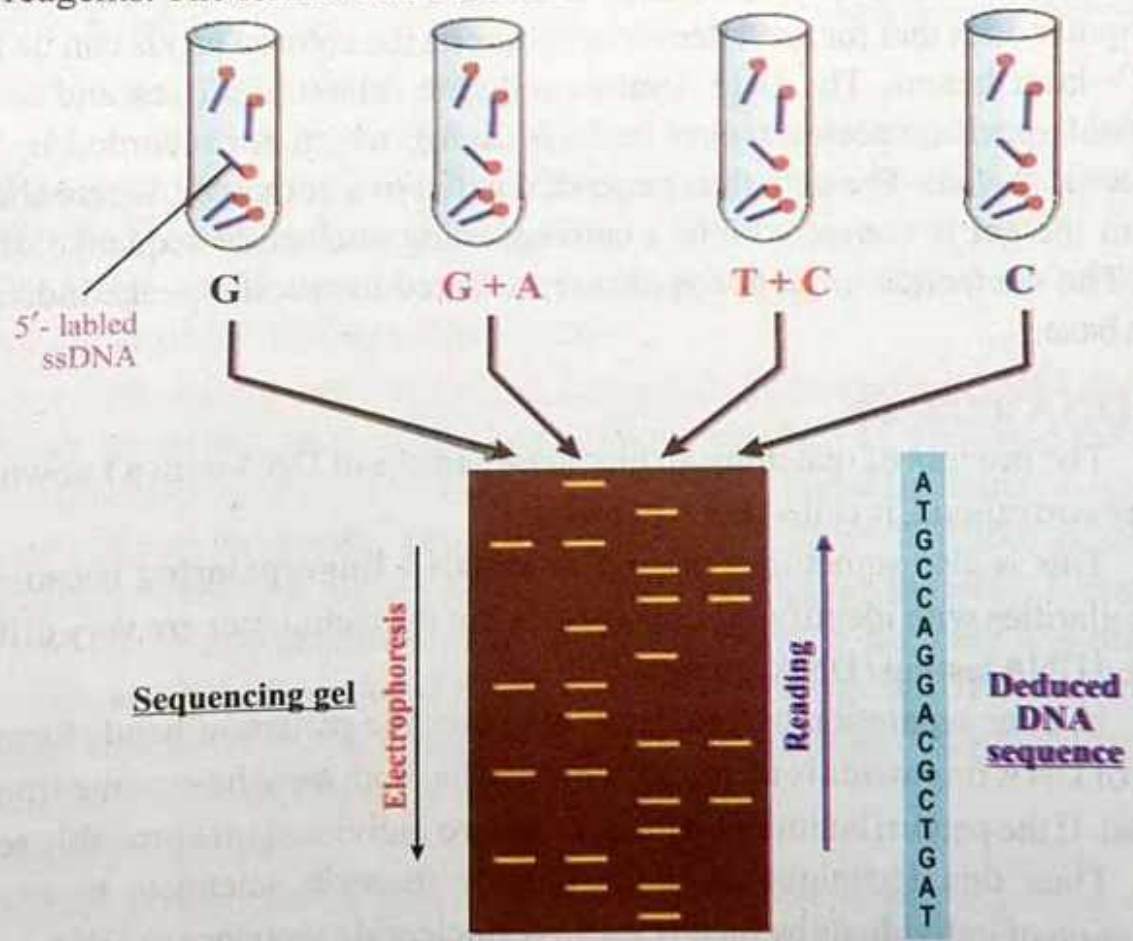


Fig.26.8: Maxam Gilbert DNA Sequencing Method

specific for, making them susceptible to cleavage while the later are used to cut DNA strand at specific point. For example, in the sample "G" the unknown DNA fragment will be cleaved from all those points where G is present. Similarly, in sample "A+G" the fragment will be cleaved from A as well as from G and so on. In other samples when all chemical reactions are completed then the products are run through gel electrophoresis and finally the sequence is read from autoradiograph of gel pattern. (Fig.26.8)

iii) Automated DNA Sequencing

Automatic sequencing machines have greatly improved the quality as well as the speed of the sequencing process. The basic principal of sequencing is quite same in manual and automated DNA sequencing except few differences.

There is no need for radiolabelling and autoradiography. The use of fluorescently labelled ddNTPs (dideoxynucleotide triphosphate) has made the reading very easy, convenient, and automatic with the help of UV laser detectors. Thus, it has greatly improved the speed of sequencing. Each of the four types of ddNTPs can be labelled with a specific dye, so that a specific color can be attributed to the presence of a particular nucleotide or base.

After electrophoresis, we don't even have to 'read' the sequence from the gel. The computer does that for us. After electrophoresis the colored bands can be monitored using UV-laser beams. The laser beams excite the fluorescent dyes and result in the emission of specific spectral waves (colored light), which are recorded by a specific photoelectric device. The data thus generated is fed to a computer, where the emission data from the gel is converted into a corresponding nucleotide sequence of the DNA sample. The nucleotide sequence is also represented in specific peaks indicating each nitrogen base.

26.3 DNA analysis

The process of matching an unknown sample of DNA with a known sample to see if they correspond, is called **DNA profiling**.

This is also sometimes referred to as **DNA fingerprinting** because there are some similarities with identifying fingerprints, but the techniques are very different (it is also called DNA testing / DNA typing).

If, after separation by gel electrophoresis, the pattern of bands formed by two samples of DNA fragments is identical, it means that both must have come from the same individual. If the pattern is similar, it means that two individuals are probably related.

Thus this technique is employed by forensic scientists to assist in the identification of individuals by their respective nucleotide sequence of DNA.

First DNA fingerprint was made by **Alec Jeffrey**, an English geneticist 1985.

26.3.1 Use/ Applications/ Purposes of DNA Analysis

- DNA fingerprinting can be used in paternity suits when the identity of someone's biological father needs to be known for legal reasons.
- At crime scene, forensics specialists can collect samples such as blood or semen, which contain DNA.
- To identify crime and catastrophe victims.
- To match organ donors with recipients in transplant programs.
- To detect bacteria and other microorganisms that pollute water, air, food, soil.
- Establishment of paternity and other family relationships.

26.3.2 Procedure/ Mechanism of DNA Analysis

There are many procedures that can be used for DNA analysis. One of the most important methods is restriction fragment length polymorphism (RFLPs). The RFLPs (pronounced as Riflips) refers to different sized fragments of DNA produced by a particular restriction enzyme. Following are the key steps of DNA analysis/DNA fingerprinting.

Extra Information

Human share about 98% of their genes with chimpanzees, 92% with mice, 76% with Zebrafish, 51% with fruit fly and 18% with E. coli bacteria.

1. Collection of DNA Samples

A very small fraction of DNA is sufficient for analysis because it can be copied for several times with the help of PCR. Thus DNA can be collected even from a drop of blood or cell of single hair root, or from single sperm.

The DNA samples can be collected from mummified organisms or from fossils when evolutionary relationship has to be studied.

Placement of Randomised Fragment Length Polymorphism (RFLPs)

As we know that every person has a unique set of RFLPs because the restriction site of a particular enzyme is always different in number and distribution in all human on earth except the monozygotic twins. Therefore, RFLPs of any two persons, when compared, one can easily analyze their individuality. However, the entire human has 99% similarity in nucleotide sequence of their genomes, this is the only 1% difference in genome sequence that establishes the individuality of every person. Placement of RFLPs is the digestion of DNA samples by a particular restriction enzyme, which produces a set of different sized DNA fragments (RFLPs).

Separations of RFLPs

The DNA fragments are then **electrophoresed** on two types of gel. An **agarose gel** to separate them by size. The mixture of RFLPs is loaded in **polyacrylamide gel** and run for electrophoresis. Fragments of various lengths begin to move at different rates from

negative to positive pole within the gel. When the movement is stopped, the gel is proceeded for further treatments in order to observe banding pattern.

Southern Blotting

This method was invented by British biologist Edwin southern. A southern blot is a method routinely used in molecular biology for detection of a specific DNA sequence in DNA samples. Southern blotting is the combination of two types *i.e.* transfer of electrophoresis-separated DNA fragments to a filter membrane and subsequent fragment detection by probe hybridization. (Fig.26.10)

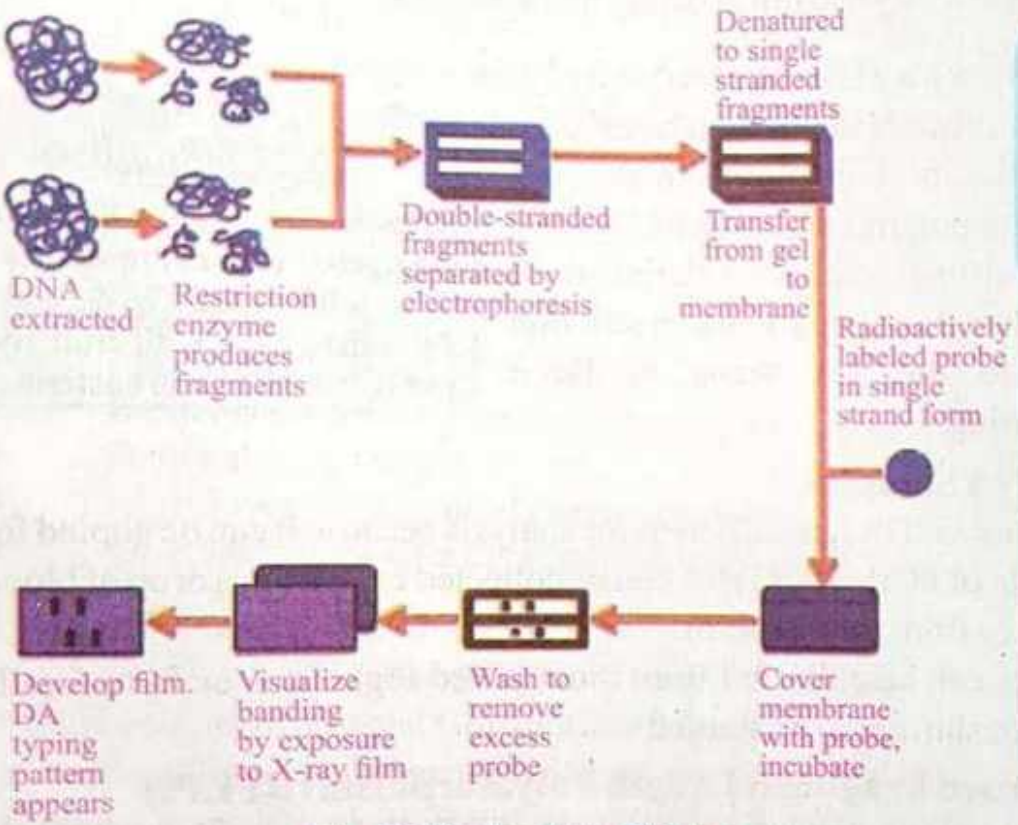


Fig. 26.10: Southern Blotting

Extra Information

The human genome is like a book" which contains 23 units (*i.e.* each unit is chromosomes), each unit possesses several thousand stories (*i.e.* genes). Each story is made up of paragraphs called exons, which are interrupted by advertisements called introns. Each word written in letters are called bases, which are thymine, guanine, cytosine and adenine (TGCA).

Autoradiography

After hybridization, excess probes are washed from the membrane, and the pattern of hybridization is visualized on X-ray film by exposing the membrane to an X-ray source. This technique is known as autoradiography. The banding pattern, which was originally obtained in the gel due to the separation of RFLPs, is now developed on an X-ray film.

26.4 Genome Maps

As you know **gene** is the basic unit of biological information. Hereditary characteristics pass from parents to offspring through genes in their gametes. The collection of all the genes found in one complete set of chromosome is called **genome.**

The **haploid organism or egg and sperm** have one copies of genome while **diploid organism (cell)** contains two copies of genome.

Genome Analyses

For the study of genome of various organisms, a new sub branch of biotechnology has been created called **genomics** which deals with exploration and analysis of complete DNA sequence of an organism's genome. The genome of ***Haemophilus influenzae*** was published in 1995.

Frederick Sanger also sequenced the first bacteriophage genome. The project was also launched in 1990. Thus so far the genomes of many organisms have been described by the new branch of biotechnology.

Genome Maps

The genome analysis helps us to develop two broad categories of maps *i.e.* genetics maps and physical maps. The **genetic maps** exhibit the sequence of gene loci along the length of DNA. The **physical mapping** is used to find the order and physical distance between DNA base pairs by DNA markers. This technique can determine the sequence of DNA base pair with high accuracy.

Genetic markers

The genetic maps have landmarks called genetic markers, contain variable number of **tandem repeats** (short tandem repeats and single nucleotide polymorphism). These genetic markers are useful for generating genetics maps when there are occasional, predictable mutations that occur during meiosis. Over many generations, lead to a high degree of variability in the DNA content of the marker from individual to individual.

26.4.1 Human Genome Project (HGP)

In 1990, international cooperative venture called the human genome project (HGP) set out to sequence the complete human genome because the genome of an organism is a catalogue of the bases. HGP hoped to determine the order of all the bases A, T, C and G in human DNA. This project was originally founded by the **U.S. Department of Energy and National institutes of health**. They have established **National Human Genome Research institute (NHGRI)**, who completed this task in 2003, the first director of NHGRI was James D. Watson later this institute was being led by Dr. Francis Collin. This institute was first founded by US government later on **"Welcome Trust"** of UK became a major partner, additional contributions for china, France, Japan, Germany and others. In



Fig.26.11: James Whatson

2003, the project announced that it had succeeded in achieving its goal. Finally, it came to know that human genome comprises 3.22 billion nucleotides and approximately 20,000 to 25,000 genes.

26.4.2 Major Goals of Human Genome Project

The goals and objectives of HGP were as under:

- To identify all the approximately 20,000 to 25,000 genes in human genome.
- To determine the sequences of the chemical base pairs those, make up human DNA which are about 3.22 billion.
- To store this information in database.
- Improve tools for data analysis.

Transfer related technologies to the private sector, and address the **ethical, legal, and social issues (ELSI)** that may arise from the project.

Benefits of HGP

Some potential benefits from human genome project are expected in the following fields:

Molecular Medicine

- Improved diagnosis of diseases.
- Earlier detection of genetic predisposition to certain diseases.
- Rational drug design.
- Gene therapy and control systems for drugs.
- **Pharmacogenomics** *i.e.* study how genes affect a person's response to drugs.

26.5 Tissue Culture

Tissue culture is the growth of a tissue in an artificial liquid culture medium. In 1902, the German botanist **Gottlieb Haberlandt** revealed that plant cells are **totipotent,** *i.e.* each cell has the full genetic potential of the organism. Its mean a single cell could become a complete plant. But it wasn't until 1958 that **British botanist F.C. Steward** grew a complete carrot plant from a tiny piece of phloem. He provided the cells with sugars, minerals and vitamins, but he also added coconut milk. (Later it was discovered that coconut milk contains the plant hormone **cytokinin**). When the cultured cells began dividing, they produced a **callus** (an undifferentiated group of cells), which later differentiated into shoot, root and developed into complete plants. The initial plant part which is used to develop tissue culture is known as **explants**. It may be a single cell (protoplast) a piece of tissue or complete organ (seed, leaf and twig). Thus on the basis of explants tissue culture is variously called **cell culture** or **organ culture. Plantlets** are young plants that developed during tissue culture. **Micro-propagation** is one of tissue culture techniques. It is the production of a large number of plants from a small plant material.

Somatic embryogenesis is an artificial process in which a plant or embryo is derived from a single somatic cell. Somatic embryos are formed from plant cells that are not normally involved in the development of embryos, *i.e.* ordinary plant tissue. No endosperm or seed coat is formed around a somatic embryo.

The plants produced from tissue culture are genetically identical to the original plant from which they are grown, so they are called **soma clones.** But a number of observations have indicated that this is not the case, sometime genetic variation observed among progeny of plants regenerated from somatic cells cultured *in vitro*. This is called **soma clonal variation.**

Differences between Cell culture and Organ Culture

Cell culture is a technique where cells are artificially grown under laboratory conditions (*in vitro*). While organ culture deals with the culture of the isolated organs such as root, stem, anther, *etc.*

Under laboratory condition (*in vitro*). There are different names for organ culture depending upon the organ utilized for the culture.

26.5.1 Methods of Tissue Culture

Many methods of tissue culture have been developed which are primarily based upon type of explants used such as meristem, anther, ovary, embryo culture, callus culture and suspension culture. *etc.*

Meristem Culture

Meristems are tissues in plants that consist of undifferentiated cells capable of rapid cell division. A tissue culture in which meristems are used is called **meristem culture**. Tissue culture technique have by now led to micro-propagation, or commercial method of producing thou-sands, even millions of identical seedlings in limited amount of space. The correct proportions of auxins and cytokinin are added to a liquid medium with a single root tip, many new shoots

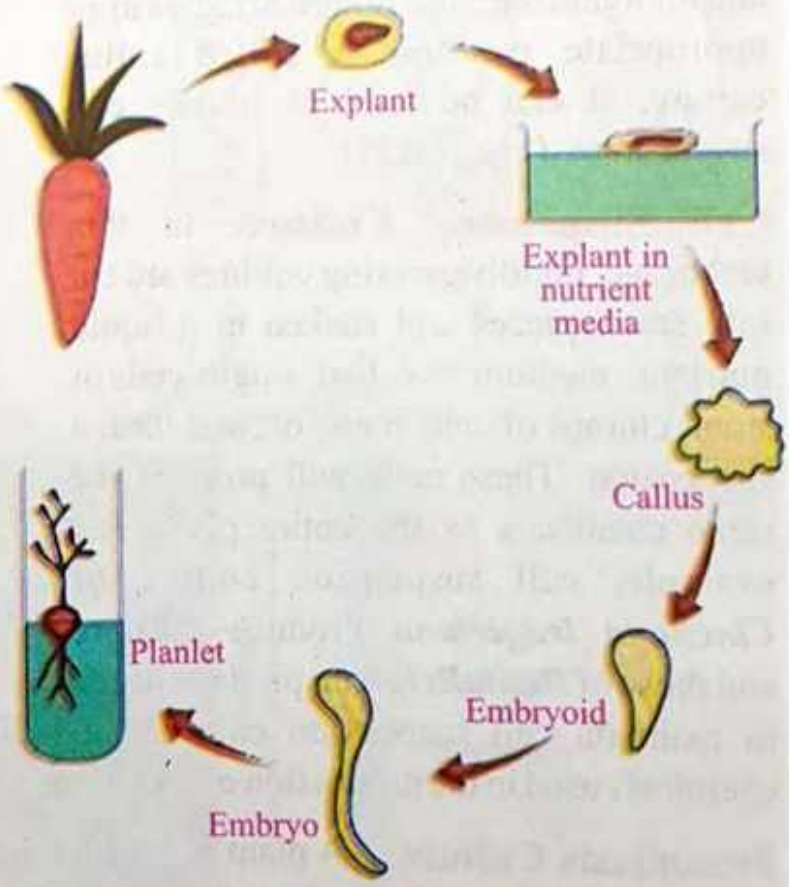


Fig.26.12: Tissue Culture

develop from a single shoot tip. When these are removed more shoots form. The advantage of meristem culture is that it is germ free (devoid of viruses) due to absence of vascular system in them, as the vascular system has prime importance in the travelling of viruses through the body. (Fig.26.12)

Anther Culture Technique

In this technique mature anthers are cultured in a medium containing vitamins and growth regulators the haploid tube cells within the pollen grains divide, producing pro-embryos consisting of as many as 20-40 cells. When the pollen grains rupture releasing haploid embryos. The experimenter can now generate a haploid plant, or chemical agent can be added that encourage chromosomal doubling. After chromosomal doubling the resulting plants are diploid but homozygous for all their alleles. Anther culture is a direct way to produce plants that express recessive alleles. If the recessive alleles govern desirable traits, the plants have these traits.

Differences between Callus Culture and Cell Suspension Culture

Callus Culture: Callus is formed by the proliferation of the parent tissue. The cells of a callus are parenchymatous, amorphous and unorganized. The culture of callus in an appropriate medium is called callus culture. It can be used to initiate cell suspensions. (Fig.26.13)

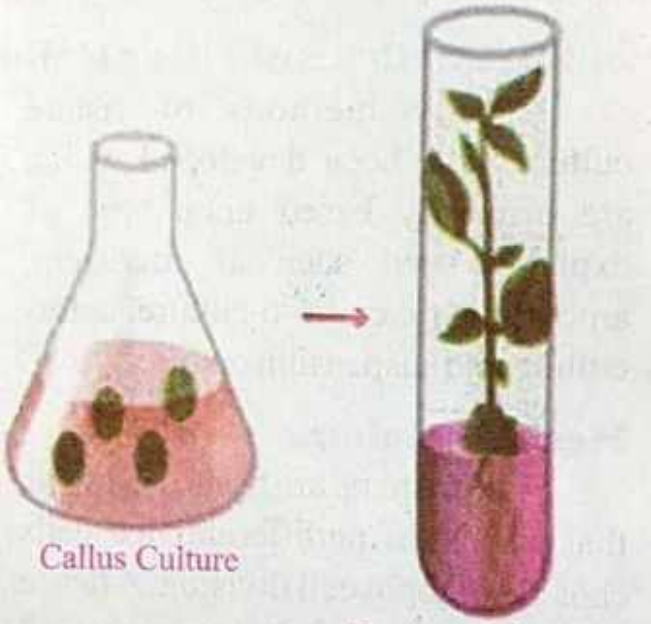


Fig.26.13: Callus Culture

Cell Suspension Culture: In this technique, rapidly growing cultures are cut into small pieces and shaken in a liquid nutrient medium so that single cells or small clumps of cells break off and form a suspension. These cells will produce the same chemicals as the entire plant. For example, cell suspension culture of ***Cinchona ledgeriana*** Produce **quinine** and those of ***Digitalis lanata*** produce **digitoxin**. Scientists imagine that it will be possible to maintain cell suspension cultures in bioreactors for the purpose of producing chemicals used in the production of drugs, cosmetics and agricultural chemicals.

Protoplasts Culture: - A plant cell with removed cell wall is called **protoplast**. It is commonly isolated from either leaf mesophyll cells or cell suspensions. Protoplast culture can be used to develop whole plant by **somatic embryogenesis** (synthetic

embryos that developed from somatic cells). Genetic variation can also be induced in these somatic embryos, if they are exposed to chemical of physical mutagens. These variations are known as **soma clonal** variations. Protoplasts also act as ideal targets for transformation by a variety of means.

Embryo Culture: - It is the culture of mature embryos; zygote or seed embryos that are often used as explants in plant tissue cultures. This embryo develops properly when nourishing tissues, endosperms were present in seed during the development.

Ovary Culture: - This culture is the ***in vitro* technique** which is carried outside on a suitable nutrient medium in an unpollinated flower to grow new haploid plants. The process of ovary culture is referring as **gynogenesis.** The gynogenesis or ovary culture is based on the regeneration principles, where an ovary can regenerate into a fully differentiated plant.

26.5.2 Methods of Animal Cell Culture

The biotechnological processes are helpful to culture the animal cells in artificial media but unlike plant and bacterial cells, these cells can grow only to a limited generation. The growth (division) of cells also depends on the source of the tissue isolated, such as some cell cannot divide and grow *e.g.* nerve cells, lens cells while some other can repeatedly divides and grow to limited generation *e.g.* fibroblast. The cultured cells are being used in variety of process *e.g.* in recombinant DNA technology, a variety of industrial processes (vaccine, monoclonal antibiotics and drugs production), genetic manipulation, cancer research, *etc.*

Techniques of Animal Cell Culture

We can use plastic containers to culture animal cells. A cell culture which is initiated by the cells isolated from a tissue or animal's organ is known as **primary cell cultures**, it is called secondary culture or cell line. If primary culture is sub cultured in fresh media to establish **secondary culture.**

The culture of native tissue that retains most of the *in vivo* histological features is regarded as organ culture while the culture of the cells for their reaggregation to form a tissue like structure represents **histotypic culture.** The culture of different cell types to form tissue or organ is called **organotypic culture**.

A special incubator is needed for animal cell culture that has capacity to maintain level of carbon dioxide, oxygen, temperature and all other substances which are necessary for this purpose.

There are two different patterns of animal cell growth *i.e.* anchorage dependent and anchorage independent.

Anchorage dependence can be defined as an increase in proliferation which is seen when cells are allowed to attach to a solid surface.

Anchorage independence is a condition in which a cell maintains its capacity to spread, divide and function despite of absence of a stable or inert surface to anchor with.

Applications of Animal / Tissue Culture

The animal cell cultures are used to:

- Produce antiviral vaccines / pharmaceutical drugs using for cell lines.
- Amniocentesis (*i.e.* chromosomal analysis of fetus for various diseases).
- Produce monoclonal antibodies required for cell lines in culture.
- Helpful to study the function of the cell neurons.
- Use of artificial skin.
- Culture tumor cells, to know whether benign or cancerous tumor.
- To know the effects of toxins and pollutants using cell lines.

26.6 Transgenic Organisms (Bacteria Plants and Animals)

Modern genetic technology can be used to modify the genomes of living organisms. This process is also called **genetic engineering**. Gene of one species can be modified, or gene can be transplanted from one species to another. The organisms that have altered genomes are known as transgenic.

Bacteria were the first transgenic organisms produced in 1973, since then many other transgenic organisms (plants and animals) are produced by this method.

26.6.1 Transgenic Bacteria

Herbert Boyer (1978), University of California was able to produce first transgenic bacterium *(E. coli)*. He inserted human insulin gene in it. The bacteria

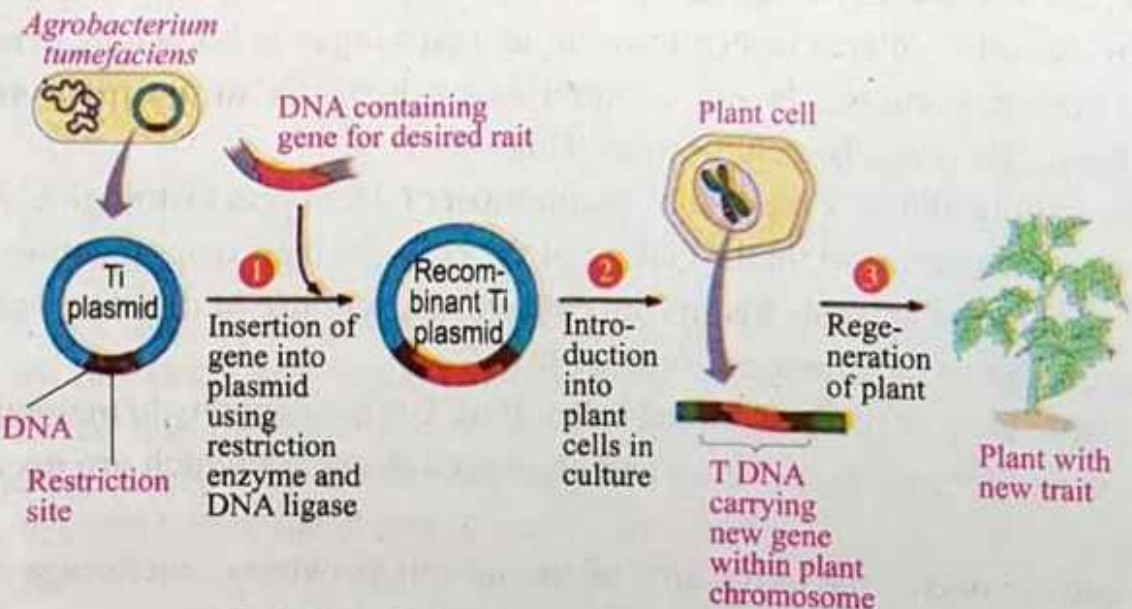


Fig.26.14: Formation of Recombinant Bacteria

synthesized human insulin "in Vats". Later many other human genes and genes for medicine were inserted in their plasmid or directly to their nuclear chromosome to get desirable products. (Fig.26.14)

- **Formation of Ice Crystal:** A strain of bacteria, named ***Pseudomonas syringae***, commonly called **ice plus bacteria,** they have certain surface protein **(ice-nucleation –active protein (INA protein)** on their outer cell wall, which promotes ice crystal formation. Now a new strain of bacteria called ice minus in which gene encoding INA protein is removed, thus their surface lack INA "protein", therefore, provides a less favorable environment for ice formation. Now plants can be protected from cold stress if these bacteria are thrown on their surface.
- **Bioreactors:** Recombinant DNA technology is used to produce bacteria that reproduce in large **vats** called **Bioreactors**. If the foreign gene is replicated and actively expressed a large amount of protein products can be obtained.
- **Biotechnology products:** Many biotechnology products are made by transgenic bacteria, such as insulin, human growth hormone, clotting protein for haemophilia (haemophilia factor VII), hepatitis B vaccine, **interferon** (to treat viral infections), **tissue plasminogen activator (tPA)** to dissolve blood clot (used by heart patients).
- **Anti-insect toxin:** Bacteria that normally colonize the roots of corn plants have now been endowed with gene (from another bacterium) that code for an insect toxin. The toxin protects the roots from insects.
- **Cleaning up Beaches after Oil Spills:** Bacteria can be selected for their ability to grade a particular substance and this ability can be enhanced by genetic engineering *e.g.* naturally occurring bacteria may be changed to engineer bacteria which can clean up beaches after oil spills.
- **Importance of transgenic bacteria in industry:** Bacteria can be used by biofilters to prevent air born chemical pollutants from being vented into the air. Transgenic bacteria can also remove sulphur from coal before it is burned and help to clean up toxic waste dumps. One such bacteria was given genes that allowed it to clean up levels of toxin that would have killed other bacteria. Further these bacteria were given "suicide genes" that caused them to self-destruction when job had been completed.
- **Synthesis of organic chemicals:** Organic chemicals are often synthesized by having catalyst act on precursor molecules or by using bacteria to carry out the synthesis. Today, it is possible to manipulate genes that code for these enzymes. Biochemists discovered a strain of bacteria that is especially good for producing phenylalanine which is needed to make aspartame. **Aspartame** is **dipeptide sweetener** called as **"Nutra Sweet".** They isolated, altered and formed a vector for appropriate genes so that various bacteria could be genetically engineered to produce phenylalanine.

- **Extraction of Metals:** Many major mining companies already use bacteria to obtain various metals. Genetic engineering may enhance the ability of bacteria to extract copper, gold and uranium from low grade ore sources.
- **Bioleaching:** Some mining companies are testing genetically engineered organisms that have improved bioleaching capabilities.

Ecological Concerns Surrounding Transgenic Bacteria

There are some ecological concerns also associated with transgenic bacteria. Their uses may create serious hazard, such as if cancer cell genes were transferred into micro-organisms, antibiotic resistance may develop in many bacteria and some bacteria create pollution. Thus these transgenic bacteria can disturb the natural environment if their number exceed limits.

26.6.2 Transgenic Plants

The first transgenic plants (Tobacco plants) were made and cultivated in France and USA in 1986. In these tobacco plants herbicide resistant genes were inserted. In most cases to produce transgenic plants, the aim is to produce a new trait to the plant which does not occur naturally in the species. These plants can overcome environmental problems thus grow more successfully than natural species.

Methods of gene transformation in plants

Many techniques have been developed to introduce foreign genes or gene of choice into immature plant embryos or into plant cells. In all these techniques the cell wall of plant cells are removed, called protoplast cells.

Electroporation method

The protoplasts of plant cells are treated with an electric current while they are suspended in a liquid containing foreign DNA. The electric current makes tiny self-sealing holes in the plasma membrane through which foreign gene (DNA) can enter into cytoplasm and then to the nucleus of plant cell. This transgenic protoplast will develop into a complete plant.

Agrobacterium mediated transformation

In this technique, foreign DNA is inserted into the **tumour inducing plasmid (Ti plasmid)** of the bacterium, ***Agrobacterium tumefaciens.*** The plasmid of this pathogenic plant bacterium is widely used to produce recombinant DNA, therefore, known as **natural genetic engineering** of plants.

These bacteria have natural ability to insert **T- DNA (Transfer DNA)** of their plasmid into plant genome when they cause infection to plant at wound site. The **T-DNA** contains genes for auxin production, therefore, the infected plant cells are compelled to divide and redivide to produce a tumour often called **gall** (causes crown gall disease).

The gene of choice is cloned in the T. DNA region of tumour inducing plasmid in place of unwanted sequences. When these transgenic bacteria infect the plants, the genes of choice are entered into the nucleus of host cell. The transformed cells can be regenerated into whole plants.

Particle Gun

In 1987, **John C Sanford and Theodore M. Klein of Cornell University** developed another method of introducing DNA into a plant tissue culture callus. They constructed a device, called the **particle gun** which bombards a callus with DNA coated microscopic metal (gold or tungsten), then genetically altered somatic embryos develop into genetically altered adult plants. Many plants including corn and wheat varieties have been genetically engineered by this method. (Fig.26.15)

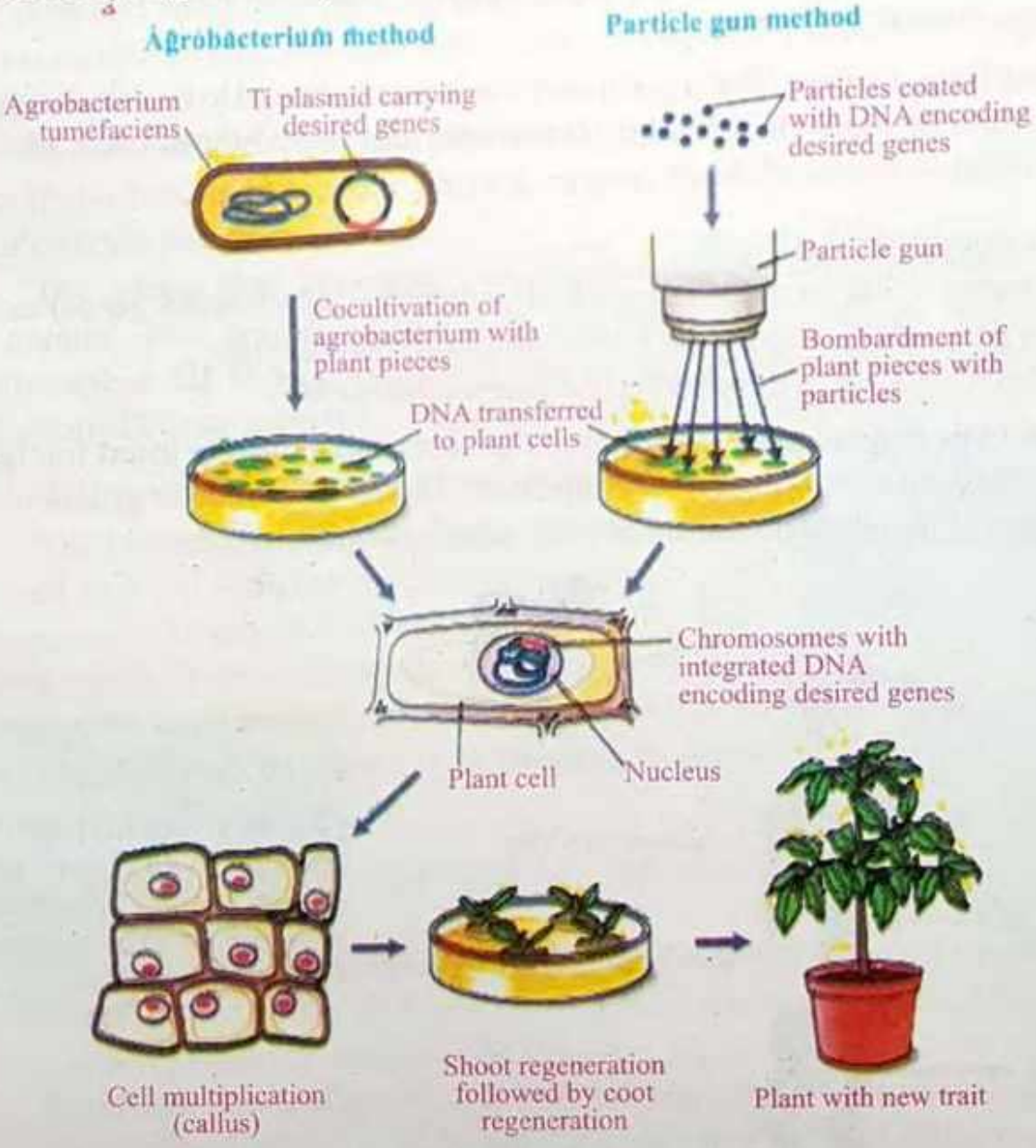


Fig. 26.15: Particle Gun Transformation

Advantages of Transgenic Plants

- **Resistance to pest:** Foreign genes transferred to cotton, corn and potato strains have made these plants resistant to pests because their cells now produce toxin against insects, *e.g.* Cotton, maiz.
- **Resistance to Herbicide:** Transgenic soybeans are resistant to herbicides. Some corn and cotton plants are also herbicide resistant, *e.g.* Grasses in lawn.
- **Increase in protein, oil and starch contents:** Improvements still to come for increase protein or starch content and modified oil or amino acid composition, *e.g.* Soya bean, potato, canola, maiz, golden rice.
- **Transgenic Wheat and Rice Versions:** To meet the increasing demand of rice, wheat and corn agribusiness, companies are trying to develop transgenic wheat and rice in addition to corn.
- **Green Revolution:** World grain harvests have continued to rise since the 1960's, when special high-yield hybrid plants were developed during so called green revolution.

26.6.3 Transgenic Animals

The animals that have been genetically altered (carry foreign genes) using the techniques of genetic engineering are known as transgenic animals.

The three methods of developing transgenic animals are:

i) By micro- injection: This technique has been developed to insert foreign gene into the eggs of animals through micro-injection. Then the fertilized egg is transferred into the oviduct of female to implant, *e.g.* Dolly sheep. (Fig.26.16)

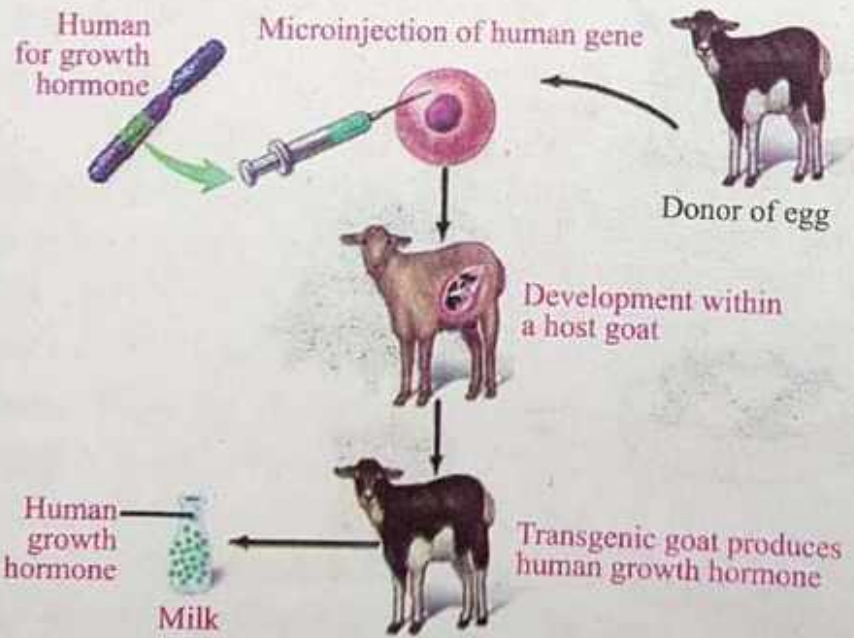


Fig. 26.16: Formation of Transgenic Goat

Extra Information

Alpha-1- Antitrypsin (AAT), produced in liver, protects lungs from infections. Its deficiency causes respiratory diseases.

ii) **Vortex Mixing:** In this method the egg is placed in an agitator with DNA and **silicon-carbide needle;** and the needles make tiny holes through which the DNA can enter. When these eggs are fertilized, the resulting offspring are transgenic animals.

iii) **Retrovirus-Mediated Gene Transfer:** In this method retroviruses are commonly used as vectors to transfer genetic material into the cells of blastocyst *in vitro* conditions. The blastocyst is then implanted into the womb of the female animal. Thus the resulting offspring is transgenic animal.

26.6.4 Importance of Genetic Engineered Farm Animals

Genetic engineering has also been used to produce **bovine growth hormone**, which are inserted into the animal's eggs to produce large size animals *e.g.* larger fishes, cows, pigs and sheep. Genetically engineered fishes are now being kept in ponds that offer no escape to wild because there is much concern that they will upset or destroy natural ecosystem.

In addition, the transgenic animals are also used to produce pharmaceuticals (drugs for the treatment of cystic fibrosis, cancer, blood disease) such transgenic animals are called **transpharmer animals**.

The genes that are code for therapeutically and diagnostic proteins are incorporated into animal's DNA and the proteins appear in animal's milk e.g. **Antithrombin III (hAT)** for blood clot during surgery, which prevent blood clot, production of human growth hormone in mice, which excrete it in their urine.

26.7 Biotechnology and Healthcare

The biotechnological techniques and tools create new and modern learning methods about human and other organisms body but sometime goes wrong when problems arise from it. Biotechnology has made great difference in our health care. It also has enable the researchers to develop products which fulfil our needs, safer vaccine and medicines.

Extra Information

Human Lactoferin (HLF) is a protein that helps to protect the body from infections and strengthens the immune system. This is found in human tears and lung secretion, protect them, from infection. Now these are produced by transpharmer animals.

26.7.1 Development of vaccine in biotechnology

There are three different ways are used in the development of vaccine:

a) Separation of a pure antigen using a specific monoclonal antibody, which is used for developing vaccine against pathogen.

b) Synthesis of an antigen with the help of a cloned gene or from cDNA.

c) Synthesis of peptides to be used as vaccines (protein region of pathogen for immune genic response).

26.7.2 Role of Biotechnology in diagnosis of diseases

Several human diseases can be diagnosed by using biotechnology products, such as monoclonal antibodies and DNA/RNA probes.

Monoclonal Antibodies

The response of the immune system to any antigen, even the simplest, is polyclonal; monoclonal antibodies (mAB) are a group of identical antibodies because they are made by identical immune cells which are all clones of a unique parent cell.

It is possible to produce monoclonal antibodies that specifically bind to the substance; they can then serve to detect or purify that substance. They can also help to diagnose a wide variety of illnesses; can detect the presence of drugs, viral, bacterial products, and other unusual or abnormal substances in the blood. Monoclonal antibodies are typically made by fusing **myeloma cells** (cancerous B-lymphocytes) with the spleen cells from a mouse that has been immunized with the desired antigen. The technique is called **somatic cell hybridization**

DNA/RNA Probes

A **probe** (in biotechnology) is a florescent or radioactive labelled piece of DNA or RNA of variable length (usually 100-1000 bases long), that is used in complementary to the sequence in the target DNA. These probes are widely used in diagnosis of many microbial diseases. Some specific DNA/RNA probes are useful to detect prenatal diseases, *e.g.* Short tandom Repeats (STR).

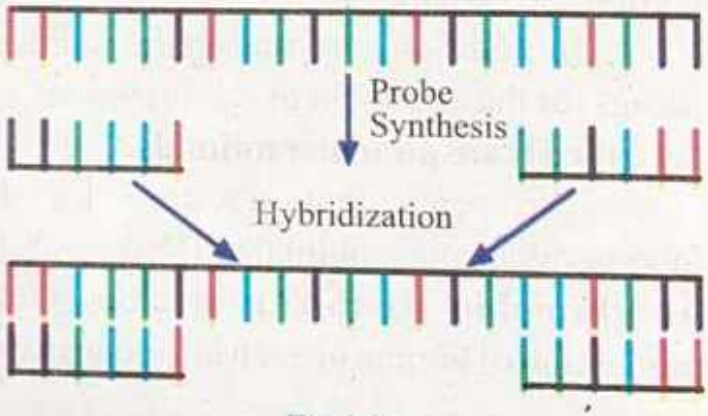


Fig.26.17

Diagnosis of diseases caused by protozoa and helminths

The monoclonal antibodies and DNA probes are being used as very sensitive tools in biotechnology to diagnose the diseases caused by protozoa and helminths. Monoclonal antibodies can be used through serological tests which takes only minutes as compared to conventional methods which require some weeks, as the bacteria and viruses have to be cultured *e.g.* in Herpes virus.

The DNA probes are more sensitive than monoclonal antibodies and the process takes hours instead of weeks. Ready made DNA probes for herpes virus and other human, animal and plant viruses are being prepared. Probes are now available for a number of human parasites from the group protozoa and helminths *e.g.* polio, hepatitis, *etc.*

26.7.3 Gene Therapy

It is a technique to replace defective genes (by normal genes) responsible for disease development. There are many approaches for correcting defective genes such as:

1. A normal gene may be inserted into a non-specific location within the genome to replace a non-functional gene. This approach is most common.
2. An abnormal gene could be swapped for a normal gene through homo-logous re-combination.
3. The abnormal gene could be repaired through selective reverse mutation, which returns the gene to its normal function.
4. The regulation (the degree to which a gene is turned on or off) of a particular gene could be altered. (Fig.26.17)

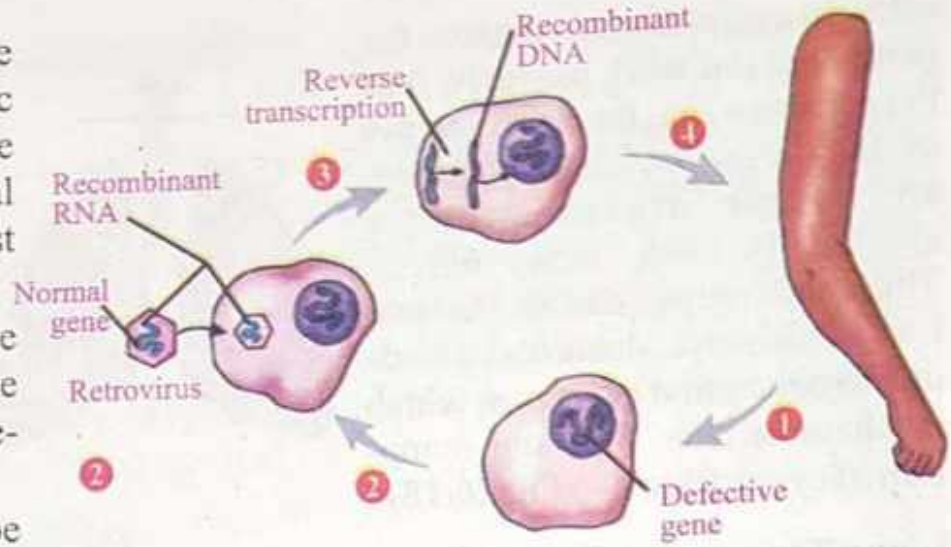


Fig. 26.17: Ex-vivo gene Therapy in Humans

Mechanism of gene therapy

This technique is done either "*in vivo*" or "*ex vivo*". During in vivo, the gene is delivered directly into the body, while *in vitro* into the cells outside the body. These transgenic cells are again implanted into the body in both cases. A "**normal gene**" is inserted into the genome to replace an "abnormal gene, diseases-causing gene". A carrier molecule called a vector must be used to deliver the therapeutic gene to the patient's target cells. The virus is most common vector which has been genetically altered to carry normal human DNA. Viruses have evolved a way of encapsulating and delivering their genes to human cells in a pathogenic manner. Scientists have tried to take advantage of this capability and manipulate the virus genome to remove disease causing genes and insert therapeutic genes. Besides, virus mediated gene delivery system, some non-viral approaches are also used *i.e.* creation of an artificial lipid sphere with an aqueous core. This **liposome**, which carries the therapeutic DNA, is capable of passing the DNA through the target cell membrane.

26.7.4 Cystic Fibrosis

It is an inherited disease, affects the mucus and sweat glands. The affected person with severe symptoms can have serious lung and digestive problems, while person with a mild form of the disease shows symptoms of disease after adolescence. The mucus of normal person is watery, which keeps the linings of certain organs moist and prevents them from drying out or getting infected. However, the cause of cystic fibrosis (CF) is a defect in the **Cystic Fibrosis Transmembrane Conductance Regulator (CFTR)** gene that encodes a protein by which the movement of salt and water is controlled in and out o

cells. In cystic fibrosis patient, the gene does not work properly, thus the cells that line the passageways of the lungs, oviduct, pancreas, and other organs produce abnormally thick, sticky mucus. This thick mucus causes obstruction to air ways, ducts and glands due to deposition of mucus, which is characteristic sign and symptom of cystic fibrosis. (Fig.26.18)

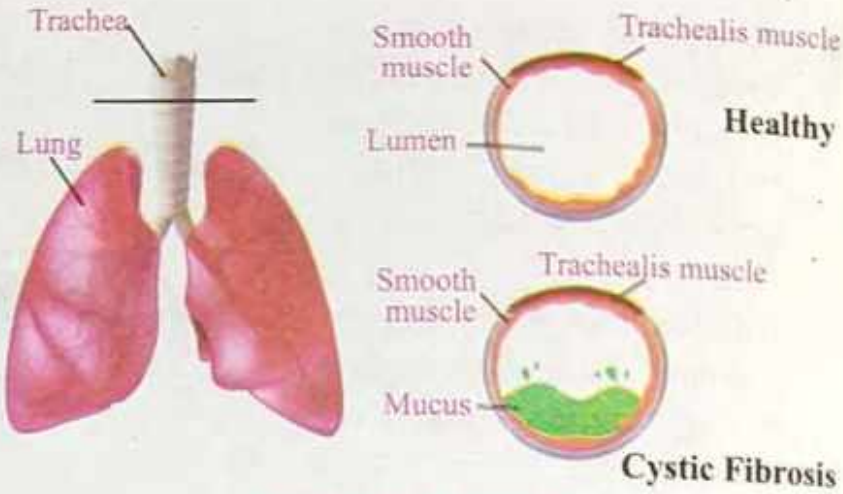


Fig. 26.18: Cystic Fibrosis

Gene Therapy of Cystic Fibrosis

The cystic fibrosis genes were identified in 1989, and were named as the **CFTR.** The discovery of this defective gene help scientists that it can be treated by gene therapy. Gene therapy is the process of creating a healthy version of the flawed CFTR gene and

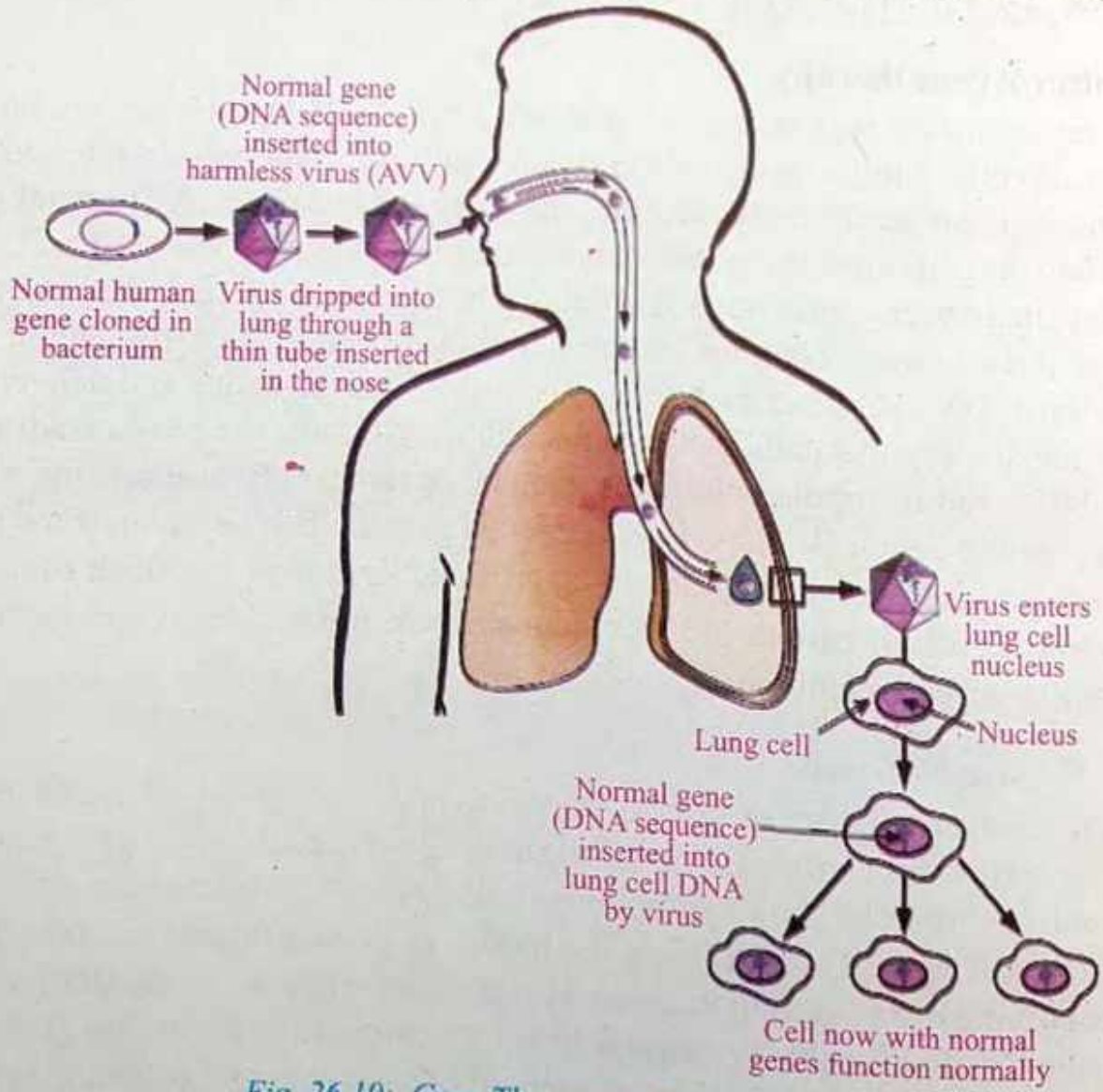


Fig. 26.19: Gene Therapy of Cystic Fibrosis

infusing it into the affected patients. (Fig.26.19)

Importance of Biotechnology

Biotechnology emerged as new discipline during 1970s. Although biotechnology is not a pure science, but an integration of biological science with technology created revolution in human life. Biotechnology is defined by different organizations in different ways. It has been broadly defined as, "the development and utilization of biological processes, forms and systems for obtaining maximum benefits to human and other forms of life". Biotechnology is "the science of applied biological processes". Importance of biotechnology is highlighted in the following fields.

Biochips and Biological Computers

Biochips are the result of combination of microchips business with biotechnology. In future, there is the possibility of developing of biological computers. The formation and use of biochips is a major thrust of the rapidly growing biotechnology industry, which encompasses a very diverse range of research efforts including genomics, proteomics, computational biology, and pharmaceuticals, among other activities.

It reveals, the complex biochemical processes occurring inside cells, with the larger goal of understanding and treating human diseases. At the same time, the semiconductor industry has been steadily perfecting the science of **microminiaturization**. The merging of these two fields in recent years has enabled biotechnologists to begin packing their traditionally bulky sensing tools into smaller and smaller spaces, onto so-called biochips. These chips are essentially miniaturized laboratories that can perform hundreds or thousands of simultaneous biochemical reactions. Biochips enable researchers to quickly screen large numbers of biological analytes for a variety of purposes, from disease diagnosis to detection of bioterrorism agents.

Biofertilizers:- In recent years, use of microbial inoculants as a source of biofertilizers (nutrient inputs of biological origin for plant growth) has become a hope for most of countries, as far as economic and environmental viewpoints are concerned. Biologically fixed nitrogen is such a source which can supply an adequate amount of nitrogen to plants and other nutrients to some extent. It is a non-hazardous way of fertilization of field. Moreover, biologically fixed nitrogen consumes about 25 percent to 30 percent less energy than normally done by chemical process.

Nanotechnology:- A new and exciting sub-branch requiring biotechnologists is the field of nanotechnology. **Nanotechnology** gives us the capability to engineer the tiniest of objects, things at the molecular level. Nanotechnology includes the study and

manipulation of materials between 1 and 100 nanometres. Nanotechnologists are imparting their expertise in the development of such Nano particles that can be used for efficient drug delivery at the target cells and in the diagnoses of disease.

Scope of Biotechnology: - The biotechnology is the fastest growing field in the area of research and development. It is also called a technology of the future or technology of tomorrow because of its unprecedented impacts on the mankind and the universe as a whole.

Due to its interrelation with other fields such as industry, agriculture, computers, *etc.* it is going to create amazing opportunities for manipulating the biological systems and thereby understanding the mysteries of fundamental life process.

Students of biotechnology after completing their studies can have scope in the following fields:

- **Communications/media**-reporting, writing editing, *etc.*
- **Computer science**-data base development, bioinformatics, web site development, *etc.*
- **Pharmaceutical companies** *i.e.* drug development.
- **Genetic engineering** working in bioprocess chambers, instrumentation development, fermentation technology.
- **Research e.g.** cancer, genetically linked diseases, AIDS.
- **Diagnostic laboratories** funded by public and private sectors.
- **Waste management,** bio-monitoring bodies and pollution control boards.
- **Medicine** - The medical genetics, genetic counselling, gene therapy and gene testing, uses biotechnological tools.
- **Bio power plants,** *e.g.* There are many types of bio power plants including corn, sugar cane and bamboo, *etc.*
- **Bio-processing industry e.g.** enzyme technology, paper technology, metabolic engineering, protein engineering, food processing, *etc.*
- **Agriculture and animal husbandry,** Animal husbandry is the branch of agriculture concerned with animals that are raised for meet, fiber, milk, eggs, *etc.*
- **Legal field** involving issues related to intellectual property rights, patency, and copyrights related to the field of biotechnology. The issues related to Genetic and Paternity testing also requires the combined expertise of biotechnologist and a law expert.
- **Military** - With the fear of Biological warfare looming largely on the human civilization, a biotechnologist is needed in pathogen identification, in the development of protection against the chemical and biological warfare, and in conducting the risk assessment studies.

- **Crime and law** - With the use of DNA finger printing in forensic science it has become easy to create a data bank of the criminals and thereby catch the culprits faster.

Social/Ethical Implications of using Biotechnology

The field of biotechnology has had a lot of beneficial contribution in the area of healthcare, agriculture, food production, manufacture of industrial enzymes, and appropriate environmental management. However, the advancement in this field has also led to some concerns and controversies raised by a number of groups, None Governmental Organizations (NGOs), *etc.* ELSI is the short form to represent the **ethical, legal, and social implications** of biotechnology. ELSI broadly covers the relationship between biotechnology and society with particular reference to ethical and legal aspects.

Concerns about the genetically Modified Organisms (GMOs)

There are concerns regarding the biosafety, ethics and issues related to the release of GMOs in the environment. Many countries and NGOs have opposed the release of the GMOs due to several reasons. In order to address these issues, the United Nations has built up an informal working Group on biosafety. In 1991, this group prepared the "voluntary code of conduct for the release of organism into the environment". The main areas of consideration for safety aspects in biotechnology are the following:

- To dispose of spend microbial biomass and purify the effluents from biotechnological processes.
- The toxicity of the allergy associated with microbial production.
- To deal with the increase in the number of antibiotic resistant pathogenic microorganisms.
- To evaluate the pathogenicity of the genetically engineered microorganisms to infect humans, plants and animals.
- To prevent contamination, infection or mutation of the processed strains.
- The evaluation of the interaction of the genetically engineered microbes with the elements of natural environment.

Biological Warfare

Most of the countries of the world are signatories to the **Biological Weapons Conventions** of 1972. As a signatory, it is a voluntary pledge by a nation "Never to produce microbial or other biological agents or toxins, whatever may be their method of production, for use in wars. However, many people have expressed their concerns about the possible use of genetic manipulations for military purposes in the near future.

Intellectual Property

With the fast pace development in the field of biotechnology, the issues related to

legal characterization and the treatment of trade related biotechnological processes and products are of immense importance. These are popularly known as **Intellectual Property**. Intellectual property includes patents, trade secrets, copyrights, and trademarks. **Intellectual property Rights (IPR)** is a collective term applied to a number of different types of legal rights granted by each country. The rights to protect this property prohibit others from making, copying, using or selling the proprietary subject matter.

Interesting Information

Blue Biotechnology: The study of biotechnology of water and bodies of water.
Red Biotechnology: It is medical biotechnology.
Green Biotechnology: It is the plant biotechnology.

In biotechnology, the intellectual property covers the processes and products which result from the development of genetic engineering techniques through the use of restriction enzymes to create recombinant **DNA.** Another example of intellectual property is the development of crop varieties which are protected through "Plant Breeder's Rights or **PBRs.** The **PBRs** ensure that the plant breeder who developed a particular variety gets the exclusive rights for marketing the variety.

Science, Technology and Society (STS)

Describe the applications of polymerase chain reaction (PCR).

Application of PCR: PCR has application in almost all areas of molecular biology, genetics and in clinical areas.

- PCR is an efficient diagnostic technique used for the detection of specific infectious agents *e.g.* HBV, HCV, HIV.
- It is also used for the detection of microorganisms in food samples, water and in the environment with the help of species-specific primers.
- PCR can also be used for genome analysis and for generating markers for the construction of genetic and physical maps of organisms.
- There is the PCR-based cDNA synthesis known as RT-PCR (reverse transcriptase-PCR), which can be directly carried out with purified mRNA.
- Reactions for DNA sequencing are also simplified by introducing the PCR method.
- PCR has also shown its impact in criminology. The DNA of the suspects and the DNA sample recovered from the crime scene can be analysed by PCR techniques with the help of a set of identical random primers or specific primers.
- DNA fingerprinting is also made simple by PCR as described above.
- The genetic mutations responsible for certain genetic diseases and cancers can be detected using PCR tools. Early detection of genetic disease is even possible in embryonic conditions or even sex cells-sperm and egg.

SUMMARY

- The molecular genetics enables us to manipulate genetic material for the welfare of mankind.
- Nanotechnology is the branch of biotechnology that deals with dimensions and tolerances of less than 100 nanometres especially the manipulation of atoms and molecules.
- Genetic engineering deals with manipulation or alteration in genetic material of a living thing.
- Staggered restriction endonuclease enzymes cut the duplet DNA fragments in such a way that each piece shows single stranded projected end called sticky ends. The sticky ends also help the insertion of foreign DNA into vector DNA.
- The organisms that have had a foreign gene inserted into them are called genetically engineered (GE), or genetically modified (GM) or transgenic organism.
- PCR was developed by Kary B. Mullis in 1983.
- Tissue culture is often a genetic term that refers to both organ culture and cell culture.
- A DNA probe means a small single stranded DNA nucleotide sequence that will hybridize (pair) into certain piece of DNA, may be used to search a genetic library.
- The Taq DNA polymerase is a temperature tolerant enzyme isolated from *Thermus aquaticus*, a bacterium found in hot spring. It is used for carrying out PCR reactions.
- Biochips are the result of combination of microchips business with biotechnology.
- Gene therapy is a technique for correcting defective genes responsible for disease development.
- The three methods on which mechanism of any DNA analysis sequencing is based are (i) Sanger-Coulson Methods, Maxim Gilbert Method and automated DNA sequencing.
- Gene cloning is a technique for developing a large number of genes or genetically identical cells or organisms.
- The sign and symptom of Cystic Fibrosis are obstruction of the airways, ducts and glands due to deposition of mucus.
- A cell culture which is initiated by the cells removed from an animal's organ is called as primary cell culture.
- Gel Electrophoresis is a technique used in molecular biology to separate charge bearing fragments (proteins, nucleic acids) under the influence of electric field in a solid medium called gel made of agarose and polyacrylamide.

EXERCISE

SECTION-I: OBJECTIVE QUESTIONS

Multiple Choice Questions (MCQs)

A. Select the correct answer.

1. The enzyme which joints two pieces of DNA is:
   (a) DNA polymerase III (b) Restriction endonuclease
   (c) DNA ligase (d) DNA polymerase I
2. Antibody made by soybeans can be used as treatment for:
   (a) AIDS (b) Herpes Simplex
   (c) Genital Herpes (d) Hepatitis
3. Antithrombin III is biotechnical product produced in:
   (a) Sheep (b) Goat
   (c) Mice (d) Cow
4. Cell suspension cultures of *Digitalis lanata* produce.
   (a) Anti-toxin (b) Digitoxin
   (c) Polludrin (d) Quinine
5. EcoRI is commonly used as
   (a) Bacteriophage (b) Gene
   (c) Restriction enzymes (d) DNAase
6. Recombinant DNA is introduced into the host cell by means of
   (a) Phage (b) Vector
   (c) Bacterium (d) Fungus
7. The PCR was developed by K. Mullis in
   (a) 1970 (b) 1983
   (c) 1975 (d) 1978
8. Taq polymerase is an enzyme present in
   (a) Bacteria (b) Protozoans
   (c) Algae (d) Helminths
9. A complete set of genes of an individual is called as
   (a) Gene pool (b) Genome
   (c) Gene library (d) Recombinant gene
10. Those organisms which have had a foreign gene into them are called as:
   (a) Transgenic (b) Transmuted
   (c) Hermaphrodites (d) Polygenesis

11. The use of transgenic animal to produce pharmaceutical is termed as
(a) Gene pharming (b) Antibiotic
(c) Gene therapy (d) Antiviral

12. Transgenic soybeans are made to resist against
(a) Herbicides (b) Fungicides
(c) Insecticides (d) Pesticide

13. Which of the following is the genetic marker that is used in DNA finger printing.
(a) Primer (b) Probe
(c) RFLP (d) Intron

14. RFLP is a (an)
(a) Intron (b) Exon
(c) Anticodon (d) Codon

B. Fill in the Blanks.

1. Recombinant DNA technology is a series of procedures that is used to join ..... Segments.
2. First restriction enzyme was discovered in 1970, by .....
3. The collection of bacterial clone containing recombinant DNA is called ..... library.
4. Human genome comprises ..... billion nucleotides.
5. The initial plant part which is used to develop tissue culture is called .....
6. Interferons are used to treat ..... infections.
7. A plant, containing foreign gene is called .....
8. The transgenic animals which produce drugs are also called ..... animals.
9. DNA molecules with complementary sticky ends associated by ..... bond.
10. PCR is the abbreviation of .....

SECTION-II: SHORT QUESTIONS

C. Give the short answers of the following questions.

1. Write the role of restriction endonucleases in gene cloning.
2. Write note on Taq polymerase.
3. Briefly describe monoclonal antibodies.

4. Write short note on callus culture.
5. Define anther, explain briefly anther culture.
6. List some applications of animal cell culture.
7. Write methods of gene transformation in plants.
8. Define DNA/RNA probes.
9. Illustrate bio-fertilizers.
10. Write brief note on nanotechnology.
11. Explain Hazards and ethical implications of using biotechnology.
12. List some biotechnological products.
13. Write the process of the automated DNA sequencing.
14. Write short note about biochips.

SECTION-III: EXTENSIVE QUESTIONS

D. Give detailed answers of the following questions.

1. Explain method for production of recombinant DNA.
2. Describe uses of transgenic bacteria.
3. Write note on components of PCR technique.
4. Define genomic library and also explain it.
5. Write a detail note on gel electrophoresis.
6. Explain Sanger's methods of DNA sequencing techniques.
7. Describe automated DNA sequencing technique.
8. Write note on Human genome project. What are its applications?
9. Define cystic fibrosis, and also describe role of gene therapy in cystic fibrosis.
10. Explain the scope and importance of biotechnology in promoting human welfare.

UNIT 27

BIOLOGY AND HUMAN WELFARE

Major Concept

27.1 Vaccination and Integrated Disease Management
27.2 Animal Husbandry
27.3 Latest Techniques Applied to Enhance Crop and Fruit Yield
27.4 Home Gardening
27.5 Role of Microbes in Human Welfare

Learning Outcomes

Students will be able to:

- Explain what is meant by integrated disease management.
- Describe vaccination and its importance.
- List some common viral diseases against which vaccination are required *e.g.* polio, measles, influenza and hepatitis.
- Describe the role of vaccines in preventing polio, measles, hepatitis and tetanus.
- State the schedule of the vaccination against polio, measles, hepatitis and tetanus.
- Describe animal husbandry and the role of life stock in national economy (milk, meat, eggs, wool and other miscellaneous products).
- List the outstanding milk producing breeds of cows and buffaloes.
- Describe different methods adopted for plant improvements (acclimatization, selection, hybridization and back crosses, *etc.*).
- Explain home gardening and its importance.
- Identify some seasonal vegetable and fruit plants suitable for home gardening.
- Explain the role of microbes in household food processing, industrial production, sewage treatment and energy generation.

Introduction

The aim of this unit is to establish proper importance of learning of biology for human benefits. Biology has a strong influence in health and diseases. **Health** is defined as a state when an individual is free from illness and injury. Biology has an impact in diagnosing, treating and preventing diseases. Biology gives awareness about causative agents (pathogens) for diseases and symptoms caused by them. Biology has contributed in enhancement of food production. Mechanisms have been developed to improve quantity and quality of food production. It has been made possible to preserve food for long duration. Knowledge of biology is helpful in using microbes for human welfare. Biological-control against **pests** and insects has greatly contributed in saving crops.

Animal and plant breeds have been improved by techniques of genetics and biotechnology.

27.1 Integrated Disease Management and Vaccination

There are several methods of disease control that have been developed and being used.

27.1.1 Integrated Disease Management

Integrated disease management is a struggle of combating fatal and other common diseases by using a range of measures to prevent and manage diseases by involving the whole society. All the effective measures necessary to get rid a particular disease are taken.

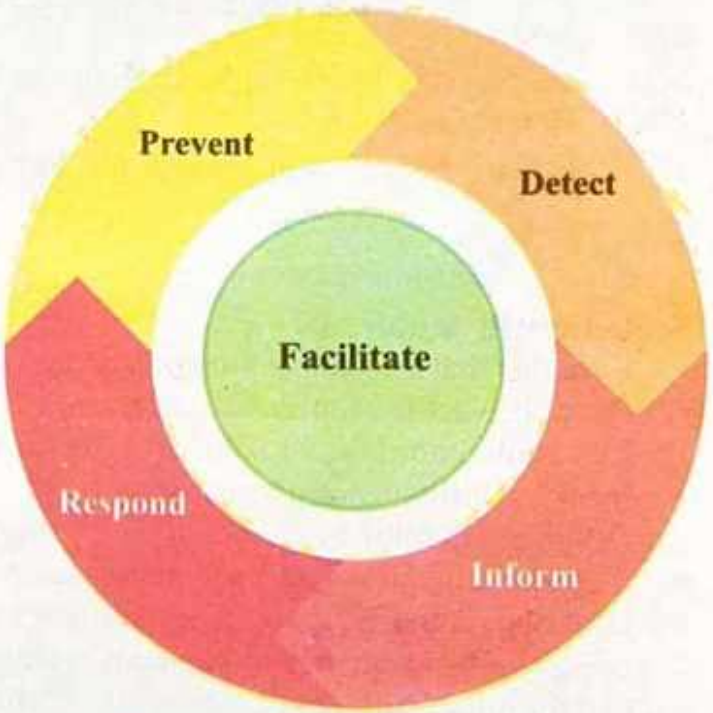


Fig.27.1: Integrated Disease Management

Objective

Integrated disease manage-ment aims to improve and maintain quality of life. It is concerned with improving health in populations and reduction of future complications associated with those diseases. By integrated disease manage-ment we can make our society healthy and progressive. (Fig.27.1)

Procedure

The initial step in integrated disease management is to involve community by creating awareness among them about a particular disease. This awareness can be created through **social and electronic media, magazines** or **newspapers**.

Discussion programs among various colleges can be arranged in order to share information regarding disease. Certain causes of disease spread, effective remedies and precautions should be communicated to whole community. Every possible method is used to prevent and cure disease such as: vaccination, drug treatment and other therapies. Paramedics, Doctors, Basic Health Unit, District and Provincial Level Hospitals, Provincial and Federal Health Authorities are all part of integrated disease management. World Health Organization (WHO) is a global body to assist the governments and societies in promoting health and imparting health education.

27.1.2 Vaccination

The introduction of an **antigenic substance** (vaccine) in the body to produce active immunity against a specific disease is called vaccination.

Vaccine is a biological preparation; it contains pathogen in killed or attenuated (weakened) form which can develop immunity but is not able to cause disease. A vaccine may also contain components of pathogen such as its proteins or toxins. Vaccines artificially activate the immune system to produce **antibodies** against the antigen present in vaccine. So that in future if one gets infected by such **pathogen**, the body has the potential to form accurate antibodies to destroy that particular **antigen**. Vaccination provides a lasting effect; it usually takes several weeks to develop immunity.

Extra Information

In last 70 years' vaccines have helped to eradicate infectious diseases like small pox. World Health Organization (WHO) estimates that 2 to 3 million deaths are prevented every year through immunization against diphtheria, tetanus, whooping cough and measles.

Importance of Vaccination

Vaccination is the most effective way used to **boost** immune system and prevent serious life threatening diseases that were once common worldwide *i.e.* polio, mumps, measles and tetanus. Vaccination is largely responsible for eradication of small pox worldwide. There can be mild side effects after vaccination such as low grade fever, nausea, fatigue, pain or redness on that area and chills. (Fig.27.2)

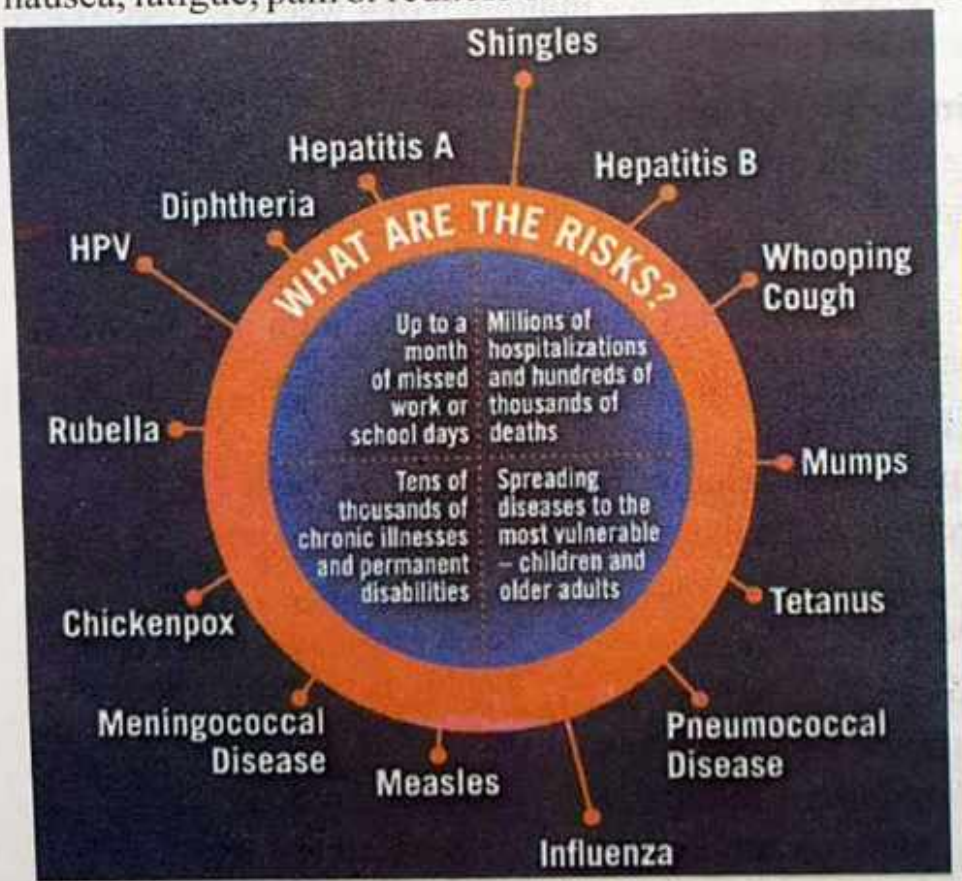


Fig.27.2: Vaccines for 14 Deadly Diseases

Interesting Information

Human papillomavirus (HPV) is most common sexually transmitted infection, causes genital warts and cancer.

Shingle: Shingle is viral infection that causes a painful rash blisters occur anywhere on the body, most often appears in torso.

Table 27.1: List of Viral Diseases Against which Vaccine are Required

i)	**Hepatitis A**	Hep-A Vaccine protects against hepatitis A.
ii)	**Hepatitis B**	Hep-B Vaccine protects against hepatitis B.
iii)	**Flu**	Flu-Vaccine protects against influenza.
iv)	**Measles, Mumps and Rubella**	MMR-Vaccine protects against measles, mumps and Rubella.
v)	**Polio**	OPV and IPV-Vaccine protects against polio.

27.1.3 Role of vaccines in Preventing Diseases

It is always better to prevent a disease than to treat it after it occurs. *i.e.* **prevention is better than cure**. Diseases that used to be common around the world can now be prevented by vaccines. Over the years' vaccines have prevented countless cases of disease.

i) Vaccination against Polio

Poliomyelitis is a **disabling disease** caused by polio virus that results in muscle weakness and **paralysis**. Two types of polio vaccines are used: (1) An inactivated polio virus (IPV) given by injection and (2) weakened polio virus (OPV) given by oral route. WHO recommends OPV vaccine at birth followed by a primary series of 3 OPV and at least one IPV doses starting at 6 weeks of age with a minimum of 4 weeks between OPV doses. These vaccines have **eliminated** polio from most of the world.

ii) Vaccination against measles and mumps

Measles and mumps are caused by different viruses but share unique symptoms. There is a common vaccine against measles, mumps and rubella called **MMR vaccine**. MMR vaccine is administered via **subcutaneous route**, starting with first dose at 12-15 months of age and second dose is at 4-6 years of age. The maximum age for MMR vaccine administration is 12 years.

iii) Vaccination against Hepatitis

Hepatitis is an inflammatory condition of liver, commonly caused by viral infections of the liver that are classified as hepatitis A, B, C, D, and E, Vaccine is available only for hepatitis A and B.

iv) Vaccination against Tetanus (Lockjaw)

Tetanus also called **lockjaw** is a serious infection caused by a bacterium ***Clostridium tetani***. This bacterium produces a toxin that affects brain leading to stiffness in the muscles. Tetanus is prevented by tetanus

Extra Reading

Vaccines cause "herd immunity" which means if the majority of people in a community have been vaccinated against a disease, an unvaccinated person is less likely to get sick because others are less likely to get sick and spread disease.

vaccine also known as **tetanus toxoid**, is an **inactivated vaccine**. During childhood five doses are recommended. Additionally, one dose every ten years is recommended.

27.1.4 Schedule of Vaccination of Common Infectious Disease

Table 27.2: Schedule of Vaccination

Disease	Vaccine	Type	Age group
Polio	OPV (Oral Polio Vaccine)	Live weakened vaccine	From birth to 5 years of age
Hepatitis	Hepatitis-B Vaccine	Recombinant DNA	At any age
Measles + Mumps+ Rubella	MMR (Measles, Mumps, Rubella and Vaccine)	Combination vaccine	Up to one year of age
Diphtheria + Tetanus	Diphtheria toxoid (DT) vaccine, Tetanus toxoid (TT) vaccine	Toxoid vaccine	Generally in childhood

27.2 Animal Husbandry

Animal husbandry is the branch of agriculture which deals with the practice of breeding, farming, management and care of livestock like cattle, sheep, horses, cow and chickens for advantages. In animal husbandry genetic qualities and behaviours considered to be advantageous to humans are further developed. Animals are raised for meat, milk, eggs, fibre, leather and other products like vaccines and antiserum for medical use. Cattle and sheep are improved to yield more meat, milk and wool by **agriculturalists**. Animal husbandry includes proper feeding, watering and cleaning the living area of animals. The breeding of farm animals is managed by farmers with a view to encouraging traits considered as desirable that include fast growth rates, low feed consumption, higher yields, better quality fibres. **Selective breeding** has been responsible for large increases in productivity. Good husbandry, proper feeding and maintaining hygiene contribute to animal health which brings economic benefits. When animals become sick they are treated by veterinary medicines by farmer and veterinarian.

Extra Information

Cows have almost 360-degree sight and can see all colors except red. It can drink a whole tub of water in just one day and have strong sense of smell.

Role of Livestock in National Economy

Livestock are the domesticated animals **reared** commercially for sale on a farm or agricultural business. It is an inclusive general word, which includes animals like cattle, sheep, goats and birds *etc.* The livestock animals give us food like meat, eggs and milk. The horses, donkeys and mules are also part of livestock.

The livestock plays an important role in the economy of Pakistan. About 30-40%

of income in our country comes from livestock. The livestock sector contributes 50% of the agriculture value added products and 11% to national gross domestic product (GDP). 8% of total exports derived from livestock and their products.

Pakistan is luckily having some best dairy breeds like **Nili**, **Ravi** and **Kundi buffaloes** and **Red Sindhi** and **Sahiwal cattle**. (Table 27.3)(Fig.27.3)

Table 27.3: Some outstanding Breeds of Milk Producing Cows and Buffaloes

S.No.	Name of Cow	Milk yield per lactation Cycle
i)	Holstein-Friesian	12,700 L
ii)	Friesen	7800 L
iii)	Ayrshire	7,711 L
iv)	Jersey	7,260 L
	Name of Buffalo	
i)	Nili-Ravi	1500 - 2300 L
ii)	Jaffarabadi	1000 - 1200 L
iii)	Godavari	1200 - 1500 L
iv)	Bhadawari	800 - 1000 L



Fig. 27.3: Cow and Buffalo

27.3 Latest Techniques applied to Enhance Crop and Fruit Yields

27.3.1 Plant Breeding

It is the application of genetic principles to produce plants that are more useful to humans. Genetic potential of crops is improved through **plant breeding**.

There are various plant breeding techniques used for changing the traits of plants to improve quality and

Extra Information

Plant breeding was initiated by Mendel when he crossed different varieties of pea plants.

quantity of crops. Some methods are mentioned below.

Interesting Information

Dairy cows typically live to their third lactation before being **culled**. Naturally, a cow can live for 20 years.

i) Selection

One of the ancient and major techniques of plant breeding is selection. In this method plants with desirable characteristics are selected and used for further breeding and cultivation.

ii) Hybridization

It is the frequently used method of plant breeding in which desired traits found in different plants are brought together into plant via cross pollination. Individual produced as a result of cross between two genetically different parents is called **hybrid**. Hybridization does not change genetic contents of organisms but it produces new combination of genes. The main objective of hybridization is to create genetic variation. Segregation and recombination produce many new gene combinations in second generation. Improved or increased function of any biological quality in a hybrid than both of its parents refers to **heterosis** or **hybrid vigour**. Heterosis is used to increase yields, uniformity and vigour. Hybrid breeding methods are used in maize, sorghum, rice, sugar beet, onion, spinach, sunflower, and broccoli.

Acclimatization

This is the process in which the plants are introduced to a new environment where plants adjust to gradual changes of climatic conditions in its new environment *i.e.* change in temperature, humidity photoperiod and pH. In acclimatization the introduction of genotypes from the place where it is grown to an entirely new area takes place. It is the easiest and most common method of crop rotation.

Acclimatization is different from adaptation as **acclimatization** is short term response to the change in the environment while **adaptation** is long term response to the change in environment occurs over several generations. Moreover, acclimatization does not bring genetic change and reversible while adaptation brings genetic changes and irreversible.

Backcross

Backcross is formed when a hybrid is crossed with one of its parents to introduce a specific trait such as disease resistance. Backcross breeding is an effective method to transfer one or a few genes controlling a specific trait from one line into a second breeding line. Backcross is significant in **Horticulture** and **Animal Breeding** to produce desired characters in species.

Home Gardening

A home garden is a plot of ground usually inside or near a house where ornamental

flowers, fruits, vegetables and herbs are cultivated. It is a delightful and fertile region of house. It is a place for people to live, children to play and it also produces a variety of foods and other things for use in home and to enhance income. A well-developed home garden is a complete farming system. (Fig.27.4)



Fig. 27.4: Home Garden

Importance

A home garden creates a healthy atmosphere in house. It provides instant access to fresh products one can save time and money on buying products from the market. **Organic fruits** and vegetables can be grown at home by skipping the chemical fertilizers and pesticides. The flavour and quality of freshly picked produce from a home garden is superior to store-brought produce with unknown chemicals. Garden plots often reduce soil erosion by holding soil in place. **Ornamental plants** add beauty to the garden.

Table 27.5: Seasonal Vegetables and Fruit Plants

Winter January, February	Cabbage, cauliflower, celery root, grapefruit, mandarin oranges, sweet oranges, pears, spinach, sweet potatoes, *etc.*
Spring March, April, May	Asparagus, basil, beans, berries, broccoli, cabbage, cucumbers, radish, mangoes, okra (lady's finger) oranges, papayas, peas, *etc.*
Summer June, July, August	Corn, cucumbers, dates, figs, grapes, mangoes, okra, peaches, chilli peppers, sweet peppers, plums, tomatoes, watermelon, *etc.*
Fall Sept., Oct., Nov.	Apples, cabbage, cauliflower, cranberries, cucumbers, dates, grapes, pears, chilli peppers, sweet peppers, spinach, sweet potatoes, *etc.*

27.4 Role of Microbes in Human Welfare

Living organisms that are not visible to naked eye are called **microbes** or **microorganisms**. Microbes exist everywhere in air, soil, water, human body and inside plants and animals. Microbes are essential components of life on earth and can be beneficial to humans in several ways. Not all microbes are **pathogenic**.

Extra Information

There are more microbes in human body than the number of cells in our body. There number is estimated to be in trillions.

27.4.1 Role of Microbes in Household Food Processing

Microbes are useful in household food processing in a number of ways. Microbes' convert food items to other varieties. By the action of lacto bacillus bacteria Yogurt can be produced from milk. **Dough** used to make bread is fermented using baker's yeast. Other food items produced with the help of microbes are cheese, wine, soya sauce, *etc.* The yeast used to make bread is also used to ferment malted cereals and fruits juices to make **beverages** *i.e.* beer, whiskey, wine, brandy, *etc.*

Table 27.6: Role of Microbes in Household Food Processing

Source/ Substrate	*Microbe Used*	*Food Product*
Pasteurized milk	*Streptococcus thermophilus* *Lactobacillus vulgaricus*	Yogurt
Pasteurized milk	*Streptococcus sp.* *Lactobacillus sp.*	Cheese
Variety of organic compounds	*Penicillium sp.* *Saccharomyces sp.*	Acetic acid *i.e.* vinegar
Mixture of wheat and soya beans + salt water	*Aspergillus oryzae* *Lactobacillus* and yeast	Soya sauce
Cereal grains ground into flour	*Saccharomyces cerevisiae*	Bread

27.4.2 Role of Microbes in Industrial Production

Industries use microbes to make products that are valuable to Human. Microbes produce chemicals (**Antibiotics**) that can kill or stop the growth of disease causing organisms.

Detergents used to remove oily stains contain enzymes such as **lipases** are derived from microbes. Further microbes help to produce bioactive molecules like **Cyclosporine-A** used to suppress immune system during organ transplant. Microbes can also be used to produce certain non-microbial products such as the diabetes medication **insulin**. They produce chemicals like **ethanol** which is used as fuel, solvent and for various other purposes. **Biofertilizers** consist of living microbes that are added to soil to increase fertility.

Interesting Information

All microbes in a person combined weigh about as much as your brain: about three pounds.

27.4.3 Role of Microbes in sewage treatments

Sewage that is generated by humans daily is treated in **sewage treatment plants (STPs)** to make it less harmful before releasing in to natural water bodies. The main

component of sewage is organic matter but there are other substances such as oil, heavy metals, nitrogen and phosphorous compounds (from detergents and artificial fertilizers). Microbes use the organic material in sewage as their sources of carbohydrate for respiration. Treatment of sewage by microbes involves the following three steps:

i) Primary Treatment
ii) Secondary Treatment
iii) Tertiary Treatment

Extra Information

Researcher suggest that the microbes play a role in digestion, the regulation of your immune system, disease prevention, wound healing, gut lining protect-tion, appetite control, brain development and even our emotions.

i) Primary Treatment

The first step in treating sewage is filtration to remove large objects. These large objects usually go to a **landfill site** or **incinerator**. The remaining material is then allowed to settle so that much of solid material drops to the bottom of tank. The process of sedimentation removes soil and small pebbles. The solid material that settles is primary sludge while the **supernatant** forms the **effluent**. The effluent is then passed through secondary treatment.

Extra Information

Sewage or domestic / municipal wastewater, is a type of wastewater that is produced by a community of people. It is characterized by volume or rate of flow, physical condition, chemical and toxic constituents and its bacteriologic status (which organisms it contains and in what quantities).

ii) Secondary Treatment

The treatment of waste water subsequent to the removal of suspended solids by microorganisms such as algae. Fungi or bacteria under aerobic or anaerobic conditions during which organic matter in waste water is oxidized is termed biological treatment or secondary treatment. In aerobic conditions the **organic contaminants** are converted to CO_2, water and other products. In anaerobic conditions the organic contaminants are converted to a **biofuel gas** comprising CO_2, methane or other products.

iii) Tertiary Treatment

It is the final cleaning process that improves waste water quality before it is discharged. The treatment removes remaining inorganic compounds such as nitrogen and phosphorus. (Fig.27.5)

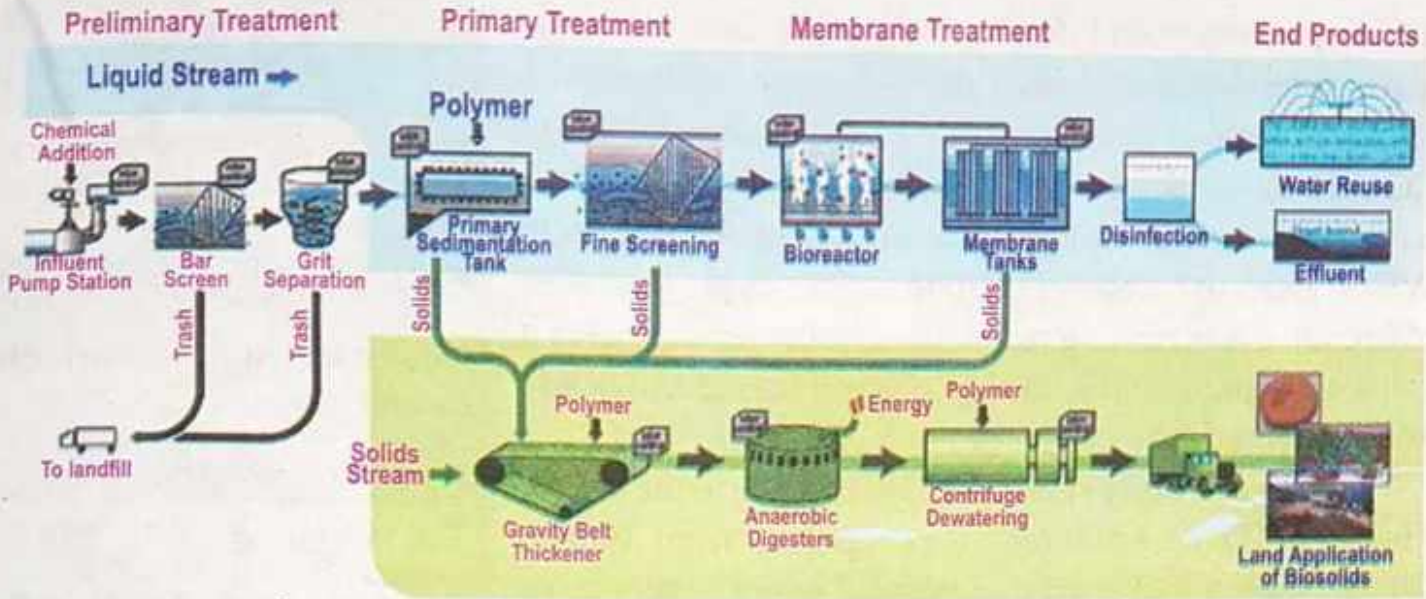


Fig. 27.5: Sewage Treatment Plant

27.4.4 Role of Microbes in Energy Production

Microbes have tremendous potential to produce energy. A microbial fuel cell is capable of generating electricity directly from large variety of organic and inorganic compounds using microbes as **catalyst**. Conventionally fuel cells convert chemical energy to electrical energy by **consumption of fuel** at **anode** and an **oxidant** at **cathode**. The electrons and protons released, travel through an external circuit producing electricity. Microbes can be used to convert the sunlight, CO_2 and nitrogen into a renewable fuel sources. Production of **biodiesel** from **microalgae** and production of hydrogen gas (H_2) by bacteria are other examples of microorganisms in energy generation.

Extra Reading

The SARS (Severe Acute Respiratory Syndrome) is a group of viruses which cause respiratory tract disorders. These viruses thought to be spread from animal sources (perhaps bats). An epidemic of SARS affected 26 countries and resulted in more than 8000 infected cases reported in 2003. This virus was called SARS CoV-1.

The recent **Coronavirus** was first identified in December, 2019. Therefore, it was given name COVID-19 (Coronavirus Disease 2019). In March 2020, the name SARS-CoV-2 is given to this virus. The word corona is a Latin word meaning crown or halo. It is a +ve strand RNA enveloped virus. It is minute in size (65-125 nm in diameter). It is roughly spherical in shape. It causes flu

Pandemic

An epidermic occurring Worldwide or over a very wild area, crossing international boundaries and usually affect a large number of people.

Epidemic

It is rapid spread of disease to a large number of people in a given population with a short period of time.

like respiratory tract infection. It is a contagious disease and is spreading with a high speed throughout the world. So for 16 million people worldwide have affected due to COVID-19 infection. More than half million people have been died from this viral infection. According to WHO, signs of infection include fever, cough, shortness of breath and breathing problem. In more severe cases it can lead to pneumonia, multiple organ failure and death. Some infected patient may be asymptomatic.

The mortality rate is 3.4% according to the WHO. The COVID-19 **epidemic** was reported from Wuhan City of China and spread almost all over the world, so WHO declared it as **pandemic**. Most of the death cases are found in USA, UK, Brazil, Italy, Spain, France, Iran and China. In Pakistan hundreds of thousands of people have been affected. So for more than six thousand people have been died.

Oxidant

Substance that accepts electron from another substance in a redox reaction. It is reduced in a reaction.

Anode

The electrode at which oxidation occurs.

Cathode

The electrode that which reduction occurs.

Science, Technology and Society (STS)

Assess the impact of livestock in boosting up the national economy.

Livestock and poultry production including milk and eggs is the second most important sector of agriculture in our country. Pakistan being an agricultural based economy has a great potential in livestock. Livestock has a share of 10.8% of Pakistan total GDP. Livestock sector employs 35 million people and produces almost $500 million products. Vast majority is of small firms of less than 2 hectors that maintain herds of 1 to 3 animals. Pakistan is fortunate to be the home tract of some of the finest natural breeds of livestock as compared with other regional countries.

SUMMARY

- Animal and plant breeds are improved by techniques of genetic engineering.
- Integrated disease management is a struggle of combating fatal and other common diseases by using a range of measures.
- Introduction of an antigenic substance (Vaccine) in the body to produce active immunity against a specific disease is called vaccination.
- It is always better to prevent a disease than to treat it after it occurs.
- Poliomyelitis is a disabling disease caused by polio virus.
- Measles and mumps are caused by different viruses but share unique symptoms.

- Tetanus is caused by a bacterium *Clostridium tetani*.
- Animal husbandry includes proper feeding, watering and cleaning the living areas of animals.
- Livestock are the domesticated animals reared commercially for sale on a form or agricultural business.
- Backcross is formed when a hybrid is crossed with one of his parents.
- Living organisms that are not visible to naked eye are called microbes.
- Industries use microbes to make products that are valuable to men.
- Microbes have tremendous potential to produce energy.

EXERCISE

SECTION-I: OBJECTIVE QUESTIONS

Multiple Choice Questions (MCQs)

A. Select the correct answer.

1. Td-vaccination is the best way to prevent a tetanus infection.
   (a) Morphology (b) Histology
   (c) Anatomy (d) Physiology
2. Casein is?
   (a) Milk protein (b) Starter culture
   (c) Toxin (d) Gyle
3. Integrated disease management aims to improve the quality of
   (a) Environment (b) Life
   (c) Food (d) Animals
4. Tetanus is also called
   (a) Muscle cramp (b) Muscle fatigue
   (c) Lockjaw (d) Paralysis
5. Animal husbandry is the branch of science deals with care of
   (a) Livestock (b) Fruits
   (c) Diseases (d) Vaccination
6. The best way to prevent polio is
   (a) Antibiotics (b) Cleanliness
   (c) Vaccination (d) Healthy food

7. Which of the following method is used for crop improvement
   (a) Selection (b) Fertilization
   (c) Vaccination (d) Watering
8. The main component of sewage is
   (a) Oil (b) Inorganic matter
   (c) Minerals (d) Organic matter
9. A back cross is made when a hybrid is crossed with its
   (a) Sibling (b) Offspring
   (c) Parents (d) Other species

B. Fill in the Blanks.

1. Integrated disease management aims to improve and maintain the ..... of life.
2. Vaccine is a biological preparation contain ..... in killed or attenuated form.
3. Prevention is better than .....
4. Hepatitis is an inflammatory condition of .....
5. About 30-40% of income in our country comes from .....
6. Hybridization does not change ..... contents of organism but it produces new combination of genes.
7. Measles and mumps are caused by different viruses but share unique .....
8. A home garden creates a ..... environment in house.
9. Biofertilizers consist of living .....
10. Microbes have tremendous potential to produce .....

SECTION-II: SHORT QUESTIONS

C. Give the short answers of the following questions.

1. Define integrated disease management.
2. Write importance of vaccination against prevention of diseases.
3. Write two types of vaccines recommended for polio.
4. Write importance of acclimatization for plant breeding.
5. Define back cross, write its importance.
6. Write importance of home gardening.
7. Write role of microbes for energy production.

D. Give detailed answers of the following questions.

1. Define and explain animal husbandry and role of livestock in national economy.
2. Explain the latest techniques applied to enhance crop production.
3. Describe the role of microbes in human welfare.
4. Describe three steps of sewage treatment by microbes.

GLOSSARY

A

A-band: The length of myosin with overlapping actin in a sarcomere.

Abiotic: The non-living components of the environment or ecosystem like water, sunlight, soil, heat, *etc.*

Abortion: Termination of pregnancy.

Acid Rain: The rain containing sulphuric acid and nitric acid; with pH range from 3 to 6.

Acrosome: Cap-like head of sperm cell which helps it in penetrating the egg cell contains enzymes.

Adrenocorticotropic Hormone (ACTH): This hormone is secreted by the anterior pituitary gland which stimulates the adrenal cortex to release corticosteroids.

Addictive Drug: The drug which makes a person dependent on it, or addicted.

Aldosterone: A hormone secreted by the adrenal glands that controls the reabsorption of sodium in the descending loop of Henle's of nephron.

Allele: The alternative form of a gene (Tt, Rr).

Alternation of generations: In plants, the phenomenon in which the sporophyte (diploid and asexual) and gametophyte generations (haploid and sexual) alternate with each other.

Alveolar duct: The bronchioles end as fine tubules called the **alveolar ducts.**

Alveolus: A sac-like structure present next to the alveolar duct in lungs (Unit of lung).

Ammonification: The decomposition of protein of dead plants and animals, and nitrogenous wastes to change ammonia by ammonifying, bacteria.

Analgesic: The medicines that reduce pain.

Androecium: The male reproductive whorl of the flower; consists of stamens, produce pollen grains.

Aneuploidy: Variation in chromosome number involving one or a few of chromosomes.

Anticodon: A sequence of three nucleotides on the transfer RNA molecule that recognizes and pair with a specific codon on a messenger RNA molecule.

Anther: The sac-like structure of a stamen in which pollen grains are enclosed.

Antibiotics: The medicines which inhibit or kill bacteria.

Artificial selection:	Selective breeding between individuals for certain traits, or combination of traits.
Aspirin:	Acetaminophen; A pain-killer medicine.
Asthma:	An inflammation of the bronchi of lung that causes swelling and narrowing to the airways.
Autosomes:	Other than the sex chromosomes contains genes for bodily traits.
Atmospheric Nitrogen fixation:	The conversion of atmospheric gaseous nitrogen to nitrates by thunderstorms and lightning.

B

Ball-and –socket joint:	The joint that allows movement in all directions *e.g.* hip and shoulder joints.
Biceps:	A flexor muscle on the front of the upper arm bone contains two heads.
Biomass:	The total weight of living tissue in a community.
Binary fission:	Division into two; the simplest method of asexual reproduction in prokaryotes and many unicellular eukaryotes.
Biocidal:	The antibiotics that work by killing bacteria.
Biogeochemical cycle:	The cyclic pathway through which chemical elements move from environment to organisms and back to the environment.
Biosphere:	The last level of ecological organization, all the ecosystems of the world together form the biosphere (living and non-living part of world).
Biostatic:	The antibiotics which reduces bacterial multiplication and prevent the reproduction of bacteria.
Biotechnology:	The use of living organisms in systems or processes for the manufacture of useful products or for services for humankind.
Biotic:	The living components of the ecosystem include producers, consumers and decomposers.
Bone:	Hard connective tissue; moves, supports and protects the various organs of the body.
Breathing:	The process through which animals take air in their bodies to get oxygen and remove carbon dioxide.
Breeds:	The animals which are bred through artificial selection.
Bronchioles:	Fine tubules without cartilages formed by the division of the bronchi.
Bronchitis:	Inflammation in the bronchi or bronchioles of lungs.
Bronchus: (Pl. bronchi)	The part of air passageway; formed by the division of the trachea.

Blastocoels:	The fluid-filled cavity in blastula.
Blastocyst:	The developmental stage of the fertilized ovum by the time it is ready to implant.
Blastula:	A ball of cells surrounding a fluid-filled cavity called blastocoel. It is produced by the repeated cleavage of a zygote.
Budding:	An outgrowth; a type of asexual reproduction in which a bud develops as a small outgrowth on parent's body and forms the new individual.
Bulb:	Underground vertical shoots which have modified leaves such as onion.

C

Calcitonin:	Thyroid hormone that plays a role in regulating calcium levels.
Calyx:	The outer whorl of flowers; consists of sepals (green part).
Carbon Cycle:	The biogeochemical cycle in which carbon flows between organisms and the environment.
Carnivore:	The consumers which eat only animal flesh.
Carpel:	Part of the gynoecium of the flower; consists of stigma, style and ovary (female part).
Cartilage:	The connective tissue that makes part of the human skeleton, soft and flexible.
Cervix:	In female reproductive system, the part between uterus and the vagina.
Chemosynthetic:	Organisms (usually bacteria) that derive energy from inorganic reactions; also known as chemosynthetic.
Chondrocytes:	Cartilage forming cell.
Chromatin:	The chemical material that make the structure of the chromosome (DNA and Proteins).
Chromosomes:	These are thread like structures in the nucleus of a eukaryotic cell which is made of DNA and protein.
Chromosome theory of inheritance:	Holds that chromosomes are the cellular components that physically contain genes; proposed in 1903 by Walter Sutton and Theodore Boveri.
Clavicle:	The collar bone, in pectoral girdle.
Climax community:	The stage in community succession where the community has become relatively stable through successful adjustment to its environment.
Cloning:	Type of asexual reproduction in which identical offspring are produced form a vegetative tissue or cell of one parent.

Dialyzer:	The apparatus used for haemodialysis, which act as artificial kidney.
Diaphragm:	The muscular structure that forms the floor of the chest cavity; present below lungs, separate thorax from abdomen.
Diencephalon:	Part of the forebrain; consists of the thalamus and hypothalamus.
Dihybrid cross:	A genetic cross in which two pairs of contrasting traits are studied (Rr Yy).
Distal convoluted ubule:	The last part of the nephron between collecting duct and loop of Henle.
Divergent evolution:	The divergence of a single interbreeding population or species into two or more descendant species came due to adapting in different environment.
Dominant:	An allele or a gene that is expressed in an organism's phenotype, masking the effect of the recessive allele or gene when present.
DNA hybridization:	The formation of hybrid DNA molecules that contain a strand of DNA from two different species.
DNA ligase:	An enzyme that seals together two DNA fragments from different sources to form a recombinant DNA molecule.
DNA polymerase:	An enzyme that links the complementary nucleotides together to form the newly synthesized strand.
Dominance hierarchy:	A social structure among a group of animals in which one is dominant and the others have subordinate nonbreeding positions.

E

Ecological niche:	The role, occupation or job an organism it performs in an ecosystem; closely associated with feeding.
Ecological Pyramid:	A representation of the number of individuals or amount of biomass or energy present in various trophic levels of a food chain.
Emphysema:	Lung disease in which the walls of the alveoli are destroyed.
Endosperm:	In the female gametophyte, the triploid nucleus formed by the fusion of sperm and the fusion diploid nucleus (Nutritive in function).
Endometrium:	The inner most lining of the uterus.
Endospore:	The spore formed inside the bacterial cell (during unfavorable conditions).
Endothermy:	The internal control of body temperature; the ability to generate and maintain internal body heat.

Environment:	The sum total of physical (abiotic) and biotic conditions which influence the organism.
Epididimys:	A storage area for sperms on the upper part of the testes.
Epinephrine:	A hormone of adrenal medulla that secreted under stress; contributes to the "fight or flight" response.
Epistasis:	The masking of the effects of one gene (hypostatic) by the action of another gene (epistatic).
Excretion:	The process by which the metabolic wastes (ammonia, urea and uric acid) are removed from the body.
Exons:	Exons are coding portion of DNA separated by introns that does node code for any amino acid sequences.
Exhalation / expiration:	The phase of breathing in which air is removed from the lungs.
Extensor:	A muscle that extends a joint.
Extinction:	The elimination of a species, both by natural (dinosaurs) and human-induced.

F

Fallopian tube or oviduct:	A part of the female reproductive system; receives egg cell discharged from the ovary.
Fermentation:	The process in which there is an incomplete oxidation-reduction of the organic substrate (glucose).
Fermenter:	A device that provides optimum environment in which organisms can grow to produce commercial products.
Fibroblast:	Connective tissue that secrete elastin and collagen protein fibres.
Fibrous cartilage:	The cartilage that has large number of fibres in the matrix *e.g.* the cartilage in intervertebral disc.
Flexor:	A muscle that bends a joint.
Follicle:	A structure in the ovary in which the mature egg develops.
Food Chain:	The series of organisms in an ecosystem, in which an organism eats the preceding one and is eaten by the next one.
Food Web:	A network of interconnected food chains; has a number of feeding connections among different organisms of a community.
Founder effect:	The difference in gene pools between an original population and a new population founded by one or a few individuals randomly separated from the original population.
Fragmentation:	A type of asexual reproduction in which an organism breaks up into many pieces and each piece develops into mature animal.

G

Gametogenesis:	The process of the formation of gametes.
Gametophyte:	The haploid generation in plant life cycle; produces gametes.
Gaseous exchange:	Taking in and giving out of gases (oxygen and carbon dioxide) by organism during respiration.
Gene:	Unit of inheritance; consists of the length of DNA that contains specific instructions for the synthesis of a protein molecule.
Gene pool:	The sum of all the genes carried by members of a population.
Gene therapy:	The insertion of foreign genes into cells through the use of recombinant DNA technology; usually done to replace defective genes to treat genetic disorders.
Genetic drift:	Random changes in the frequency of alleles from generation to generation; especially in small populations, can lead to the elimination of a particular allele by chance alone.
Genetically Modified Organism (GMO):	The organisms which are genetically modified such as cattle / chicken).
Genotype:	The specific combination of allele in an individual; may be homozygous or heterozygous (TT, Tt, tt)
Glial cells:	The cells that serve as support and nourish cells in the nervous system. Thus help to protect neurons.
Global Warming:	Increase in the temperature of the earth. Due to the addition of greenhouse gases in atmosphere, which do not allow solar radiations to reflect back into the space.
Glomerular filtrate:	The material that passes form glomerulus into the Bowman's capsule.
Glomerulus:	The network of capillaries in the bowmen' capsule of nephron.
Gonorrhoea:	A sexually transmitted disease that is caused by a bacterium (*Neisseria*).
Gout:	A type of arthritis; characterized by the accumulation of uric acid crystals in the moveable joints.
Grafting:	A type of artificial vegetative propagation in which a piece of stem is cut from the plant and is inserted into another plant with established root system.
Guttation:	Appearance of drops of xylem sap on the tips or edges of leaves (in early morning)
Gynoecium:	The central whorl in the flower; consists of carpels (Female part).

H

Hallucinogen:	Drug that causes changes in perception, thoughts emotions and consciousness.
Hemizygous:	Having one or more genes that have no allele counterparts *e.g.* "XY" sex chromosomes.
Hemodialysis:	The dialysis in which patient's blood is pumped through the dialyzer for cleaning.
Heroin:	A commonly abused narcotic; derived from morphine; affects the central nerve system and causes drowsiness, disorientation, hypotension, *etc.*
Heterozygous:	The genotype that has two different alleles of a trait (Tt, Rr).
Hilus:	A depression in the kidney through which the ureter, blood and lymphatic vessels and nerves enter and leave the kidney.
Hinge joint:	A joint that permits movement of bones in one plane *e.g.* elbow and knee joints.
Histone:	The protein present in the structure of chromosome.
Homeostasis:	The maintenance of a constant internal environment in response to environmental changes.
Homologues:	A pair of chromosomes in which one member of the pair is obtained from the organism's maternal parent and the other from the paternal parent; found in diploid cells. Also commonly referred to as homologous chromosomes.
Homologous chromosomes:	A pair of chromosomes having the same size and shape and carrying alleles for the same traits.
Homozygous:	Having two identical alleles of a trait (TT, tt).
Hyaline cartilage:	The cartilage that has collagen fibres in its matrix; found covering the ends of the long bones, in the nose, larynx, trachea and bronchial tubes.

I

Implantation:	The process in which the blastocyst (embryo) embeds in the endometrium.
Incomplete dominance:	A type of inheritance in which neither of the pair of contrasting alleles is dominant over the other and the heterozygous individual is intermediate in phenotype (Japanese 4 o'clock) plant
Inhalation:	Inspiration! Intake of air to lungs.
Inheritance:	The transmission of characteristics forms parents to offspring.

Inheritance of acquired characteristics:	Lamarck's view that features acquired during an organism's lifetime would be passed on to succeeding generations, leading to inheritable change in species overtime.
Initiation codon (AUG):	Three-base sequence on the messenger RNA that codes for the amino acid, methionine. The start codon on mRNA.
Insertion:	The end of the muscle that is attached with a moveable bone.
Interspecific Interactions:	Interactions between the members of the different species.
Intraspecific Interactions:	Interactions between the members of the same species.
Intron:	In eukaryotes, bases of a gene transcribed but later removed from the primary mRNA, the non-coding portion of DNA.
Iodopsin:	A pigment present in the cones of the retina (green, red and blue).
Iris:	Colored portion of eyeball, formed by the bending of the choroid behind the cornea of the eye.
Islets of Langerhans:	Scattered groups of endocrine cells present in pancreas; secrete hormones insulin and glucagon.

J

Joint:	The location at which two or more bones meet.

K

Karyotype:	Total complement of chromosomes in a cell.
Klinefelter syndrome:	In humans, a genetically determined condition in which the individual has two X and one Y chromosome. Affected individuals are male and typically tall and infertile (male eunuch).

L

Lacuna:	The fluid filled space in bone and cartilage, where their cells are present.
Larynx: / Sound Box:	The part of the air passageway between pharynx and the trachea, contains vocal cord, produces sound.
Lenticels:	Respiratory pores in the bark of woody stems and mature roots.
Ligament:	Strong but flexible connective tissue that joins bone to bone.
Lithotripsy:	Method for the removal of kidney stones, without surgery.
Linkage:	The condition in which the inheritance of a specific chromosome is coupled with that of a given gene. The genes stay together during meiosis and end up in the same gamete.

Locus:	The location or position of gene on chromosome.
Loop of Henle:	The U- shaped portion of the renal tubule of nephron.

M

Medulla oblongata:	Last part of brain (part of Hindbrain), controls breathing, heartbeat, blood pressure and many reflexes.
Meninges:	Three membranous layer around the brain and the spinal cord protect them and provide nutrients and oxygen through their capillaries.
Messenger RNA (mRNA):	"Blueprint" for protein synthesis that is transcribed from one strand of the DNA (gene) and which is translated at the ribosome into a polypeptide sequence.
Mixed nerve:	Those nerves which possess axons of both the sensory and motor neurons.
Monohybrid cross:	A genetic cross in which only one pair of contrasting traits is studied (Tt or Rr).
Motor Nerve:	Nerves contain the axons of motor neurons only.
Morula:	The solid-ball of cells, stage of the pre-implantation embryo.
Multiple fission:	Division into many; a method of asexual reproduction used by many unicellular organisms.
Mutation:	Change in chromosome or DNA (gene); produces variations in the traits.
Mutualism:	The symbiotic association in which both the partners get benefit and neither is harmed.
Myelin Sheath:	Formed of Schwann cells. The insulating sheath around the axons of some neurons.
Myofibrils:	Each skeletal muscle cells contain many myofibrils.
Myosin:	Thick myofilament in the centre sections of sarcomeres of muscle cells.

N

Nasal cavity:	Hollow space in the nose; opens to the outside through nostrils.
Natural Resources:	The resources on earth, which provide everything that humans use or consume.
Natural selection:	The process in which organisms with favourable variations survive and produce more offspring than less well-adapted organisms.
Nephron:	The structural and functional unit of kidneys.
Nerve impulse:	Conduction of information to and from brain.

Nerve:	Bundle of axon, covered by myelin sheath.
Net primary productivity (NPP):	The rate at which producer (usually plants) biomass is created in a community.
Neuron or Nerve cell:	The unit of the nervous system; able to conduct nerve impulses.
Niche:	The biological role played by a species, in a ecosystem.
Nitrification:	The oxidation of ammonia to nitrites and nitrates by the nitrifying bacteria.
Nitrogen Cycle:	The flow of nitrogen between environment and the organisms.
Nitrogen Fixation:	Conversion of nitrogen into nitrates.
Nodes of Ranvier:	A gap between two of the Schwann cells that make up an axon's myelin sheath; serves as a point for generating a nerve impulse.
Nostrils: / Nares:	The openings of the nasal cavity called nostrils.
Nondisjunction:	The failure of chromosomes to separate properly during cell division.
Nucleosome or Bead:	The structure formed by the wrapping of DNA around at histone proteins.

O

Oogenesis:	The formation of ovum (egg cell).
Organic evolution:	Biological evolution: The modification of characteristics in the species or populations of organisms during their descent, generation by generation.
Origin:	The initiating end of the muscle that is attached with an immoveable bone.
Osmoconformers:	Marine organisms that have no system of osmoregulation.
Osmoregulation:	The regulation of water content in body fluids, or solute regulation.
Osteoarthritis:	Inflammation in joints due to degeneration in the cartilage present at the joints or due to decreased lubricant production at the joints.
Osteoblasts:	Bone-forming cells.
Osteoclasts:	Cells (a type of WBC) that remove material to form the central cavity in a long bone.
Osteocyte:	The mature bone cells.
Osteoporosis:	A disorder in which the mineral portion of bone is lost, making the bone weak and brittle; occurs most commonly in postmenopausal women.
Ovary:	The female gonad; produces egg cells and female sex hormones.

Oviducts:	Tubes that connect the ovaries and the uterus; transport sperm to the ova, transport the fertilized ova to the uterus.
Ovulation:	The release of the oocyte onto the surface of the ovary.
Ovum:	The female gamete, egg.
Oxytocin:	A peptide hormone secreted by the posterior pituitary that stimulates the contraction of the uterus during childbirth.
Ozone:	A triatomic (O_3) form of oxygen that is formed in the stratosphere. This atmospheric ozone helps filter radiation from the sun.

P

Pacinian corpuscles:	The skin sensory receptors located deep in the epidermis that detect pressure and vibration.
Palaeontology:	The study of ancient life (fossils).
Papillary ducts:	The ducts formed by the joining of many collecting ducts; open into renal pelvis.
Paralysis:	Complete loss of function by one or more muscle groups due to damage in the nervous system.
Parasitism:	A type of interspecific interaction in which smaller partner (parasite) derives food and shelter form the body of larger partner (host) and harms the host.
Parathormone:	Hormone of the parathyroid glands; increases the level of calcium ions in the blood.
Parathyroid:	The endocrine glands located on the posterior sides of the thyroid gland; secrete parathormone.
Parasympathetic system:	The part of the autonomic nervous system that controls heartbeat, respiration and other vital functions. (rest and digestion)
Parthenogenesis:	A form of asexual reproduction in which an unfertilized egg develops into new offspring.
Peritoneal dialysis:	The dialyzing fluid is pumped into the abdominal peritoneal cavity; the wastes from the blood vessels of the peritoneum diffuse into the dialysis fluid which is then removed out.
Phenotype:	The expression of the genotype in the form of trait *e.g.* tall.
Pituitary:	The endocrine gland attached to the hypothalamus that controls many other endocrine glands in the body thus called master gland of the body.
Pineal gland:	A small endocrine gland located between the cerebral hemispheres of the brain that secretes melatonin.
Pioneer community:	The initial community of colonizing species.

Placenta:	An organ of placental mammals; supplies nutrients to the embryo and fetus and removes wastes.
Plasmids:	Self-replicating, circular DNA molecules found in bacterial cells.
Pleiotropic:	A term describing a genotype with multiple phenotypic effects *e.g.* sickle-cell anaemia produces a multitude of consequences in those it affects, such as heart disease, kidney problem, *etc.*
Pneumonia:	The infection of one or both lung; caused by specific bacteria, viruses or fungi; the infected part of the lung becomes filled with fluid and pus.
Pollen grain:	Anther has pollen-sacs in which haploid microspores (pollen grains) are produced through meiosis.
Pollination:	The transfer of pollen grains from flower's anther to stigma.
Polygenic inheritance:	Occurs when a trait is controlled by several gene pairs; usually results in continuous variation.
Polymerase chain reaction (PCR):	A method of copying DNA fragments that is faster than cloning.
Pons:	Part of the hindbrain; assists the medulla in controlling breathing and serves as a connection between the cerebellum and the spinal cord.
Pressure filtration:	The process in which most of the water salts, glucose and urea of the blood is forced out of the glomerulus and passed into bowman's capsule, pressure is generated by contraction of heart.
Producer:	An organism that produces organic compounds form inorganic compounds; an autotroph.
Progesterone and estrogen:	Ovaries secrete estrogen and progesterone, which are responsible for the development of female secondary characters such as the development of breast, *etc.* prepare uterus for implantation.
Prostate gland:	An accessory gland in the male reproductive system; produces a secretion that neutralizes the acidity.
Proximal convoluted tubule:	The portion of nephron between Bowman's capsule and the loop of Henle`s.
Pupil:	The opening in the centre of the iris of the eye.
Purine:	One of the groups of nitrogenous bases that are part of a nucleotide. Purines are adenine and guanine and are double-ringed structures.
Pyrimidine:	One of the groups of nitrogenous bases that are part of a nucleotide. Pyrimidines are single ringed and consist of the bases thymine (in DNA), uracil (replacing thymine in RNA).

R

Receptor:	May be organs; tissues or cells which detect particular type of stimuli.
Recessive trait:	Expresses only in homozygous, do not express heterozygous condition.
Recombinant DNA:	The combination of two different DNAs.
Reflex:	A response to a stimulus which occurs without conscious control
Reflex arc:	The pathway of reflex action.
Renal Corpuscle:	The glomerulus and Bowman's capsule of the nephron.
Renal pelvis:	The funnel-shaped cavity into which the renal pyramids of kidney project, funnel shape portion of ureter.
Renal pyramid:	Cone- shaped areas in the renal medulla.
Renal tubule:	The tubular portion of nephron consists of proximal convoluted tubule, loop of Henle and distal convoluted tubule.
Renin:	An hormone secreted by the kidneys that converts angiotensinogen into angiotensin II (increase BP).
Replication:	The process by which DNA is duplicated before each cell division.
Resting potential:	The non-conducting portion of neuron *i.e.* inside –ve charge and outside +ve charge.
Restriction Endonucleases:	Enzymes used to cut the gene from the DNA of the organism.
Retina:	The innermost and the sensitive layer in the eye, contains rods and cons.
Rheumatoid arthritis:	Painful inflammation of the membranes at the joints (especially fingers).
Rhodopsin:	A pigment present in the rods of the retina.
Rods:	The photosensitive cells present in the retina of the eye; sensitive to dim light.
RNA transcript:	The term applied to RNA transcribed in the nucleus.

S

Sarcomeres:	The functional units of skeletal muscle.
Schwann cells: (neuroglial cells)	The supporting cells around neurons; form the myelin sheath.
Secretin:	A hormone produced in the duodenum that stimulates alkaline secretions by the pancreas and inhibits gastric emptying.
Sclera:	The tough; white outer layer of the eye.
Semen:	The material containing sperms.

Seminal Vesicle:	The associated gland in male reproductive system; produces secretions having nutrients for the sperms.
Seminiferous tubule:	The coiled tubes present in testes; sperms are formed in these tubules.
Sensory nerve:	The nerves which contain only the axons of sensory neurons.
Single-Cell Protein:	The protein content extracted from pure or mixed cultures of algae, yeasts, fungi or bacteria; the micro-organisms are grown in fermenters where they produce a high yield of protein.
Skeleton:	The framework of hard, articulated structures that provide physical support, attachment for skeletal muscles, and protection for the bodies of animals.
Skeletal muscle:	These are generally attached to the skeleton and causes body parts to move; consists of muscle fibers.
Smooth muscle:	The non-striated, found around all pollen internal organs except heart.
Social behaviour:	Behaviour that takes place in a social context and results from the interaction between and among individuals.
Somatic nervous system:	The portion of the peripheral nervous system consisting of the motor neuron pathways that innervate skeletal muscles.
Somatotrophin:	(STH) or Growth hormone A hormone of the anterior pituitary; promotes the growth of the body.
Sperm:	The male gamete.
Spermatid:	The immature non-motile forms of sperms; are converted into sperms after many changes.
Spermatogenesis:	The process of formation of sperms.
Spermatogonium:	A spermatogonium is an intermediary male gametogonium (a kind of germ cell) in the production of spermatozoa.
Spinal nerve:	The nerves which arise from the spinal cord.
Spongy bone:	The soft and porous interior of the bone; contains blood vessels and bone marrow help in formation of blood cells.
Start codon:	The codon (AUG) on a messenger RNA molecule where protein synthesis begins. AUG code for methionine amino acid.
Sternum:	The breastbone.
Stop codon:	The codon on a messenger RNA molecule where protein synthesis stops. The stop codons are UAA, UGA, UAG.
Suspensory ligament:	The ring that attaches the lens of the eye to the ciliary muscles.
Symbiosis:	Long or short term relationship between members of different species i.e. commensalism and mutualism (in which both are beneficial).

Synapse:	The junction between an axon and an adjacent neuron, help to transmit impulse.
Synapsis:	The alignment of chromosomes during meiosis-I so that each chromosome is beside its homologue (Pairing of homologous chromosomes).

T

Tarsals:	The bones that make up the ankle joint, heal and instep.
Taxis:	The behaviour when an animal turns and moves toward or away from an external stimulus.
Template strand:	Strand of DNA that is transcribed to make RNA.
Tendon:	Tough connective tissue that attaches muscles to bones.
Testes:	The male sex organs (produces sperm).
Testosterone:	The male sex hormone secreted by testis.
Tetrad:	The four chromatids in each cluster during synapsis; formed by the two sister chromatids in each of the two homologous chromosomes.
Thalamus:	The part of the forebrain; which is a relay centre between various parts of the brain and spinal cord.
Thyroid:	The endocrine gland located in front of the trachea beneath the larynx secretes hormones thyroxin and calcitonin.
Thyroid-stimulating-hormone: (TSH)	A hormone secreted by the anterior pituitary of the pituitary gland that regulates the formation and secretion of thyroid hormone.
Thyroxin:	The hormone of the thyroid gland; increases metabolic rate and release of energy; also responsible for the growth of body.
Trachea:	Also called wind pipe and part of the passageway between larynx and bronchi, made of C- shaped cartilages.
Trait:	The characteristics which are controlled and transmitted to next generations through genes.
Transcription:	The synthesis of RNA from a DNA template. The making of RNA from one strand of the DNA molecule.
Transgenic:	Organisms contain recombinant genes.
Translation:	The synthesis of polypeptide on a template of messenger RNA.
Triceps:	An extensor muscle on the back of the upper arm bone.
Tropic hormone:	The hormone made by one endocrine gland that causes another endocrine gland to secrete a hormone.
True-breeding:	The homozygous individual.

U

Umbilical cord:	The structure containing arteries and vein that connects the placenta and the embryo.

Uracil:	The pyrimidine that replaces thymine in RNA molecules and nucleotides.
Ureter:	A tube that carries urine from a kidney to the urinary bladder.
Urethra:	The tube that carries urine from urinary bladder to the outside of the body.
Urinary bladder:	A sac-like organ where urine is temporarily stored before being excreted.
Urinary system:	The system responsible for the production and excretion of urine includes kidney, ureters, urinary bladder and urethra.
Urine:	Fluid containing various wastes that is produced in the kidney stored in blade and excreted from the body via urethra.

V

Vaccine:	The material used to produce immunity to a disease by stimulating the production of antibodies.
Variations:	A characteristic in an individual that differs from the typical characteristics of other individuals of the same species.
Vasectomy:	A contraceptive procedure in men in which the vas deferens is cut and the cut ends are sealed to prevent the transportation of sperm.
Vasopressin:	It is also called antidiuretic (ADH). The hormones secreted by the posterior pituitary; responsible for the reabsorption of water from renal tubules of the nephron.
Vector:	Self-replicating DNA molecules that can be joined with DNA fragments to form recombinant DNA molecules.
Vestibule:	Part of the inner ear; helps to maintain balance of the body.
Vestigial structures:	Non-functional remains of organ that were functional in ancestral species and may still be functional in related species *e.g.* appendix.
Vital capacity:	The maximum volume of air that a respiratory system can inhale and exhale.
Vocal cords:	The bands of muscle within larynx vibrate to produce voice.

W

Wild type:	An individual with normal phenotype.

X

X-chromosome:	One of the sex chromosomes.

Z

Z lines:	Dense areas in myofibrils that mark the beginning of the sarcomeres. The actin filaments of the sarcomeres are anchored in the Z line.
Zygote:	One cell life *i.e.* diploid product of the union of haploid gametes.

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