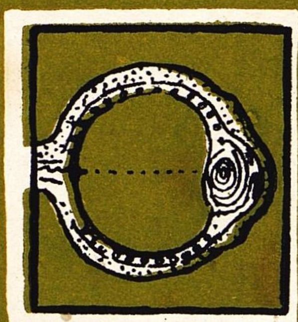
ZOOLOGY

HIGHER SECONDARY - SECOND YEAR



TAMILNADU TEXTBOOK SOCIETY

ZOOLOGY

Higher Secondary—Second Year

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CHAPTER I

PHYSIOLOGY

The word physiology was in use as early as the 16th century, but it was only in the 19th century that it was used widely to denote that branch of biology concerned with the functions of living organisms. Most of our knowledge on the physiology of animals are based on a study of mammals. In a study of physiological aspects of animals, it is necessary not only to study the functions of various organs and organ systems, but also to study the interaction and integration between different organ systems and the way in which the whole organism maintains itself under different environmental conditions. W. B. Cannon (1932) Harward University was the first to realise the importance of an integration of organ systems. He called the phenomenon as homeostasis. A similar concept was formulated by Claude Bernard when he distinguished between milieu interieur or internal environment and milieu exterieur or external environment. He maintained that the internal environment, formed of the fluid in which tissue and cells are bathed in the body, was constant and that it permitted independence from the external environment. **CYBERNETICS** means the study of the science of control systems applied to artificial and living systems (temporary regulation).

Homeostasis therefore includes the co-ordinated (Integrated system) physiological processes which maintain most of the constant or steady states in living organisms, i.e. it is **the tendency in the animal to maintain itself in a given condition or steady state.** It does not imply a static condition however, for a given state may fluctuate as the various controlling factors interact with one another.

1. Nutrition

All organisms require food for their sustenance, growth, and energy requirements. This food is synthesised by plants from natural resources like CO_2 and water with the help of the wonder pigment chlorophyll and sunlight. But animals have to depend upon the food synthesised by plants directly or indirectly.

The food taken by the animals are divisible fundamentally into three main chemical principles, namely carbohydrates, proteins and fats. Traces of inorganic salts and vitamins are also necessary for the well being of organisms.

CARBOHYDRATES

These are popularly called the sugars and starches. These are composed of carbon, hydrogen and oxygen, the last two elements of which are in the proportion of 2:1 (as in water). There are simple or single sugars called monosaccharides (glucose) double sugars or disaccharides (maltose) and polysaccharides or multiple sugars (cellulose, glycogen).

These sugars and starches are broken down to simple glucose before being absorbed and utilised in the organisms Carbohydrates are energy givers. When they are oxidised they give energy and by products like CO_2 and water. Excess of carbohydrates can be stored in the body and utilised later whenever necessary.

PROTEINS

These are necessary for the body growth and building up protoplasm. These are composed of carbon, hydrogen, oxygen and nitrogen. In addition there will be sulphur and phosphorus. This is the only nitrogenous food. The proteins are broken down to simpler molecules of amino acids before being assimilated. Though proteins can also give energy the main purpose is to build up the tissues of the organisms, and they are called "Body Builders". Excess of proteins taken in, cannot be stored for future use and therefore are excreted.

FATS

There are also energy giving food substances. Fats give more energy than carbohydrates (nearly double the amount as carbohydrates). Fats contain carbon, hydrogen, oxygen but oxygen is very little. Fats are oxidised to give energy and by-products of CO_2 and water. Fats are broken down to simpler molecules of fatty acids and glycerol before being absorbed into the system. Excess of fats can be stored in organisms for later use.

WATER

This is very important for organisms as it is a good solvent for many materials and helps the chemical interactions. Besides, water forms roughly two thirds of body weight of all organisms. Water is obtained by animals either as drinking water or as contained water in food materials or as a metabolic by-product inside. Excess water will be excreted.

INORGANIC SALTS

Chlorides, carbonates and sulphates of many elements like sodium, calcium, potassium, magnesium, iodine, iron etc., are required for the proper functioning of many tissues and glands. These are obtained in traces along with the food that is taken in.

VITAMINS

These are more clearly understood by observing animals which do not have vitamins in their diet. The vitamins are by themselves not very useful to organisms but these become essential as coenzymes or cofactors to effect many biological processes. The diseases caused by the absence of particular vitamin in diet are called vitamin deficiency diseases. These can be cured by taking food containing these vitamins. Vitamins are classified into fat soluble vitamins and water soluble vitamins. They are also known by alphabet symbols as *A B C D* etc. The table gives an idea of these vitamins, their sources, deficiency diseases their symptoms etc.

Taking in food or feeding is of different types in the animal world.

(1) **Holophytic nutrition** Some animals like the Euglena can synthesise food like green plants by photosynthesis. This method of obtaining food is called holophytic nutrition.

(2) **Holozoic nutrition** This is typically animal like nutrition where prepared food (by plants) is swallowed by the animals directly or indirectly and then reduced to simpler molecules inside the digestive system.

(3) **Saprozoic or Saprophytic nutrition** This is mainly the type of getting nourishment from decaying or dead organic material.

VITAMINS

Name of the vitamin	Materials where the vitamin occurs	Disease caused by the deficiency	Symptoms of the disease
Vitamin A or Antixerophthalmic	codliver oil, carrot, milk, butter etc.,	xerophthalmia	dry skin, night blindness.
Vitamin B complex			
B_1 or Thymin or Antineuritic	yeast, whole grains outer bran of rice, etc.	beri-beri	nervous breakdown leading to paralysis, loss of appetite, stunted growth.
B_2 or Nicotinic acid or anti-pellagra	yeast, eggs, green vegetables, etc.,	pellagra	patches on the skin, intestinal disorders
Riboflavin	green vegetables, whole grains etc.,	eye defects, ulcers of the mouth.	eye becomes very sensitive to light ulcers on the mucous membrane of the mouth.
Vitamin C or ascorbic acid or Antiscorbutic	citrus fruits, indian goose berry, germinating seeds etc.	scurvy	haemorrhage in the gum and in joints.
Vitamin D or Antirachitic	fish, meat, eggs etc.,	rickets	malformation of bones, pigeonchest etc ,
Vitamin E or Antisterility	seeds and leafy vegetables	sterility (in rats)	reproduction is affected
Vitamin K or Antihaemorrhagic	leafy vegetables like cabbage	haemorrhage	blood does not clot easily.

Usually the fungi resort to this type but lower organisms like Euglena also show this type of nutrition.

(4) **Parasitic nutrition** : Organisms which depend on other living organisms for their nourishment by living on them are called parasites. They usually cause some inconvenience to the hosts. Parasites produce enzymes, which destroy the tissues of the hosts or rob them of their food in order to get their food. There are various types of parasites (intra cellular, extra cellular, internal external, temporary, permanent etc).

(e.g) malarial parasite, intestinal worms, louse, leech etc.

2. Physiology of Digestion

Digestion is the process by which the various items of food become broken up into a form that can be assimilated into the blood and lymph. The chemical action in the breakdown is called hydrolysis whereby water is inserted across the junctions of the initial molecule,, making many smaller units.

Digestion in animals is of two types-(1)intracellular digestion by which the food particles are taken directly into the cells lining the gut (lower animals) (2) Extra-cellular digestion by which the enzymes are liberated into the alimentary canal and the product of the action of the enzymes are absorbed. This is the type of digestion in mammals and all other vertebrates.

The **alimentary canal** of the vertebrates is differentiated into two regions--for functions of digestion, and absorption, In mam-

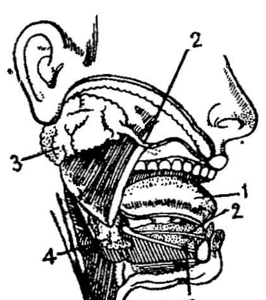


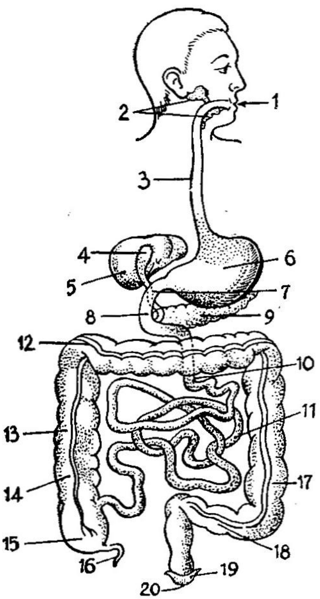
Fig. 1 (a)
Head showing salivary glands
1. Tongue, 2. Duct, 3. Parotid Salivary gland, 4. Mandibular glands, 5. Sublingual gland.

mals the digestion begins in the buccal cavity were the teeth are differentiated according to the diet of the animal and where salivary enzymes begin their chemical digestion of food (refer rat anatomy for structure of alimentary system of a mammal).

Physiology of digestion in man. The enzymes are organic catalysts which hasten the chemical reactions of the body. Three pairs of salivary glands viz., the parotid, sub-lingual and mandibular open into the buccal cavity. The presence of the food in the mouth stimulates sensory structures in the buccal cavity which in turn stimulates the salivary glands, to secrete saliva. The stimulation is also carried to the stomach via the tenth cranial nerve viz. the vagus and the stomach is thus prepared to receive the food.

Buccal cavity

Saliva contains the enzyme ptyalin, sodium bicarbonate (which makes saliva alkaline), mucus and water. Carbohydrates are the only substances on which ptyalin acts. It hydrolyses it



1. Mouth
2. Salivary glands
3. Oesophagus
4 Gallbladder
5. Liver
6. Stomach
7. Pylorus
8. Duodenum
9. Pancreas
10. Jejunum
11. Intestine
12. Transverse colon
13. Large intestine
14. Ascending colon
15. Caecum
16. Appendix
17. Descending colon
18. Sigmoid colon
19. Rectum
20. Anus

Fig. 1 (b)
Alimentary canal of Man

to maltose (malt sugar) by a number of steps. The mucus lubricates the food the teeth and the tongue help to mix the food and enzyme. The mastication of the food by teeth aids in subsequent digestion by breaking food into smaller particles on which the enzymes act.

Oesophagus: No digestion takes place in the oesophagus and it serves merely as a tube conducting the food from the buccal cavity to the stomach by peristaltic movements (wave of relaxation).

Stomach: The lining of the stomach contains a number of gastric pits, where gastric juice is secreted. It contains:

(1) **Mucus**: whose function is to protect the tissues from the action of the enzymes, to neutralise the medium and to provide a mechanical buffer between hard substances and living tissues.

(2) **Hydrochloric acid**:-It is secreted by special cells called oxyntic cells. Its function is to make the medium acidic which is a suitable medium on which pepsin (enzyme produced by stomach) can work and to kill a majority of bacteria taken with the food.

(3) **Pepsin**: It is an enzyme which acts on proteins. The enzymes which hydrolyse proteins are of two types. They are called exopeptidases when they attack the terminal peptide linkages and endopeptidases when they attack linkages within the protein molecule itself. Pepsin is an endopeptidase and it converts protein into peptone molecules. Pepsin is secreted in an inactive state called pepsinogen and is activated by HCl and then by its own hydrolysis (autocatalytically) it is converted into pepsin.

(4) **Rennin**: It is another enzyme found in the gastric juices of young mammals. In the presence of Ca salts, the soluble milk protein or caseinogen is converted into insoluble casein. The solubility of casein depends on pH and it is curdled in the presence of rennin and Ca.

Co-ordination of the stomach Impulses caused by food in the buccal cavity pass through vagus and prepare the stomach for receiving food. Smell or sight of food may also stimulate the stomach. Once the food reaches the stomach, a hormone by name 'gastrin' is secreted by the stomach epithelium which is discharged into the blood and through the circulation reaches the gastric pits increasing their activity in secretion. The action of sympathetic-nerves to the stomach depresses the enzyme secretion.

The food stays in the stomach for about 4 or 5 hours during which time, pepsin and rennin have done their work in the presence of HCl. The warmth in the stomach melts fatty substances and the churning action of the stomach has done much to break large particles into smaller bits to facilitate enzymatic action later.

Substances of smaller molecular weight such as monosaccharides and ethyl alcohol may be absorbed through the stomach mucosa.

Duodenum

The semisolid 'chyme' formed in the stomach passes through the sphincter muscle in small quantities into the duodenum. Here the food is first acted upon by secretions from the liver (bile) and pancreas (pancreatic juice). Bile is secreted by the liver cells and conducted through intra-cellular ducts and larger bile ducts are formed which open into the gall-bladder. Bile consists of salts such as sodium glycocholate and sodium tauroglycocholate as well as breakdown products of haemoglobin called bilirubin (red) (pH8) and biliverdin (green) which colour the faeces. A quantity of HCO_3 is released with the bile which makes the medium alkaline (pH8). Bile salts reduce surface tension and are important in emulsifying fats by which fats are made suitable for action of lipase, an enzyme secreted by the pancreas. Bile also stimulates peristaltic movements of the gut.

Pancreatic juice contains the following enzymes :-

(1) **Trypsinogen** It is an endopeptidase and is activated by enterokinase from the duodenum and also autocatalytically and is converted into trypsin. It acts best in the alkaline medium of pH8 and converts protein or peptone to di, tri or polypeptides.

(2) **Chymotrypsin** This is activated by trypsin and is also an endopeptidase. It converts proteins by hydrolysis into peptones and smaller units.

(3) **Carboxypeptidase** This is an exopeptidase and works on, peptones or polypeptides after they have been released by endopeptidases.

(4) **Lipase or Steapsin** This is a fat splitting enzyme and by hydrolysis splits the fat into fatty acid and glycerol. Not all the fats are hydrolysed but some are assimilated directly while much of it may be converted into glycerides.

(5) **Amylase** It is similar in action to, ptyalin. It converts starch into disaccharide. Amylase exists in two forms called alpha

and beta forms and they attack starch molecules in different ways of hydrolysis.

The pancreatic enzymes work best at a pH of 8 to 9.

The succus entericus of the duodenum :- The various glands present in the mucous and submucous membrane of the duodenum secrete digestive juices called succus entericus, as well as an alkaline fluid and mucus The enzymes are secreted by crypts or glands. The enzymes secreted are

(1) **Enterokinase** This activates trypsinogen from the pancreas by hydrolysis of a terminal peptide link and converts it into active trypsin.

(2) **Erepsin** This is composed of a number of enzymes, each of which has a specific action for a particular sort of polypeptide. They may be classified into carboxypeptidases and amino-peptidases. By the action of these enzymes the polypeptides are reduced to groups of 2 or 3 aminoacids, and these in turn are hydrolysed to single aminoacids by dipeptidases and tripeptidases respectively.

(3) **Lipase** acts on the hydrolysis of fat.

(4) **Sucrase and invertase** act on the disaccharide, sucrose (cane sugar) converting it to glucose and fructose.

(5) **Maltase** acts on maltose (malt sugar) converting it to glucose.

(6) **Lactase** converts the disaccharide lactose (milk sugar) to glucose and galactose.

The duodenal enzymes act best in a medium of pH8, but owing to the very acidic state of the stomach, the general pH of the duodenum is about 5.5 or 6.

Now all the food substances have broken down into small molecules which can be assimilated and absorbed into blood or lymph. Carbohydrates are in the form of glucose, fats have been hydrolysed to fatty acids, glycerides or glycerol and proteins are in the form of aminoacids.

Hormonal Control Of Duodenum And Pancreas. The semi-digested chyme which passes from stomach and duodenum stimulates the duodenal mucosa to release the hormone secretin. Through blood circulation, it reaches the pancreas, causing it to secrete an alkaline fluid to neutralise the stomach acid. This is a good example of feedback system for, the greater the acidity the more secretion is formed and the more alkali is produced. Secretin also controls the rate of production of bile in the liver.

A second hormone ealled pancreozymin is also formed by duodenal mucosa and released in the presence of food. This reaches pancreas and controls secretion of various pancreatic enzy mes, along with vagus control.

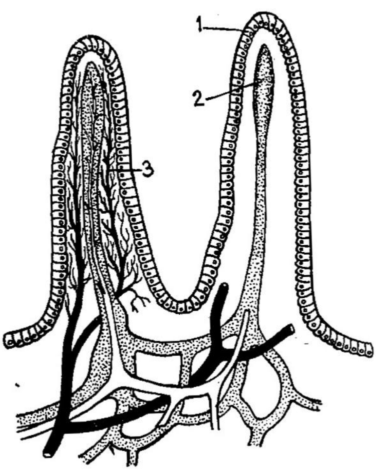
Bile release from gall bladder is regulated by another hormone called cholecystokinin.

The duodenum itself is stimulated to secrete success entericus by nervous as well as hormonal mechanism. Local stimulation of duodenal mucosa by food causes the liberation of enterokinase which in its turn stimulates duodenal glands.

Ileum

Here the bulk of assimilation takes place. The lining of the ileum secretes mucus but no enzymes. There are villi, which are provided with complex net work of capillaries from mesenteric artery and hepatic portal vein. A lacteal vessel from lymph vessel also spreads over the sub-mucosa.

Some of the glucose, galactose, small quantities of fat and aminoacids have been assimilated in the duodenum itself where also a fewer number of villi are present, but most of the food is absorbed in the ileum.



Villus
Fig 2
1. Epithelium, 2. Lacteal,
3. Blood capillaries.

The mucosa of the small intestine is rich in the enzyme phos phatase and the sugars are phosphorylated before being absorbed. Like other foods, they are assimilated against the concentration gradient i e. by active transport. Proteins and carbohydrates which are absorbed thus are transported to the liver by the hepatic portal vein. Fats may be assimilated as fatty acids, glycerol and glycerides or as very small molecules of emulsified fat. The fatty acids become water soluble in the presence of bile salts with which they combine. Most of the fatty acids are absorbed into lacteals of the villi while some enter the blood vessels. This is supported by the fact that small fat droplets are found in the gut lumen.

Water is taken up osmotically, vitamins pass into the gut by diffusion and the minerals are selectively absorbed.

Movements of the ileum are mainly peristaltic but subsidiary movements such as segmenting and the pendular movements are also present. About two hours after a meal is taken, the sphincter is reflexly opened and the contents of the gut move on to large intestine by peristalsis.

Large Intestine

It is a wide tube, made of three portions as ascending, transverse and descending limbs. Its functions are variable. In herbivores it plays a vital part in digestion of cellulose but in carnivores it is very much reduced. There are no secretions or villi in the large intestine.

In man, the large intestine receives excretory substances received from blood, especially Ca^{++}, Mg^{++}, Fe^{+} I and PO_4. It also assimilates water and other substances. The large intestine has a rich bacterial population that live on the undigested residues entering it. Many are potential pathogens. Recently it has been observed that in man, a certain amount of vitamins are provided by intestinal flora. The large intestine receives stimulation from autonomic system and by the movement of the contents by peristalsis fill the rectum. When the pressure of the contents increase, the anal sphincter sends stimulus to the central nervous system which leads to the elimination of faeces.

3. Respiratory Organs

In all terrestrial vertebrates, air is conducted to the lungs by the trachea and its major branches, the bronchi. In human lungs, each bronchus divides again and again (about 20 successive bifurcations). Finally, they end in terminal passages called alveolar ducts which end in a cluster of bubble-like spaces or alveoli.

An individual alveolus has a diameter of 75 to 300 microns. There are numerous alveoli in the two lungs and they have a surface area of about 70 square miles (40 times the average of the human skin). The alveolar walls, are richly vascular and extremely thin. In places, less than a single micron separates the air in the alveolus from the blood in the capillaries.

Each lung lies in the lateral position of the thoracic cavity and is attached only at its root medially where the bronchi and blood vessels enter its substance. Between the two lungs is a mass of tissue known as the mediastinum which is composed of the heart, major blood vessels, oesophagus, trachea and nerves. Each lung is almost completely surrounded except at its root by a space, which is completely, lined by the pleural membrane. The space between them is a potential space rather than an actual space, for the two membranes are in actual contact but are not fused together.

The thoracic walls are elastic but resist the expansion or contraction of the thoracic volume. Expansion and contraction occur as a result of muscle action during respiration. The lungs themselves are also elastic. They are inflated during inspiration by active expansion of thoracic volume; this is accomplished by the contraction of various muscles. The external layer of the intercostal muscles raise the ribs to increase the transverse diameter of the thoracic cavity and the muscles of the diaphragm contract, to increase the cranial-to-caudal dimensions of the thorax. The lungs expand and air enters them through the respiratory

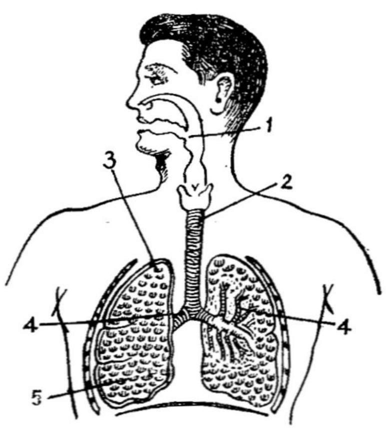


Fig 3
Lungs of Man
1. Pharynx, 2. Trachea, 3. Alveoli,
4. Bronchus & Bronchiols, 5. Lung.

passages. The respiratory function of the diaphragm is unique to mammals since no complete diaphragm exists in birds or other lower vertebrates.

Deflation of mammalian lungs is accomplished by merely relaxing the muscles of inspiration and allowing the elastic recoil of the thoracic volume (expiration.)

Under quiet conditions, the average man moves about 500 milli litres of air in and out of the lungs with each respiratory cycle. This quantity of air is called tidal respiration. By increasing muscular effort it is possible to inhale an additional 3000 milli litres (inspiratory reserve volume) and by active expiration an additional 1100 more than tidal respiration can be exhaled (expiratory reserve volume). The total tidal volume plus inspiratory reserve volume plus expiratory reserve volume represents the vital capacity, the maximum amount of air that can be inspired and expired with maximum effort. It is about 4600 milli litres in an average man (500+3000+1100). Even after the most forceful exhalation, about 1200 milli litres remain in the lungs (residual volume). Thus the lung capacity is about 5800 millilitres in the average human (4600+1200).

In addition, the respiratory passages contain about 150 milli litres of dead air space. During the usual respiratory cycle, then, the first 150 milli litres of the tidal intake is composed of air from the dead space--air which has not been exchanged with pure atmospheric air. Only 350 milli litres of the tidal respiration therefore is actually effective in lung ventilation. This imposes an obvious inefficiency in mammalian respiration.

The average human ventilation rate is about 12 to 15 complete cycles per minute.

The nervous control of respiration resides in the medulla of the brain.

THE PHYSIOLOGY OF RESPIRATION

The respiratory physiological mechanism consists of :-

1. Exchange of oxygen in the lungs
2. Carriage of oxygen by the blood
3. Exchange for oxygen in the tissues
4. Exchange and transport of CO_2

1. LUNGS AND EXCHANGE OF OXYGEN

The first step in the supply of oxygen to the tissues and the last step in the discharge of CO_2 both take place in the lungs. Thus the chief function of the lung is to provide the cells of body with oxygen and to remove their CO_2 waste. In man this is accom plished by two systems, viz., circulatory and respiratory systems. With the aid of haemoglobin, blood carries to and from the tissue cells large amounts of oxygen and carbondioxide.

In man, the bronchi which are the chief conducting airways, branch repeatedly and each small duct ends in gas-filled pockets-the alveoli. In the two lungs there are about 300 million alveoli varying in diameter from 80μ to 300μ (1 micron, or $\mu = \frac{1}{1,000}$ mm). The total surface area of the alveolar walls is about 50 times the surface area of the body.

Microscopically, each alveolus consists of 2 parts - (1) an inner very thin layer of flattened cells and (2) an outer layer of thin walled cells of lung capillaries. The distance separating gas from blood does not exceed 1.0μ. The barrier between gas and blood is called alveolar-capillary membrane through which gaseous interchanges take place.

Thus the unit of lung function is the gas filled alveolus and its companion blood capillary, and the function of this unit is to bring blood and gas in close proximity to facilitate easy exchange or gases. The mechanism of this exchange is simple physical diffusion.

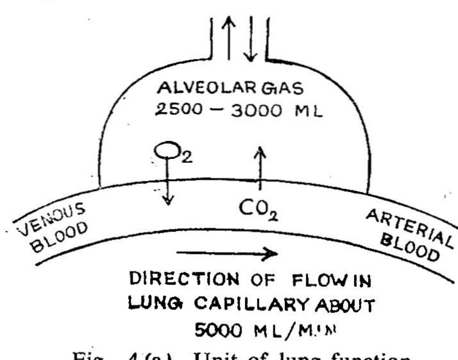


Fig. 4 (a) Unit of lung function

In resting condition, at the end of normal expiration, the alveolar gas is about 2500 ml. to 3000 ml. A resting adult inhales about 500 ml. of air with each breath. Of this amount, about 350 ml. enter the alveoli, while the remainder occupies the bronchi and bronchioles and takes no part in gas exchange. Normal breathing per minute is 15, and so 5250 ml of fresh air are drawn into the alveoli, per minute. This is known as the resting alveolar ventilation rate. The amount of fresh air entering the alveoli is balanced by a similar amount of stale air exhaled. Approximately 250 ml. of oxygen are delivered to the tissues each minute.

The movement of oxygen molecules across the alveolar capillary membrane is by passive physical diffusion. Thus, if the molecular concentration of oxygen is greater in one region than in another, molecules will move from one region of high concentration to the region of low concentration until the concentration of the gas in two regions are equal. The diffusion of gases across the thin alveolar-capillary membrane is between gaseous state in the alveoli and liquid phase in the capillaries In liquids, the solubility is important in determining diffusion. and the amount dissolved is proportional to its partial pressure. since CO_2 is 20 times more soluble in water than oxygen, it diffuses at a much greater speed.

The partial pressures of oxygen exerted on the opposing sides of the alveolar-capillary membrane differ and this is mainly responsible for the oxygen diffusing out of the alveolar gas into capillary blood stream.

The total atmospheric pressure is about 760 mm Hg. and of this 20.9% is due to oxygen. Therefore the partial presssure of oxygen (PO_2) is 20.9% of 760 mm Hg. In practice, however, as the air is breathed, it becomes saturated with water vapour at body temperature, so that from the total dry gas pressure the partial pressure of water-vapour (47 mm Hg) must be deducted. So the PO_2 of moist inspired gas is 20.9% (760-47) = 149 mm Hg. The alveolar gas contains 14% of oxygen, corresponding to a PO_2 of about 100 mm Hg. while the partial pressure of gases in the venous blood arriving at the alveolus is 40 mm Hg. Thus there is a pressure gradient facilitating the diffusion of oxygen molecules from alveolus to blood vessel. As the diffusion takes place, the PO_2 of the blood stream rises and, when blood has completely flowed through the lung capillaries and made arterial. its PO_2 is very nearly equal to that of alveolar gas (Fig 4b)

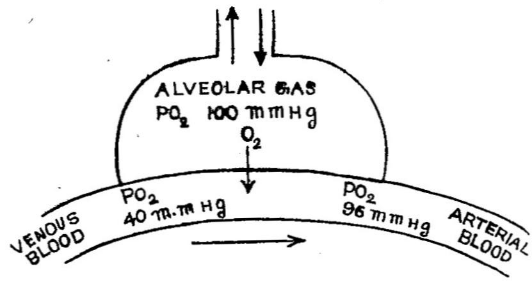


Fig 4 (b)

The oxygen which thus enters the blood stream, reaches the red blood corpuscles, where it combines chemically with the respiratory pigment haemoglobin, to form oxyhaemoglobin.

2. THE CARRIAGE OF OXYGEN BY BLOOD AND THE EXCHANGE OF OXYGEN IN THE TISSUE

The carriage of oxygen to the tissue cells is one of the important functions of blood. Oxygen is soluble in the plasma and while loading and unloading of O_2, it is first dissolved in the plasma. The reaction of haemoglobin with oxygen is represented as $Hb + O_2 \rightleftharpoons HbO_2$. It is a reversible reaction. Both oxygenation and reduction are rapid (less than 0.01 seconds).

OXYHAEMOGLOBIN DISSOCIATION CURVE

The haemoglobin behaves in an unique manner under different physiological conditions. This is expressed by plotting the percentage saturation of Hb with oxygen against the PO_2 (oxygen partial pressure) in the varying physiological ranges. This is called the oxyhaemoglobin dissociation eurve. In practice, the amount of oxygen chemically combined with the Hb at each PO_2 value is measured. The percentage of saturation is the ratio, of the oxygen combined with Hb to the oxygen capacity of Hb multiplied by 100, where the oxygen capacity is the maximum amount of oxygen that will combine with Hb at a high PO_2. Normally, the oxygen capacity of the Hb contained in 100m.l of blood is usually about 20 ml. and this figure corresponds to 100% saturation with oxygen.

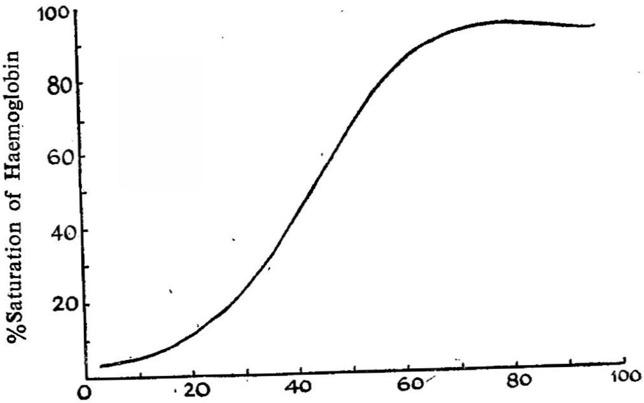


Fig. 5 The oxyhaemoglobin dissociation curve

A study of this curve illustrates some remarkable properties of Hb.

1. The curve is S-shaped (sigmoid curve).
2. At PO_2 of 96 mm Hg, Haemoglobin is saturated with 97.5% of oxygen.
3. The dissociation curve is flat at the top; at PO_2 greater than 100 mm Hg, haeomoglobin cannot accept more oxygen. Thus, when the demands for oxygen increase as in active exercise, the oxygen content of blood as it flows through lungs is not raised but the amount of blood supplied to the lungs is increased and by increased utilisation of the available oxygen.
4. There is little change in the amount of oxygen held by haemoglobin, between PO_2 of 100 mm Hg and 70 mm Hg. This means that man can live at an altitude (for example, of 10,000 ft where atmospheric pressure is about 500 mm Hg and PO_2 is about 70 mm Hg) without much reduction in the amount of oxygen carried by the blood.

5. At low PO_2 (between 10mm Hg and 40 mm Hg) the curve is very steep. It means that, in the tissues where the PO_2 may fall to 10 mm Hg or less, the amount of oxygen dissociating from oxy-haemoglobin correspondingly increases.

The dissociation curve is not fixed. It changes with temperature, pH and other physiological conditions.

3. THE EXCHANGE OF OXYGEN IN THE TISSUES

The freshly oxygenated blood is supplied to all parts of the body. On reaching the tissue capillaries, each 100 ml of blood holds about 19·5 ml of oxygen, corresponding to a percentage haemoglobin saturation of about 97·5 at a PO_2 of approximately 96 mm Hg. Under resting conditions 5 ml of oxygen are removed from each 100 ml. of blood passing through tissues.

Like the gas exchange in the lungs, the exchange of gases in tissues also occurs by passive diffusion of oxygen molecules from one region of high PO_2 to another of low PO_2. The dissolved oxygen diffuses out of the plasma through capillary walls to reach the cells. Loss of oxygen from the plasma lowers the PO_2, surrounding the red corpuscles and, in turn, oxyhaemoglobin therefore dissociates, liberating about 25% of its available oxygen for tissue consumption. Finally the venous blood issues from the capillaries with a PO_2 of 40 mm Hg and an oxygen load of about 14·5 ml per 100 ml.

The structural barriers from red corpuscles to cell through which oxygen diffuses are the thin membranes of red corpuscles, layer of plasma, thin walled capillary, tissue fluid and plasma membrane of the cell. The diffusion path is aqueous throughout.

4. EXCHANGE AND TRANSPORT OF CARBONDIOXIDE

In addition of supplying oxygen, the blood also removes the waste products of cellular activity such as carbondioxide. It is carried by the venous blood to the lung capillaries where it is discharged in the expired gas. At rest, a man produces about 200 ml of carbondioxide per minute. Carbondioxide is also lost through skin surface and in the urine.

Carbondioxide is readily soluble and dissolved as it is formed in the tissue cells. In solution, it is transferred to the tissue fluid surrounding the cells, and from there enters the capillaries, where a small part of it, carried in the plasma is present as dissolved gas.

The amount of carbondioxide that goes into solution chiefly depends on the partial pressure. The carbonic acid (H_2CO_3) weakly dissociates, forming hydrogen and bicarbonate ions.

$$CO_2 + H_2O \rightleftharpoons H_2 CO_3 \rightleftharpoons H^+ + HCO_3^-$$

The reactions are reversible.

Carbondioxide exchange in the lungs

The carbondioxide molecules passively diffuse rapidly across the alveolar capillary membrane. The reactions associated with the uptake of CO_2 by the blood in the tissues is reversed. Thus bicarbonate ions migrate back into the red corpuscles as chloride ions move out, and simultaneously reduced haemoglobin becomes oxyhaemoglobin. Carbonic anhydrase now accelerates the decomposition of the carbonic acid thus formed to CO_2 and H_2O and the gas diffuses across the corpuscular membrane into the plasma and finally through the alveolar capillary membrane into the alveoli.

The nerve cells in the medulla oblongata control the exchange of gases.

4. Human heart and its working

The human heart is a muscular conical organ placed inside the chest, in between the two lungs. It is the size of one's own first and protected by a double walled bag called pericardium. The pericardial fluid protects the heart from shocks and lubricates its movements.

The heart has four distinct chambers, namely two auricles and two ventricles. The two auricles are anterior in position and the two ventricles are posterior. The wall of the auricles is thin compared to the wall of the ventricle, which is very thick. The two auricles are separated by an inter auricular septum and the two ventricles are separated by an inter ventricular septum.

The right auricle is separated from the right ventricle by an aperture guarded by a valve called tricuspid valve. This has 3 flaps, the free ends of which are connected by chordae tendinae to the papillary muscles on the inner wall of the ventricle. This valve allows blood to flow only from the auricle to the ventricles.

The left auricle is separated from the left ventricle by an aperture guarded by a valve called the bicuspid or mitral valve. This has 2 flaps, the free ends of which are attached to the papillary muscles by the chordae tendinae. This valve also allows the blood to flow from the auricle to the ventricle.

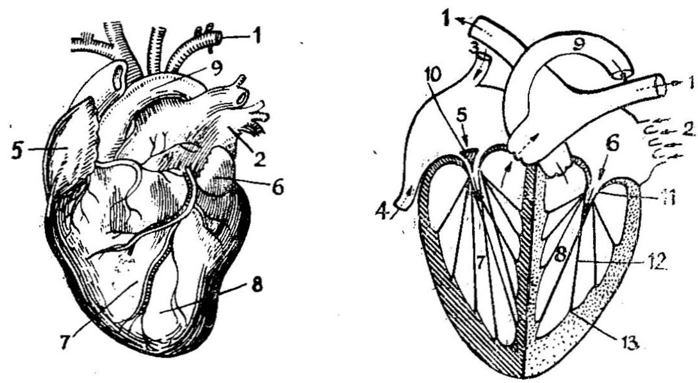


Fig. 6 Human heart and section

1. Pulmonary artery, 2. Pulmonary vein, 3. Superior vena cava, 4. Inferior vena cava, 5. Right auricle, 6. Left auricle, 7. Right ventricle, 8. Left ventricle, 9. Aorta, 10. Tricuspid valve, 11. Bicuspid valve, 12. Chordae tendinae, 13. Papillary muscles.

Blood vessels connected with the heart

The superior vena cava (combined precaval veins) opens near the anterior end of the right auricle. This brings deoxygenated blood from the head and the hands to the right auricle. Opening into the right auricle at its posterior end is the inferior vena cava (postcaval vein) bringing blood from all the regions posterior to the heart. The left auricle receives oxygenated blood from the lungs through the pulmonary veins.

A blood vessel called pulmonary artery takes blood from the right ventricle to the lungs. Another blood vessel called aorta takes blood from the left ventricle to all parts of the body. The opening of the pulmonary artery and the aorta are guarded by sets of semilunar valves. The heart wall itself receives blood supply through the coronary artery, arising from the aorta. Similarly blood from the heart wall is drained by coronary vein which opens into the superior vena cava.

Working of the heart

Deoxygenated blood from all parts of the body is brought to the right auricle through the superior and inferior vena cavae. At the same time, the left auricle is filled with oxygenated blood brought from the lungs through the pulmonary veins. At this time, when the auricles are getting filled up they are said to be in diastole (relaxed).

The two auricles contract simultaneously. This contraction is called auricular systole and it starts from the anterior end. A branch of the vagus nerve initiates the action. This is taken up further by the bundle of His which transmits the impulse down to the ventricles.

When the auricles contract blood is forced into the respective ventricles through the cuspid valves. The two ventricles are in diastole (relaxed condition) and receive the two different bloods. The right ventricle receives deoxygenated blood from the right auricle and the left ventricle receives oxygenated blood from the left auricle.

Then the ventricles contract. During the ventricular systole the deoxygenated blood from the right ventricle is forced into the pulmonary artery to be taken to the lungs and the oxygenated blood is forced into the aorta, which takes blood to all parts of the body.

A heart beat is equal to one auricular systole, a ventricular systole and then a short pause. The human heart beats about 72 times per minute in a normal person.

PHYSIOLOGY OF BLOOD AND BODY FLUIDS

The blood, lymph and coelomic fluids form the internal medium of the body. It is regulated in a precise way with respect to its ionic content, osmotic pressure, gas content and temperature. This homeostatic mechanism, or the tendency to maintain a constant internal environment is a characteristic feature of all vertebrates, particularly mammals and birds.

Composition of blood

Blood is a fluid tissue and consists of solid corpuscles suspended in a fluid plasma. The red blood corpuscles or **erythrocytes** constitute about 50% of the blood volume. They are formed in the marrow at the end of the bones, in particular, the ribs and vertebrae. They live for about 90 to 120 days in circulation and are destroyed at a high and continuous rate in the spleen, liver and connective tissues. The products of their breakdown are returned to the liver and discharged into the bile. Most of the iron is released and stored in the liver for future use. The functions of the erythrocytes is to transport oxygen, in the form of oxy-haemoglobin and CO_2 as a carbamino compound with haemoglobin. Anaemia is a condition in which there is decrease in the number of erythrocytes, in the amount of haemoglobin, or in both. These conditions may result from impaired blood formation, increased destruction of erythrocytes or both.

An abnormal increase in the number of erythrocytes is called **polycythemia** which often results from a loss of body fluids, hence of blood plasma. Often there is an over-production of erythrocytes in the red bone marrow.

The leukocytes or white blood corpuscles are produced by reticulo-epithelial cells in the liver, spleen and lymph ducts or by the bone marrow. They live for about 2 to 3 weeks. They are nucleated and at least 5 types can be distinguished viz. neutrophils, monocytes, lymphocytes, basophils and eosinophils. They play a part in the defence of the body against infection, by acting as phagocytes. A decrease in the number of leukocytes is called **Leukopenia** and an increase is **Leukemia.**

Platelets are formed by the disintegration of very large cells called megakaryocytes of the red bone marrow. They are non-nucleated and are concerned with the clotting of blood, which is an important wound healing device.

Blood plasma is the fluid part of the blood and is about 90% water. It serves as the basic carrier for the cells and other materials. Plasma proteins form about 8% of the remaining fraction; and inorganic ions, foods, wastes, hormones, etc., account for the rest. Most of the protein is **albumen** which is important in maintaining the osmotic pressure of the blood, **globulins** which are essential to antibody formation and immunity, and **fibrinogen** which functions in clotting of the blood. The iron concentration is important in maintaining pH and all metabolism.

Clotting of blood

Loss of blood is known as haemorrhage. It initiates certain protective activities in the body, such as:

1. Clotting of blood at the site of injury
2. Decrease in the general blood pressure
3. Contraction of the small vessels of the skin, muscles and intestines in order to supply the vital parts of the body
4. Increase in the blood volume by the contraction of the spleen, which normally contains a large quantity of blood
5. Passage of water and salts from the tissues into the capillaries because of increased osmotic pressure.

One of the marvellous phenomena of blood is the ability to maintain its fluidity while it flows through normal blood vessels while preserving its inherent capacity to coagulate when it leaves blood vessels. As long as blood remains in normal blood vessels, no **fibrin** is formed and the fluidity of blood is maintained.

Clotting is one of the most complicated chemical processes in our body. Approximately 35 compounds take part in clot formation. Many theories have been proposed concerning the roles of various chemicals involved.

The conversion of the soluble protein, fibrinogen, into the insoluble protein, fibrin is caused by an enzyme called **thrombin.** In blood thrombin is said to be present inactive form called **prothrombin.** For the formation of prothrombin an adequate supply of vitamin K is essential.

Injury of tissue or blood vessels, or the disintegration of blood platelets, gives rise to the formation of **thromboplastin.** In the presence of calcium ions, this transforms the inactive prothrombin into active thrombin. The thrombin causes soluble fibrinogen to turn into insoluble fibrin and this forms a meshwork of fibrils which entangle blood corpuscles and transform the liquid blood into a gel or **clot.**

The fluid nature of blood in blood vessels is maintained due to:

1. Intact blood platelets
2. Intact blood vessels
3. Presence of anticoagulant, such as **heparin.** It is made chiefly in the liver in quantities just sufficient to prevent the formation of thrombin. A lack of heparin may result in purplish patches beneath the skin.

The formation of clot within a blood vessel that is not severed is called **Thrombosis.** This may be caused by an injury of the vessel wall from a blow or from toxins of bacteria that injure the blood platelets. If a part of a thrombus circulates in the vessels, it is called an **embolus,** which if it should block circulation to a vital party may result in serious consequences.

LYMPH

The blood passes into the capillaries from the small arterioles of the arterial system. These tiny vessels penetrate all the tissues of the body. Many substances leave the capillaries and enter the tissue spaces. The fluid thus formed is called lymph and is in immediate contact with the cells of the tissues. The composition of the lymph is the same as the blood plasma, except that no corpuscles are found. There is also less of Ca, PO_4, K, protein and fat in the lymph and more of glucose. The lymph has more lymphocytes but less of other type of white corpuscles. The lymph passes into lymphatic vessels which eventually open into the venous system at the base of the jugular vein, thus returning to general circulation. At various points along the lymphatics, lymph nodes are present which are concerned with the defence mechanisms of the body.

ANTIBODIES

One of the defensive reactions of the body against attack by foreign substances, usally proteins of either plant or animal origin of bacteria, is the production of a protective substance called **antibody** which is proteinaceous in nature. The substance that stimulates the body of the animal to produce a specific antibody is called an antigen. The antibodies may be of several types, such as antitoxins, agglutinins, bacteriolysins, opsonins etc.

If the production of antibodies by the host is sufficiently extensive and rapid, pathogenic bacteria may be destroyed and their toxins neutralized. An animal that has formed sufficient antibodies is said to have been immunized against the specific disease caused by the type of bacterium that led to the production of the antibodies. Vaccines are prepared and used to immunise the body against diseases.

HEART OUTPUT AND ITS REGULATION

Rhythmicity is a characteristic feature of all hearts and in vertebrates it is **myogenic** in origin, that is, it is initiated from the muscle tissue. In mammals, the rhythm originates in a special region of the right auricle called the sinu-auricular node. This is called the **pace-maker.** It is made of special muscle cells and the nerves controlling the heart end here. The beat originates here and spreads through the auricles. A special conducting systems formed by modified muscle fibres called **Purkinje tissue** arises at the base of the inter auricular septum at the auriculo-ventricular node, plays a vital role in transmitting the heart beat through the non-contractile connective tissue which separates auricles and ventricles. The wave of excitation spreads and is transmitted by the auriculo-ventricular bundle to the ventricles which contract simultaneously.

The aortic pressure is about 120 mm Hg falling to 80 mm Hg during diastole (Relaxation of the heart). The pressure difference between these two during each contraction is the **pulse pressure.** By the time the blood reaches the veins the pressure is extremely low. The return of the blood to the heart is made possible by the tone of the body muscles, valves in the veins, lowered pressure within thoracic cavity, etc.

The volume of blood passing to the tissues in a given time depends on the amount pumped by the heart and the resistance to its flow through the capillary system. Frequency varies among different mammals—larger animals have a slower rate. For a given animal, there is a limit to which the frequency can be raised in man it is 190-200 per minute.

Control of heart beat

The arterial blood pressure is regulated by receptors in the carotid sinus and aorta which send sensory fibres to the medulla in the glossopharyngeal nerve (ix) and depressor branch of the vagus (x). Excitation of the pathway leads to a reduced output and the blood (arterial) pressure falls. Other reflex mechanisms ensure that heart becomes accelerated when the large veins and auricles are distended. An intrinsic regulation is also produced by the heart whose tension exerted by the individual muscle fibres increases at greater lengths. The endings of vagus nerve near the sinu-auricular node secrete acetylcholine which has inhibitory effect upon the pacemaker region. The sympathetic innervation has an accelerating effect due to the liberation of adrenaline from adrenal medulla. It also helps the speed of blood flowing to the muscles by causing the plain muscles of the arterial walls to relax and dilate. This method of altering peripheral resistance is one of the important ways in which the blood flow is regulated. Thus not only the total output of the heart, but also its precise distribution is regulated by varying the diameter of the different capillary systems.

5. Excretory Organs

The principal excretory organs are a pair of kidneys which are bean seed shaped and covered by a fatty capsule. Each kidney has a concave border showing a notch like depression called the hilus which opens into the renal sinus. The renal sinus contains the major part of renal pelvis, the branches of the renal artery and renal vein.

A vertical section of kidney shows an outer dark portion, the cortex and an inner pale red region, the medulla. The medulla shows a number of renal pyramids. The renal pelvis projects in between the pyramids in the form of finger like foldings called calyces. The cortical tissue extending in between the pyramids forms the renal columns of Bertini.

The kidney is composed of a large number of microscopic structures called nephrons. These are the functional units of the kidney. Their function is to separate certain materials (urea, salt etc.) from the blood and send them out in solution as urine. In man, there are 2,000,000 nephrons-1,000,000 in each kidney.

The nephron is composed of two parts (1) a spherical, Vascular structure called the renal glomerulus or Malpighian corpuscle, and (2) the renal tubule. The Malpighian corpuscle measures about 0·2 mm in diameter and consists of about 50 separate capillaries bent into short loops to form a compact mass called the glomerular tuft. The upper end of the renal tubule is expanded into a structure called the Bowman's capsule. The cavity of the Bowman's capsule is crescentic in cross section, due

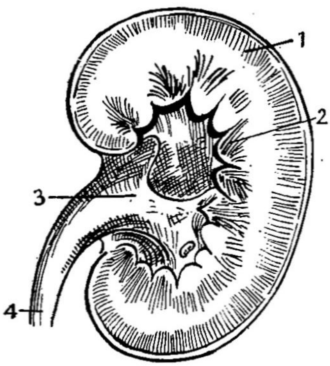


Fig. 7 (a)

Section of Kidney
1. Cortex, 2. Medulla, 3. Pelvis, 4. Ureter.

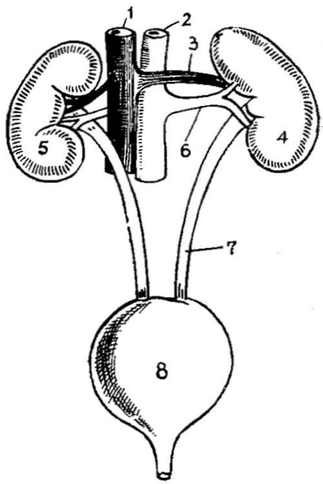
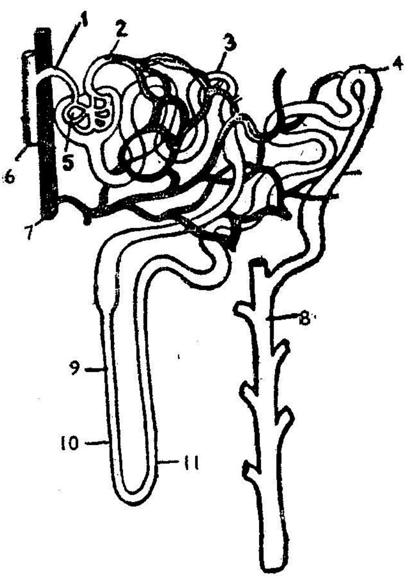


Fig. 7 (b)
Urinary system
1. Inferior vena cava, 2. Abdominal aorta, 3. Left renal vein, 4. Left kidney, 5. Right kidney, 6. Left renal artery, 7. Left ureter, 8. Bladder.

to the encroachment of the glomerular tuft into one side of the capsule. The wall of the capsule is thin composed of a single layer of flat cells, which also serves as a covering for the glomerulus. This membrane and the thin walls of the capillaries alone separate the blood from the cavity of the Bowman's capsule.

The renal tubule is divided into three parts. The proximal convoluted tubule is highly coiled and lies in close relation to the glomerulus. The afferent arteriole enters into the a glomerulus and the efferent arteriole collects the impurities from the glomerulus. The walls of this portion of the tubule are composed of a single layer of columnar epithelial cells. The free borders of the cells show fine perpendicular striations and give it a brush like appearance. This is called brush border and is not seen in any other part of the tubule. The second part follows in the form of a straight tubule which descends for a distance (descending loop) and turning upon itself, ascends again to the region of the glomerulus. This hairpin like bend is called Henle's loop and the limbs forming it are called the descending and ascending limbs of Henle's loop. The tubule composing the loop is narrower than the rest of the tubule. The ascending limb passes into the third part, a distal convoluted tubule. It empties the tubular fluid into larger channels called collecting tubules. These conduct urine to the pelvis of the kidney.



1. Afferent arteriole,
2. Efferent arteriole,
3. Proximal convoluted tubule,
4. Distal convoluted tubule,
5. Glomerulus,
6. Artery,
7. Vein,
8. Collecting tubule,
9. Henle's loop,
10. ,, ,, (Descending)Limb
11. ,, ,, Aseending Limb.

Fig. 7 (c) A Nephron

The **renal artery** supplies blood to the kidney while the renal vein collects the blood and empties it into the post caval-vein.

The tubules of the kidney empty through a number of short ducts into a funnel shaped membranous structure called the pelvis of the kidney. A narrow duct, containing smooth muscle in its walls and called ureter, conveys the urine from the kidney pelvis to the urinary bladder. The urine is propelled along the ureter by peristaltic contraction. It enters the bladder in jets which occur at the rate of one to 5 per minute.

The **urinary bladder** is a hollow muscular organ lined by modified stratified epithelium. It leads into urethra through which urine is passed to the exterior. The junction of the bladder and urethra is guarded by sphincter muscles.

PHYSIOLOGY OF EXCRETION

One of the reasons for the high degree of efficiency in the physiological processes of mammals is the maintenance of a stable internal (cellular) environment in which metabolic reactions can proceed under optimum conditions. This is done in many ways; such as, regulation of the concentration and ionic composition of body fluids. Important processes such as contraction, conduction and membrane permeability are particularly dependent on the ionic medium; also ions act in conjunction with many enzymes. Protein reactions and properties depend not only on the pH and temperature, but also on the degree of hydration and the ionic medium in which they operate. Further, the nitrogenous waste substances from protein deamination, which are toxic to the organism must be removed from the body. The regulation of all these factors makes up the physiological function of osmotic and ionic regulation and excretion. Its main agents are **kidney, lungs** and **skin.** The main substances involved are salts, water, calcium and nitrogenous waste.

To understand the physiology of the above, it is necessary to understand certain principles and terms.

Osmosis: A tendency of water to pass across a semi-permeable membrane to a medium of higher concentration.

Isotonic: Indicates that no water passes across a membrane separating two such solutes.

Hypertonic: A solution is hypertonic when water passes into it across a membrane; and the solution from which water is lost is called **hypotonic.**

The relative concentration of the two solutions are indicated, by the terms iso-osmotic, hyper-osmotic and hypo-osmotic.

The kidneys : The kidneys are excretory organs eliminating body waste and also serve to regulate the composition of the blood plasma and tissue fluids. These functions are carried out through the exchange of large amounts of water and dissolved material derived from the blood stream. The kidney receives an extremely rich blood supply.

The vertebrate kidney is made up of numerous filtration units called **Nephrons.** These tubules and their special capillary blood supply form the unit of function in the kidney. Since the functions to be carried out are complex, there is a corresponding high degree of complexity in the structure of the kidney.

There are two initial steps in the formation of the urine, viz. (1) glomerular filtration and (2) restoration to the blood stream of such of the freshly formed filtrate through the reabsorptive activity of the cells of proximal tubules.

Glomerular filtration : The blood capillaries and the tissue fluids which bathe the cells differ mainly in their composition -plasma contains protein and it is absent in tissue fluid. Further in the tissue capillaries there is a force called the **capillary blood pressure** which causes ultra filtration and there is also an additional opposing force called osmotic pressure of the plasma protein, which attracts tissue fluid back across the capillary wall.

The important difference between the glomerular capillaries and ordinary tissue capillaries which facilitate glomerular filtration lies in the blood pressure within individual glomerular capillaries. In man, this pressure is 70 mm Hg whereas in ordinary capillaries it is 45 mm Hg.

The plasma filtrate at first collects in the spaces of the Malpighian capsule surrounding the glomerular capillaries. This filtrate is very closely similar to the blood plasma from which the filtrate is derived, except that no protein is found in the filtrate. The rate at which this filtration occurs is closely related to the area of the surface available for filtration. From the capsule, the filtrate is then conveyed to the proximal convoluted tubule.

Tubular absorption : The amount filtered in the glomerulus is large in quantity and contains many materials such as sodium chloride and bicarbonate ions, glucose and other valuable nutrients. The urinary tubules conserve much of the water and contents. About 99% of the filtered water, sodium chloride. bicarbonates and glucose are fully restored by the kidneys. Thus the glomerular filtration and subsequent tubular reabsorption of almost the entire filtrate are the chief functions of the kidney; the excretion of a small final urine is quantitatively very insignificant.

The reabsorptive activity is most intense in the proximal tubules. Sodium ions are actively reabsorbed by the tubule cells with expenditure of energy. Their continuous energetic transference is related to the subsequent passive movement of chloride ions which is favoured by an electrical potential gradient; water is favoured by osmotic gradient and urea is favoured by a concentration gradient. Glucose and aminoacids are restored through independent active transfers.

Tubular Secretion : The cells of the proximal tubules also secrete many physiological and foreign substances into the fluid contents of the tubules. Secretion also takes place in the distal tubules and collecting duct.

Water exchange in the kidneys and the regulation of the osmotic pressure of the body

There is no change in the osmotic activity of the filtrate in traversing the proximal convoluted tubule and it follows that variation in the osmotic pressure of the final urine is brought about by the functions of the subsequent segments of the urinary tubules. The segment responsible is the hairpin tubule - or loop of Henle and distal tubules by counter-current exchanges.

Control : Water exchange between the distal segments of the urinary tubules and the capillary blood stream is controlled by ADH (anti-diuretic hormone) from the pituitary. As the water is lost in the loop of Henle, only 10-15% of the original glomerular filtrate flows into the distal convoluted tubules which lie in the cortex of the kidney. Here also diffusion takes place and water is lost, provided the cells are permeable to water.

If they are permeable, water is lost and in the collecting duct the amount of fluid decreases to about 4-5% of that of glomerular filtrate. As the filtrate pass down the collecting duct, further concentration of urine takes place.

The cells of the distal tubules and collecting ducts are variably permeable to water. When a man drinks a lot of water, he produces a dilute urine because the distal tubules and collecting ducts are now permeable. This response to drinking is called **water diuresis** while the reverse-the production of a scanty, concentrated urine is called an **anti-diuresis.**

This water exchange is controlled by ADH. In its presence, the cells of the distal convoluted tubules and collecting ducts are freely permeable, whereas they are virtually impermeable to water when the hormone is absent. The amount of circulating ADH varies according to the osmotic pressure of the plasma. The hypothalamus-the region of the brain that detects changes in the osmotic pressure of plasma, the postpituitary gland that secretes ADH and the kidneys that with ADH regulate water exchange; these factors combine to hold the osmotic pressure of the extra-cellular fluid of the body within the normal range.

Just before they enter the glomerulus, the afferent arterioles come close to the distal tubules. At this point the cells of both arteriole and tube are thickened to form the **juxta-glomerular complex.** This can in some way detect a change in sodium concentration in the blood. If the concentration falls, for example due to an increase in the amount of water in the blood, **rennin** is released by the complex. It causes the production of **angiotensin** from the inactive **angiotensinogen** circulating in the blood. Angiotensin not only controls blood pressure by causing vaso-constriction, but also affects the production of **aldosterone** from the adrenals, more of which causes more sodium reabsorption from the distal tubule. This continues until the level of sodium rises to its normal level when rennin ceases to be produced. Thus, these interconnecting control mechanisms are a good example of **negative feed back control.**

Acidification of urine and regulation of pH of the body

Normal cellular activities are supported not only by a favourable osmotic environment. But also by the concentration of hydrogen ion or pH. The kidneys play a valuable role in regulating the pH of the body fluids and they are helped by the lungs. The pH of blood plasma and tissue fluid bathing the cells is precisely controlled.

Under normal conditions, the pH of blood is kept within definite limits-7.35 to 7.45 in man-which means that the actual concentration of free hydrogen ions is very low. Variations above or below this range are compatible with life but when the pH goes above or below the range, it is rapidly restored through the action of the lungs and kidneys.

CO_2 is one of the chief sources of hydrogen ions in the body. When it leaves the tissue cells, a small proportion of the dissolved gas is hydrated and carbonic acid is formed which weakly dissociates into bicarbonate and hydrogen ions.

$$CO_2+H_2O \rightleftharpoons H_2\,CO_3 \rightleftharpoons HCO_3+H^+$$

By eliminating CO_2 the lungs also eliminate carbonic acid, which is a volatile acid. The kidney also excretes body acids, but the daily amount is small and the acids are nonvolatile, consisting chiefly of sulphuric and phosphoric acids. The lungs govern pH by varying the carbonic acid concentration in the extracellular fluid, i.e. by eliminating CO_2 in varying amounts. The kidneys on the other hand regulate pH through varying the bicarbonate concentration and also by excreting the nonvolatile metabolic acids. Through this, CO_2 and nonvolatile acids are continuously produced by the tissues and the H ion concentration of the body does not progressively rise, but is kept constant. The lungs and the kidneys discharge the acidic products of cell metabolism as fast as they are formed.

Normally, the filtered bicarbonate is almost completely reabsorbed in the kidney tubules. Reabsorption is most intense in the proximal convoluted tubules, where the mechanism includes the exchange of hydrogen ions for sodium. Hence, sodium bicorbonate is conserved and hydrogen ions derived from carbonic acid are excreted in the urine. Sodium-hydrogen exchange also takes place in the distal tubules where bicorbonate reabsorption is completed and the urine also finally acidified.

6. Nervous System

Structure and functions of brain, spinal cord and nerves

The parts and regions of the vertebrate nervous system can be classified in a number of ways. A useful and convenient classification is based partly on anatomical and partly on functional considerations.

All vertebrates, with certain exceptions have the same fundamental parts and regions of the nervous system, although they are developed to different degrees in different species. There are two major parts of the human nervous system. (1) The central nervous system and (2) the peripheral nervous system. The central nervous system consists of 4 regions: (i) the prosencephalon or forebrain (ii) the mesencephalon or mid brain (iii) the myelencephalon or hind brain and (iv) the spinal cord. The remaining portions of the nervous system, outside the central nervous system are collectively referred to as the peripheral nervous system. This consists largely of nerve tracts leading to and from receptors and effector organs. The peripheral nervous system is composed typically of 12 pairs of cranial nerves associated with the brain and variable numbers (in different vertebrates) of spinal nerves which occur in pairs along the spinal cord. The entire central nervous system is hollow, the central cavity varying from a small central canal to larger ventricular spaces in the brain. Also the entire central nervous system is covered by layered membranes called meninges. Both the internal cavities and spaces surrounding the central nervous system between the layers of meninges are filled with a special cerebro spinal fluid.

A classification of the parts of the nervous system.

1. The central nervous system

   A. The cerebrum

      a. Cerebral cortex

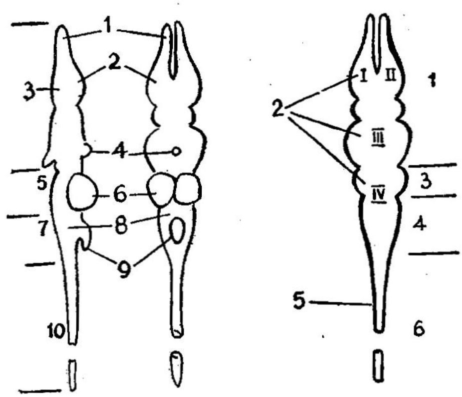
b. Cerebral nuclei
c. Lower cerebral centres
2. The midbrain
3. The medulla
4. The cerebellum

B. The spinal cord

2. The peripheral nervous system

A. Somatic nerves
1. Sensory division
a. Exteroceptive
b. Proprioceptive
2. Motor division

B. Visceral nerves
1. Sensory division (interoceptive)
2. Motor division (= Autonomic system)
a. Sympathetic portion
b. Parasympathetic portion



A [B] C

Fig. 8 Generalised Vertebrate Nervous system
(A) Lateral view (B) Dorsal view (C) Section

A&B 1. Olfactory lobe, 2. Cerebral hemi-sphere, 3. Prosencephalon, 4. Pineal body, 5. Mesencephalon. 6. Optic lobe, 7. Myelencep-halon, 8. Medulla, 9. Cerebellum, 10. Spinal cord
C 1. Forebrain, 2. Ventricles, 3. Midbrain, 4. Hind brain, 5. Central canal, 6. Spinal cord.

The human brain structure

The human brain consists of the same general regions as the brains of lower vertebrates. The pattern looks distorted due to the greater development of the cerebral hemispheres and to the repositioning of the parts to accommodate the upright posture of man. The cerebral hemispheres hide the other portions of the forebrain, most of midbrain and a part of the hindbrain.

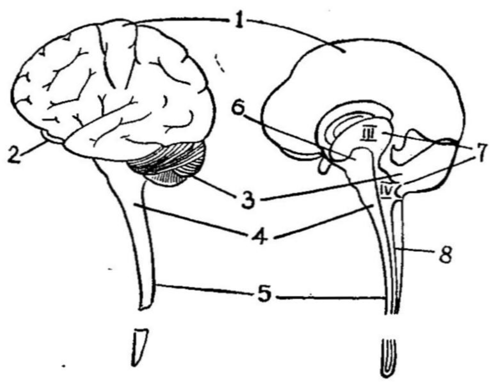


Fig. 9 Major portions of the Human Central Nervous System
Human Nervous System

1. Cerebral hemispheres, 2. Olfactory lobe, 3. Cerebellum
4. Medulla oblongata, 5. Spinal cord, 6. Mid brain,
7. Ventricles, 8. Central canal.

The cerebrum contains two large cavities (ventricles I and II) that lie lateral to the midline and a third cavity (ventricle III) in the midline. The substance surrounding these ventricles consist of nerve tracts and collections of nerve cell bodies which lie in the ganglia. The exposed surface of cerebrum consists of nerve cell bodies which are arranged to form the cortex of the cerebrum. The cortex is marked by a number of deep fissures and shallow sulci (singular-sulcus) that gives a convoluted appearance.The convolutions between sulci and fissures are called gyri (singular-gyrus). Though the convolutions appeal to be random to an observer, in actuality, the same pattern of fissures, sulci and gyri occurs on every human brain and each one of them is given a definite name by anatomists.

The right and left cerebral hemispheres are separated from each other by a deep sagittal fissure. Each hemisphere is further divided by a vertical central fissure and a diagonal lateral fissure. These, with other land marks divide the cerebral cortex into four lobes-namely-the frontal lobe anteriorly, the temporal lobe laterally and the parietal and occipital lobes posteriorly.

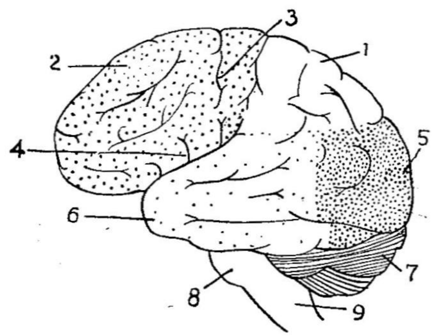


Fig. 10 Human Brain (lateral view)

1. Parietal lobe, 2. Frontal lobe, 3. Central fissure,
4. Lateral fissure, 5. Occipital lobe, 6. Temporal lobe,
7. Cerebellum, 8. Pons, 9. Medulla oblongata.

The cavities within the cerebral vesicles extend into the frontal, parietal and occipital lobes.Each of these communicates through a small interventricular foramen with the median cavity (ventricle III) which lies between and slightly below the level of lateral cavities. From the III ventricle, the cerebral aqueduct passes through the midbrain to open into the IV ventricle, of the medulla oblongata which communicates with the tiny canal of the spinal cord.

The outer surface of the entire central nervous system is covered by a thin, closely adherent membrane called the pia mater. It dips into all of the fissures and sulci following the contours of the central nervous system. Over the pia mater is a second membrane called the arachnoid membrane. It is attached to the pia mater by delicate spider-web like strands of tissue; the space between the arachnoid membrane and the piamater is crossed only by these strands. This is the subarachnoid space and is filled with cerebrospinal fluid. (as are the internal ventricles and passages). The arachnoid membrane also dips into the fissures and larger sulci but does not follow the contours of the central nervous system as does the piamater. Thus the subarachnoid space is relatively large in certain places. Finally, a third membrane, the dura mater, encloses the whole. It is tough, thick and doubled in some spaces. It follows closely the inner surface of the skull and is continuous with the connective tissue lining of the bones surrounding the central nervous system. This connective tissue, which covers all bones is called periosteum. In regions where the dura mater is doubled there are venous blood sinuses between them, which serve as the major routes of venous drainage from the brain. All the three membranes extend downward and envelop the spinal cord also.

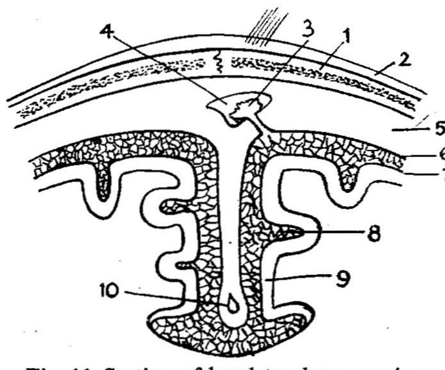


Fig. 11 Section of head to show meninges

1. Bone of skull, 2. Skin, 3. Arachnoid granulation, 4. Superior sagittal sinus, 5. Dura mater, 6. Arachnoid, 7. Pia mater, 8. Subarachnoid space, 9. Central Cortex, 10. Interior sagittal sinus.

The cerebrospinal fluid is a special filtrate of blood plasma formed by a specialized membrane (choroid plexus) composed of endothelium of blood capillaries and lining membranes of ventricles. It circulates through the interior of the central nervous system, bathes the exterior of the central nervous system and is ultimately returned to the blood through the arachnoid granulations. This fluid is like blood plasma in many respects but it lacks blood cells, its protein content is different and its pH is altered by changes in CO_2 concentration. This is probably an important factor in the controls of respiration and blood pressure.

Within the cerebrum there are many nerve tracts leading to and from lower levels of central nervous system and interconnecting various parts of the cerebrum itself. Besides these, there is a number of nerve cell bodies (ganglia). On the floor of the fore-brain extends the stalk-like infundibulum leading to the hypophysis (pituitary gland). Also olfactory bulbs, tracts, the optic chiasma, small mamillary bodies and other pairs of cranial nerves are prominently visible on the floor of the cerebrum.

The mesencephalon contains dorsal swellings, the corpora quadrigemina which contain ganglia (nuclei) which function in the integration of reflexes of body balance and optical orientation. There are also many nerve tracts connecting higher and lower portions of the central nervous system.

The medulla oblongata also contains many connecting nerve tracts and special nuclei which control respiration. Other nerve tracts pass horizontally through and around the medulla, linking the right and left hemispheres of cerebellum, forming a prominent anterior bulge called the pons cerebelli.

The cerebellum is in the form of paired hemisphere from the dorsal surface of the medulla oblongata. It is marked by long, narrow surface gyri separated from each other by deep sulci or fissures. These sulci branch below the surface, giving the cerebellum a very large surface area (cortex). Nerve tracts pass upward and downward. Special nuclei function in connection with the fine integration of skeletal muscle activity.

The human brain : Functions

By careful examination of the brains of persons with known functional losses, it has been possible to map the functional areas of the cerebral cortex.

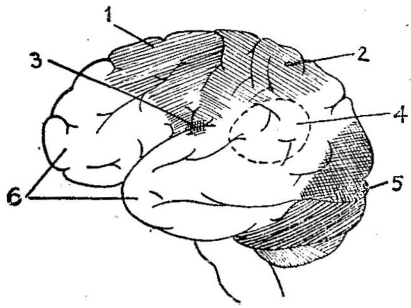


Fig. 12 Functional areas of Cerebrum

1. Motor area, 2. General sensory area, 3. Auditory area, 4. Symbolic association (language) area, 5. Visual area, 6. Psychic area.

The cortex part of the frontal lobes and most of the temporal lobes are psychic in function. The occipital cortex is the region of visual reception and interpretation. The superior portion of the temporal-lobeis the auditory receiving area. The post central gyrus area receives general cutaneous sensations (touch, temperature etc). The superior portions of the parietal lobe is the conscious association area for these sensations. The posterior and superior portions of the frontal lobe of cerebrum are concerned with the conscious production of muscular activity.The central area of the parietal lobe is involved in the interpretive function of symbols and languages, peçuliar to humans. The internal nuclei and ganglia of the cerebrum are functional in the control of gross stereotyped motor activities in man.

The functions of the mid brain and medulla oblongata, other than the conduction of nerve impulses between higher and lower levels of the central nervous systems are associated with fundamental life processes. These include the regulation of respiratory and cardiovascular activities, postural balance and control of visual reflexes involved in focussing the eyes.

The role of cerebellum is very interesting. It initiates the nerve impulses that produce voluntary movement of skeletal museles. It also monitors the effect of motor impulses of the cerebral cortex, receives messages from various senses receptors in muscles, tendons and skeletal joints. From this information it modifies motor action so that it can be carried out smoothly and effectively.

The human spinal cord

The spinal cord is composed of tracts of nerve fibres carrying ascending and descending nerve impulses. It also carries regions relating to the co-ordination of simple reflex responses.

In the ádult human the spinal cord passes through the neural canal of the vertebral column only as far as the last thoracic vertebra. Beyond this, the vertebral canal of the lumbar and sacral regions contains a bundle of spinal nerves rather than the spinal cord itself. This bundle of spinal nerves is called the cauda equina 'horse's tail'.

The outer portions of the spinal cord are composed of "white matter" and contain the ascending and descending nerve tracts. This portion may be divided into dorsal, lateral and ventral white columns. The more centrally located "grey matter" is made up of nerve cell bodies and their connective synaptic processes. This region is in the form of the letter H, and can be subdivided into dorsal, lateral and ventral grey horns. It is penetrated at its centre by the tiny central canal of the spinal cord.

Near the end of the dorsal grey horns are attached the dorsal roots of the spinal nerves on each side of the spinal cord. Similarly near the ends of the ventral grey horns are attached the ventral roots of the spinal nerves. The dorsal and ventral roots join each other on each side of and lateral to the spinal cord to form the spinal nerves themselves.

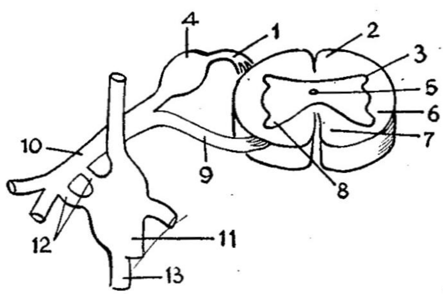


Fig. 13 Spinal cord (Section)

1. Dorsal root, 2. Dorsal white column, 3. Dorsal grey horn, 4. Dorsal root ganglion. 5. Central canal, 6. Lateral white eolumn, 7. Ventral white column, 8. Ventral grey horn, 9. Ventral root, I0. Spinal nerve, 11. Lateral (para vertebral) ganglion. 12. Rami communicantes. 13. Autonomic trunk.

The peripheral somatic nerves

The dorsal roots of the spinal nerves are each marked by a prominent swelling called the dorsal root ganglion. This ganglion contains the cell bodies of all sensory nerves. Only sen, sory neurons pass through the dorsal root, and all such neurons- therefore, enter the spinal cord near the dorsal grey horn. The ventral roots of the spinal nerves, on the other hand, contain only motor neuron tracts. The cell bodies of these neurons lie in either the lateral or the ventral grey horns of the spinal cord. Those associated with the somatic nerves (nerves carrying motor impulses to skeletal muscles) are located in the ventral grey horns, and those associated with the visceral nerves or autonomic system (nerves carrying impulses to smooth muscles) are located in the lateral grey horns. The spinal nerves, which are formed by the junction of the dorsal and ventral roots, then, contain mixtures of sensory and motor tracts of all kinds.

Laterally, each spinal nerve divides into dorsal and ventral primary rami, which lead, with many subdivisions, to the dorsal and ventral portions of the body respectively. Sensory nerves pass by these routes from receptors located in the skin (extero ceptors) which are sensitive to touch, temperature, pressure and pain. Other sensory tracts arise instead from receptors located within skeletal muscles, joints and tendons (proprioceptors) and carry impulses related to stretch, pressure and the like. Somatic motor neurons also send processes through these same nerves to innervate the skeletal muscles of the body. In addition, some visceral sensory and motor nerves make use of the same routes since they lead to the smooth muscles of arteries and glands in those regions of the body.

The peripheral viscerals nerves

Associated with the vertebral column on each side is a connected series of lateral or paravertebral ganglia. Each ganglion of these series is a collection of nerve cell bodies and synapses associated with the autonomic (visceralmotor) system. Each para vertebral ganglion connects with the corresponding spinal nerve through one or two rami communicanes. Each is also connected, by way of a peripheral nerve, to some visceral (or cardiac) muscle of the body.

Autonomic nerve fibres originating from the nerve cell bodies in the lateral grey horns of the thoracic and lumbar portions of the spinal cord are known as sympathetic nerves. The sympathetic cell body in the cord is called preganglionic neuron.

It sends its processes out through the ventral (motor) root of the spinal nerve and, through one of the rami communicates to the corresponding paravertebral ganglion. Here, most of the pre-ganglionic neurons end by synapsing with the cell body of a post ganglionic neuron. The axon of the post ganglionic neuron then passes through a peripheral nerve to innervate some smooth or cardiac muscle. There are minor anatomical variations which have no physiological significance.

Autonomic nerve fibres originating from cell bodies in the several portions of the spinal cord or in the cranial portion (the brain) are called parasympathetic nerves. Those of the several regions follow pathways similar to those described for sympathetic nerves except that no synapsing occurs in the paravertebral ganglia. Instead, the axon of the preganglionic neuron passes on through the paravertebral ganglia and its peripheral nerve and reaches the postganglionic nerve cell body only when it is in or very close to the smooth muscle to be innervated. There it contacts a very short post ganglionic neuron. The tenth cranial nerve, the vagus, carries a large number of these and descends through the neck and trunk to innervate most of the viscera of the thoracic and abdominal cavities. Acetylcholine is the transmitter substance operative at all pre to post ganglionic autonomic synapses.

The two divisions of the autonomic system are antagonistic in their effects upon any given visceral organ. Sympathetic stimulation dilates the pupil of the eye, inhibits salivation, and raises the blood pressure by speeding the heart and contracting the smooth muscles in the walls of arterioles. Parasympathetic stimulation, on the other hand, contracts the pupil of the eye, stimulates salivation and lowers blood pressure by slowing the heart. The transmitter substance at most sympathetic neuromuscular junctions is norepinephrine; the transmitter substances at most parasympathetic neuromuscular junctions is acetylcholine. Transmitter substances acting at neuromuscular junctions are called neurohumors.

The medulla of the adrenal gland receives only preganglionic sympathetic neurons. The transmitter substance, epinephrine is released not into any neuromuscular junction but into the blood stream.

The effect of sympathetic stimulation is associated with emergency stress situations. The additional output of epinephrine from adrenal medulla auguments these responses.

7. Sense Organs

Structure of the human eye

The human eye is roughly spherical in shape. It is bounded by three distinct layers of tissue. The outer layer, the sclerotic coat is extremely tough. It is white in colour (the "white" of the eye) except in the front. Here it forms the transparent cornea which admits light into the interior of the eye and bends the light rays so that they can be brought to a focus. The surface of the cornea is kept moist and dust-free by the secretion of the tear glands.

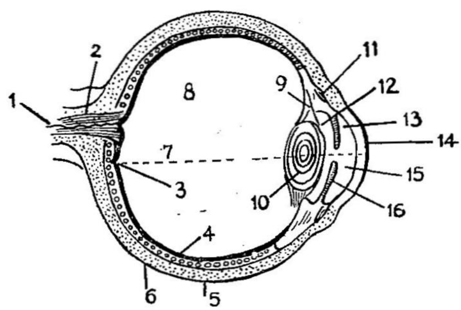


Fig. 14 Human Eye

1. Central artery of retina, 2, Optic nerve, 3. Fovea, 4. Retina, 5. Choroid, 6. Sclerotic. 7. Line of sight, 8. Vitreous body, 9. Suspensory ligament, 10. Lens, 11. Ciliary muscle, 12. Posterior chamber, 13. Anterior chamber, 14. Cornea, 15. Aqueous humor, 16. Iris.

The middle coat of the eye, the choroid coat is deeply pigmented with melanin and well-supplied with blood vessels. It serves the very useful function of stopping the reflection of stray light rays within the eye. This is the same function accomplished by the dull black paint within a camera.

In front of the eye, the choroid coat forms the iris. This, too, may be pigmented and is responsible for the "coloı" of the eye. An opening, the pupil, is present in the centre of the iris. The size of this opening is variable and under automatic control. In dim light (or times of danger) the pupil enlarges, letting more light into the eye. In bright light the pupil closes down. This not only protects the interior of the eye, from excessive illumination, but improves its image-forming ability and depth of field.

The inner coat of the eye is the retina. It contains the actual light receptors. the rods and cones and functions in the same way as the film of the camera.

The lens of the eye is located just behind the iris. It is held in position by suspensory ligaments. Ordinarily these are kept under tension and the lens is correspondingly flattened. However, contraction of muscles attached to these ligaments, relaxes them and permits the lens to take on a more nearly spherical shape. These changes in lens shape enable the eye to shift its focus (accommodate) from far objects to near objects and vice versa.

Movement of the eyeball is accomplished by three pairs of muscles; the members of each pair working antagonistically. The coordinated action of these muscles enables the eye ball to be rotated in any direction. Thus we are able to turn both eyes in a single direction. This produces two slightly differing views of the same scene which our brain is able to fuse into a single three dimensional (stereoscopic) image. Improper coordination of the muscles controlling the eye produces such defects as "cross eyes".

The actual visual receptors of the eye are the rods and cones. These are cells which are arranged closely together just beneath the surface of the retina.

1. **The rods :** There are approximately 100 million rods in each eye. They are used chiefly for vision in dim light and are extremely sensitive to light. The image produced by the rods is however not a sharp one. Careful microscopic study of the structure of the retina provides an explanation for this. The rods function in groups, that is, a number of rods share a single nerve circuit to the brain. A single rod can initiate an

impluse in that circuit but there is no way for the brain to determine which rod in the cluster was involved.

For light to be absorbed, there must be a light absorbing pigment. This is rhodopsin. It is incorporated in unit membranes that are neatly arranged in the outer portion of rod.

2. **The cones** are especially abundant (about 1,50,000 in each square millimeter) in a single region of the retina, the fovea, a region just opposite the lens.

Unlike the rods, the cones operate only in light. Further they enable us to see colours. At least two kinds of cones must be present in order to detect any colours at all. Each must contain a pigment that absorbs a certain wavelength best. In addition to providing the basis for colour vision, cones provide us with our most acute vision. The number of cones sharing a circuit to the brain is far fewer than is the case for the rods. Cones are very densely packed in the fovea. Other tissues, such as blood vessels are absent from this portion of the retina and thus do not interfere with the reception of a distinct image. The image is however, distinct and colourful over just a small area of view.

All the nerve impulses generated by the rods and cones travel back to the brain by way of neurons in the optic nerve. At the point on the retina, where the approximately one million neurons converge on the optic nerve, there are no rods and cones at all. This spot, the blind spot, is thus insensitive to light. The blind spots of our two eyes do not receive the same portions of the visual image, so that each eye compensates for the blind spot of the other.

The human ear

The ability to hear is the ability to detect mechanical vibrations which we call sound. Under most circumstances, these vibrations reach us through the air.

The ear consists of three parts: the external ear, the middle ear and the internal ear.

1. **The external ear** has an expanded outer lobe, pinna, which serves to concentrate sound waves and the auditory canal (external auditory meatus) at the end of which is the tympanic membrane or eardrum. It separates the auditory canal from the inner ear. The membrane is slightly concave, with the concavity towards the auditory canal.

2. **The middle ear** cavity contains three small bones (auditory ossicles) which are known as the malleus, incus and stapes. The

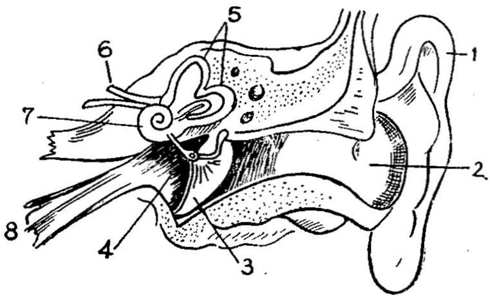


Fig. 15 Human Ear

1. Pinna, 2. External auditory meatus, 3. Tympanum, 4. Tympanic cavity, 5. Semicircular canals. 6. Acuostic nerve, 7. Cochlea, 8. Eustachain tube.

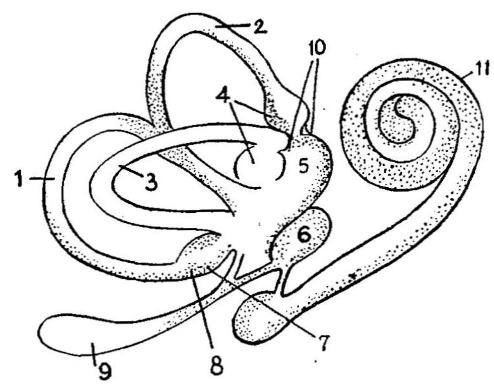
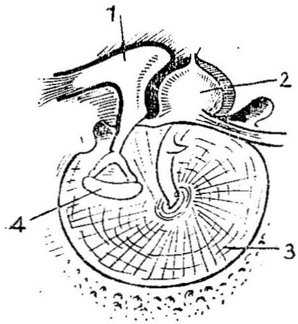


Fig. 15 (a) Membranous labyrinth

1. Posterior canal, 2. Superior canal, 3. Lateral canal, 4. Ampullae, 5. Utriculus, 6. Sacculus, 7. Crista, 8. Ampulla, 9. Endolymphatic duct, 10. Cristae, 11. Cochlear duct.



Fig, 15 (b)
Anditory ossicles
1. Incus, 2. Malleus, 3. Tympanic membrane, 4. Stapes.

malleus (hammer shaped) is attached to the centre of the tympanic membrane by its handle and its other end is joined to the next bone incus, (anvil shaped).which in its turn is articulated with the stapes (stirrup shaped) The stapes is attached to the membrane covering an oval opening leading to the inner ear. The malleus and incus act as a single lever. The articulation of the incus with the stapes causes the stapes to rock forwards and backwards with the movement of the handle of the malleus. Muscles and ligaments limit the amplitude of vibration of the inner bones.

The middle ear cavity is connected to the pharynx by the eustachian tube. Below the oval window is the round window closed by an elastic membrane.

3. **The inner ear** is also called membranous labyrinth. It consists of the utriculus, semicircular canals, sacculus and cochlea. These parts are filled with fluid, called endolymph and the fluid outside the parts is called perilymph. The cochlea is the auditory portion, while the others serve for equilibrium. The whole structure is lodged in the temporal bone of the skull called bony labyrinth.

Auditory organ : The auditory sense organ is placed within and on the outerwall of a spiral tunnel in the temporal bone called cochlea. It resembles a snail's shell. The spiral tunnel makes $2\frac{3}{4}$ turns around a central column of spongy bone. The cochlea is divided into two spiral channels by a membranous septum, called the basilar membrane and by a bony shelf of bone. Another more delicate membrane, called the vestibular membrane proceeds from the upper surface of the shelf of bone to the outer wall where it is fixed a short distance above the outer attachment of the basilar membrane. The spiral tube enclosed between these two membranes is called the membranous cochlea or duct of the cochlea. The part of the cochlea lying above this membrane tube is named the scala vestibuli and the part lying below i.e., named the scala tympani. The middle canal is the scala media. The scala vestibuli is separated from the scala media by a thin membrane, the Reissner's membrane, while the scala media is separated from the scala tympani by the thicker basilar membrane. At the apex of the cochlea, the upper and lower chambers communicate with one another through an opening, the helicotrema. The scala vestibuli begins at the oval window or fenestra ovalis, becoming continuous with the scala tympani at the apex and terminates at the round window or fenestra rotanda. These two chambers are filled with perilymph. The scala media is filled with endolymph.

Resting on the basilar membrane is a structure consisting of specialized cells of different sizes and shapes and known as the organ of Corti. It and the basilar membrane follow a spiral course throughout the length of the duct of cochlea. The specialized cells are the auditory receptors. They are elongated cells at the tips of which are hairlike processes. They are therefore called hair cells. The tips of the hairs are attached to or embedded in a thin elastic a membrane known as the tectorial membrane, which extends outward from near the attachment of the vestibular membrane and floating in the endolymph projects over the organ of Corti.

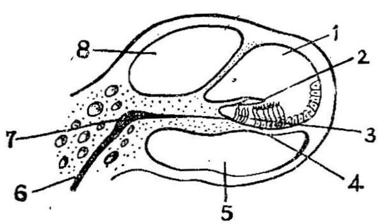


Fig. 15 (c)
Cross section of cochlea
1. Duct of cochlea (scala media), 2. Tectorial membrane, 3. Organ of Corti, 4. Basilar membrane, 5. Scala Tympani, 6. Auditory nerve, 7. Ganglion cell, 8, Scala vestibuli.

Organ of equilibrium : The inner ear contains another organ besides the cochlea, the three semicircular canals and two sacs called the utriculus and sacculus. These are concerned with maintenance of equilibrium.

The semicircular canals are membranous tubes filled with endolymph. The three canals lie approximately at right angles to one another; two are vertical and one is horizontal. One end of each canal is dilated to form a swelling, called the ampulla. A small elevation called the crista is situated in each of the three ampullae. This is composed of cells with hairs, surmounted by a cap of gelatinous material called the cupula. The cristae are the sense organs of the canals. Both ends of each canal open into the utriculus.

The utriculus and sacculus are enclosed in an oval, bony cavity called the vestibule, situated between the cochlea and semicircular canals. The utriculus communicates with the semicircular canal, and the sacculus communicates with the cochlea by a narrow duct. The utriculus and sacculus are indirectly connected. The utriculus or sacculus each contain a sense organ called the macula, also hair cells covered by a layer of gelatinous substance. Adherent to the latter are a number of crystals of carbonates of lime, known as otoliths.

Sense of smell (Olfactory sense)

The mucous membrane on each side of the nose is raised into three ridges by three scroll bones the superior, middle and inferior turbinals which spring from the outer nasal wall. The interior of the nose is thus divided incompletely on each side into four compartments. The lower three compartments form the nasal cavities and serve as air passages. The upper most compartment is a narrow cleft in which are embedded the olfactory receptors.

The olfactory receptors give rise to two types of processes (bipolar) an axon and a modified dendrite. The cells themselves are elongated and are distributed evenly among other elongated cells which are supportive in function. In man there are about 60 million receptor cells while in dog there are about 250 million. These receptors are highly sensitive and can detect even extreme dilutions of odorous substance.

Taste Receptors

Like the sense of smell, taste is also a chemical sense, and responds to chemical stimuli. In order, for a substance to arouse the sensation of taste, it must first be dissolved.

The tongue is beset with minute projections in the anterior two thirds of the upper surface. These projections are called papillae. The papillae at the edges, tip and more anterior parts of the tongue are very small conical, cylindrical or mushroom shaped structures. They are called filiform or fungi-form papillae and give a velvetty character to this part of the tongue. The more posterior part of the tongue surface is rougher owing to the presence of much larger papillae. These are called circumvallate papillae and each papilla is surrounded by a groove.

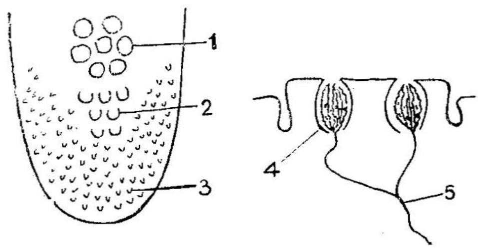


Fig. 16
Tongue and Taste buds
1. Circumvallate papillae, 2. Fungiform papillae, 3. Filiform papillae, 4. Taste bud, 5. Nerve.

Embedded in the covering of the papillae are slender cells of taste receptors. They are provided with hairlike processes and are arranged in bundles-called taste buds. Each cell receives a filament from one of the nerves of taste The taste bud opens upon the surface of the papilla through a small pore.

The fundamental sensations of taste are four in number. Sweet, bitter, sour and salty. The chief nerves of taste are branches of the facial nerve and the glossopharyngeal nerve.

Cutaneous receptors

The sensations of touch, pressure, heat and cold are each dependent upon a special type of sense organ in which the nerve fibre terminates after losing its neurilemma and myelin sheath. The sensation of pain, on the other hand, is transmitted by fibres which terminate as bare axis cylinders.

The different types of cutaneous sense organs are separated from one another by measurable distances.

8. Endocrine Glands

An endocrine gland is one which has no duct. Hence i is also known as ductless gland. The endocrine gland secrete hormones into the blood. The activities carried out by the orga nisms is highly complex and they are integrated and controlle(by two great coordinating systems—the nervous system and en- docrine system. While the nervous system delivers signals ra- pidly and repetitively to specific individual effector organs, th(endocrine system makes use of the circulatory system to distribut(chemical messengers (hormones). Its actions are comparativel; slower. The ability of the endocrine system to control an(integrate functions are dependent on the ability of the particula1 endocrine gland to secrete specific hormone in response to specifi(stimulus and the ability of certain tissues to respond to thi: hormone. One of the most important recent developments in physiology, is the recognition that the nervous system and endocrin(system are inter-related; some parts of nervous system itsel1 function as endocrine glands.

Hormones affect almost all life processes-reproduction, growth and differentiation, storage, utilisation and synthesis of substances, conservation of water and minerals, nerve and muscle activity, glandular functions etc.

General Principles of Endocrine Function

1. Hormones themselves do not create biochemical processes but modify existing metabolic processes and change the rates of actions.
2. Hormones are secreted in response to specific stimuli.
3. Hormones can be secreted independently of one another-
4. Hormones are present in blood in minute quantities.
5. Hormones are believed to be catalytic in their effects.

6. Hormones in the blood and tissues are continuously inactivated and excreted from the body.

7. Hormones have a high degree of target specificity.

The identification of endocrine glands and action of hormones are made from experiments.

i. Deficiency symptoms or physiological disturbances that follow removal.

ii. Reimplantation of the gland or administration of extracts of glands.

iii. Isolation and purification of the hormone.

iv. Synthesis of the hormonal substance.

1. THE PITUITARY GLAND

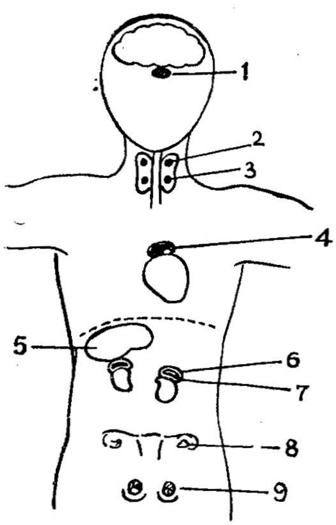


Fig. 17
Endocrine glands in Man
1. Pituitary, 2. Parathyroid, 3. Thyroid, 4. Thymus, 5. Liver, 6. Adrenal cortex, 7. Adrenal medulla, 8. Ovaries, 9. Testes.

Position :

An ovoid structure lying in the centre of the base of the brain, almost completely surrounded by bone.

Structure :

It consists of two divisions.

(1) adenohypophysis which is made up of

(a) pars distalis (anterior lobe) and

(b) pars intermedia (intermediate lobe).

(2) neurohypophysis—which is equivalent to the posterior lobe plus the median eminence of the hypothalamus.

Embryological Origin

The adenohypophysis arises from an outgrowth from the primitive mouth while the neurohypophysis arises as a profusion from the ventral wall of the hypothalamus.

Structure: Neurons lying in the hypothalamus of the brain have axons extending into the neurohypophysis and there is also a special vascular portal system which delivers blood from capillaries in the hypothalamus to other capillaries in the adenohypophysis.

Hormones secreted in adenohypophysis

Different cell types in adenohypophysis produce at least six different hormones.

(1) Somatotropic hormone (STH) or growth hormone.

(2) Thyroid stimulating hormone (TSH) or thyrotropin.

(3) Adrenocorticotropic hormone (ACTH) or adrenal cortex stimulating hormone.

(4) Follicle stimulating hormone (FSH).

(5) Lutenizing hormone (LH) or interstitial cell stimulating hormone (ICSH) and

(6) Luteotropic hormone (LTH).

The last three in this list are often grouped together as gonadotropic hormones.

Hormones produced by neurohypophysis

Two hormones are released

(1) oxytocin.

(2) vasopressin, also called antidiuretic hormone.

Adenohypophysial hormones are polypeptides and the neurohypophysial hormones are octapeptide amides.

Action of the adenohypophysis hormones

Some nerves of hypothalamus secrete chemical substances known as releasing factors which diffuse into the hypothalamic hypophysial postal circulation and are carried to the adenohypophysis where they initiate the secretion of hormones. In this instance, the hormones released are synthesised by adenohypophysis itself.

Somototropic hormone

Action: Acts during the growth period of the individual by increasing rate of protein synthesis and metabolic processes which promote growth. It increases aminoacid transport through cell membranes and the rate of fat utilization.

Deficiency: Deficiency during childhood retards growth and if severe, results in dwarfism. (midget) which normally proportioned but child-sized brain and results in body never attaining puberty or secondary sexual characters. In adults, dificiency has little effect.

Excess secretion: Produces abnormal growth leading to gigantism. Excess in adults produce thickness of bones, resulting in acromegaly.

Thyroid stimulating hormone

Action: Stimulates the thyroid gland to synthesize and release its hormone—an example of one endocrine gland controlling another. When there is an adequate amount of thyroid hormone in the blood, the production of thyrotropic releasing factor in the hypophysis is inhibited, and so less TSH is released from adenohypophysis, and the thyroid gland is less stimulated to produce more of its hormone. When the blood levels of thyroid hormone are less than adequate. The hypothalamus produces more thyrotropic releasing factor, more thyrotropin is released by the adenohypophysis and the thyroids stimulated to produce greater quantities of thyroid hormone. This type of feedback system guarantees that proper amounts of thyroid hormone will always be present in the blood of the normal individual.

Adrenocorticotropic hormone (ACTH)

Action: Stimulates the production of certain hormones in the adrenal cortex. These, in turn, inhibit the production of ACTH releasing factor by the hypothalamus. Here also there is a feedback controlling mechanism, maintaining proper levels of adrenal cortex hormones in the blood of normal individuals at all times.

Gonadotropins

Action: FSH stimulates the maturation of sex cells. In females, the lutenizing hormone (LH) along with FSH, stimulates the maturation of ova and their release from the ovary when they are matured. In the male, the same substance stimulates the interstitial cells of Leydig (intestis). For this reason, in the male, the counterpart of LH is called the interstitial cell stimulating hormone (ICSH). The luteotropic hormone (LTH) in the female is associated with lactation but it has only minor influences in the male.

Action of neurohypophysis hormones

Some of the nerve processes extending from the hypothalamus of the brain to the neuro-hypophysis transport endocrine substances which are stored in and released by the neurohypophysis.

(1) OXYTOCIN:

Action: Causes, rhythmic contractions of the mammalian uterus at the time of childbirth. The uterus does not respond to oxytocin at any other time because of the inhibiting influence of progesteron, another hormone produced by the ovaries. Oxytocin also plays a role in mammalian lactation.

(2) VASOPRESSIN:

Action: It raises the blood pressure but its more important role is the control of the water balance of the body. So it is also called antidiuretic hormone

(ADH). It increases the permeability of the collecting tubules of the kidney and thus causes the retention of the water by the kidney. The release of ADH is controlled by the activity of certain osmoreceptor cells of the hypothalamus.

2. THE THYROID GLAND

Position: It consists of a pair of lobes which lie one on either side of the larynx in the neck. The paired lobes are joined by a narrow anterior bridge of glandular tissue. The cells of the thyroid are organised into hollow spheres that are filled with a viscous secretion-a colloid:

Embryological origin: It is derived from a downward growth of oral epithelium.

Hormone secreted: Thyroxine. The structure of thyroxine was determined by Harrington in 1926. It is an iodinated form of the amino acid, thyroxine.

Action of hormone: To increase the general metabolic rate of the animal, such as the production of energy, synthesis of protein, activity of nervous system and the activity of other endocrine glands. Mechanism of action is not understood. Excess secretion results in loss of weight. Such hypersecretion may result from thyroid tumor or overstimulation by hypophysis. Deficiency results in obesity. Inadequate secretion in children prevents normal, mental development, and result in a condition called cretinism. In the adults, deficiency results in dulling of mental ability and an accumulation of fluids in tissues. This condition is known as myxedema.

Enlargement of the gland is called goitre. It may accompany either hypo or hyperthyroidism. Insufficiency of iodine in diet is one of the causes for shortage of thyroxine.

In the normal human, the shortage of thyroxine leads to the production and release of TSH from hypophysis which stimulates thyroid to produce thyroxine.

3. THE PARATHYROID GLANDS

Position: The parathyroid glands consist of four small bodies posterior to and embedded in the substance of the thyroid gland;

hormone produced is parathormone. It is a protein with about 80 amino acids.

Action of parathormone : Controls the metabolism of calcium and perhaps phosphate. It favours deposition of these salts in the bone and increases the renal retention of Ca ions. It also promotes the absorption of Ca in intestinal tracts. Thus it indirectly controls the blood calcium levels.

Removal of parathyroids results in the fall in the blood calcium level and tetany occurs. So it is essential for life. Tetany in man usually consists of spasms of the muscles and of the hands, feet and larynx, and muscular convulsions.

Excess secretion brings about demineralization of the bones and also the protein matrix may be absorbed, resulting in bone cysts and the blood calcium rises. Calcification occurs in the kidneys, arteries, stomach and lungs.

A second hormone affecting calcium homeostasis has recently been discovered and named calcitonin. It may originate in the parathyroid gland.

4. THE ISLETS OF LANGERHANS

Position and structure : The cells are found lying between the portions of pancreas which produce digestive enzymes. These endocrine parts are called the islets of Langerhans and they contain two cell types; called alpha cells and beta cells.

Hormone produced : The alpha cells produce glucagon and the beta cells produce insulin. Both the hormones are secreted into the blood of the hepatic portal vein and are carried directly to the liver where they produce their major effects. Some of the hormone passes on through the liver into the general body circulation. This influences the utilization of sugars by all the cells of the body.

Insulin is a protein containing 51 aminoacids.

Action of Insulin : Promotes the transport of glucose through the cell membranes of muscles and especially of the liver. Liver normally has large stores of glucose in the form of glycogen. It maintains proper levels of blood glucose by either taking it up or releasing it as required. Insulin facilitates this exchange as well as the uptake and utilization of glucose by the muscles and other tissues. The level of blood glucose normally acts in a feedback manner to control the rate of insulin release from the islets of Langerhans.

Dificiency of insulin causes inhibition of storage and utilisation of sugar and as a result glucose accumulates in the blood until its level may exceed the renal threshold. Then glucose appears in the urine (diabetes mellitus). When insulin levels are low fat catabolism is increased and fats are converted into glucose. This further increases blood glucose levels and results in the accumulation of ketone bodies.

Excess secretion can lead to lowered·blood glucose levels since the effect of insulin on glucose uptake by muscles exceeds its effect on liver release of glucose. Such lowered blood glucose levels can have serious consequences.

Action of Glucagon : Its effects on blood glucose level is generally opposite to the effects of insulin. Glucagon favours the release of glucose from the glycogen stores of the liver and thus, raises blood glucose levels.

A proper balance between insulin and glucagon production is therefore necessary to maintain proper blood glucose concentrations.

5. THE ADRENAL GLANDS

Position : They are pyramidal structures which lie in close association with the kidneys.

Structure : An adrenal gland is composed of an outer cortex and an inner medulla; these two portions are separate endocrine glands. The cortical tissues are arranged in three layers-the outermost of which is called the zona glomerulosa. This layer produces mineralocorticoids. The second layer, the zona fasciculata and the third layer, the zona reticularies, produce other steroid hormones known as glucocorticoids.

Action of mineralocorticoids : Their major effect is on the metabolism of sodium ions and indirectly, potassium ions.

The major mineralocorticoid hormone is Aldosterone. Its most important effect is to promote the resorption of sodium ions from the renal glomerular filtrate. Secondary effects of sodium retention are, an increased chloride retention and a decreased potassium retention by the kidneys. The retention of sodium ion also leads to water retention by it.

The most important function, of the adrenal cortex is its role in stress tolerance. This function is not well understood. After adrenalectomy an animal is not able to adjust in a normal way to stresses like injury, burns, infection etc., whereas in an intact animal, the adrenals enlarge and increase hormone production during stress.

Adrenal medulla

Hormones produced: adrenalin (epinephrine) and noradrenalin (norepinephrine).

Action: The hormones have important role in a number of physiological processes, particularly in the adaptation of an animal to sudden emergencies.

Adrenalin stimulates constriction of blood vessels supplying the intestines, kidneys, other viscera and skin and causes dilation of blood vessels supplying skeletal and heart muscle. It also increases the rate, amplitude and frequency of the heart beat. It causes relaxation of the smooth muscles of the digestive tract and brings peristalsis to a halt. However, it causes contraction of the sphincters of the intestine and bladder. Adrenalin increases sweating. It causes contraction of muscles associated with hair follicles and so makes the hair "stand on end" and causes goose flesh. It accelerates respiration and stimulates mental alertness. It stimulates the breakdown of glycogen to glucose, thereby increasing oxygen consumption and heat production.

Noradrenalin has many of the same effects but its effects on emergency responses are milder. Further it has no effect on glycogen breakdown, and in skeletal muscle, it causes constriction, rather than dilation of the blood vessels. Thus it causes a greater rise in blood pressure. The primary function of noradrenalin is believed to be regulation of the blood pressure, by means of the antidiuretic hormone mechanism. Thus, the control of the levels of blood sodium has far reaching consequences. Plasma levels of Na^+ and perhaps of K^+ act to control the rate of aldosterone secretion.

Action of glucocorticoids: These play roles in the metabolism of carbohydrates. The major glucocorticoids are cortisone and certain closely related steroids. These hormones stimulate the production of glucose from non-carbohydrate sources such as fats and aminoacids. Thus, they promote the reduction of amino-acid stores in most tissues and the uptake and catabolism of aminoacid in the liver. Glucocorticoids also decrease glucose utilization by tissues in general. All of these effects lead to increased blood glucose levels. Thus, the glucocorticoids are intimately associated with the hormones of the islets of Langerhans in the controls of blood glucose concentration.

Cortisone also acts as an anti-inflammatory agent. In addition, the adrenal cortex normally secretes small amounts of sex hormones.

6. THE GONADS

(a) The testes

Position and structure: The testes are the male gonads, composed of cords of cells arranged in lobules. Spermatozoa arise from these cords of cells under the influence of FSH secreted from the adenohypophysis. Between the spermproducing cords within the testes are the interstitial cells of Leydig which have an endocrine function. Under the influence of the interstitial cell stimulating hormone (ICSH) from the adenohypophysis these cells produce testosterone the major sex hormone of the male. Testosterone and other male sex hormones are known collectively as androgens.

Action of testosterone: Testosterone causes embryonic development of the male reproductive organs. It also induces the maturation of these organs during childhood and maintains their normal function following puberty. At the time of puberty testosterone also promotes the development of the secondary sex characteristics of males, including physical development, hair distribution, masculine voice and male behaviour.

(b) The ovaries

Position and structure: Mammalian ovaries are oblong in shape and situated in the pelvic portion of the abdominal cavity.

Each is close to the expanded opening of the oviduct (fallopian tube) which leads into the uterus.

Each ovary contains a large number of undeveloped sex cells or ova and as they develop they rise to the surface of the organ and become enclosed in blister-like-graafian follicles. At the time of ovulation, the follicles rupture and the contained ova are discharged. The entire process of ovum maturation and ovulation is a cyclic phenomenon.

Hormones produced : Under the influence of the FSH from the adenohypophysis, the ovum grows and becomes enclosed in the graafian follicle. Associated cells of the follicle produce a steroid hormone called estrogen.

As soon as the ovum is discharged from the graafian follicles, the site of the ruptured follicle becomes changed in appearance and function. The remaining follicular cells from a new structure called the corpus luteum under the continued influence of LH. The corpus luteum grows and produces another steroid hormone called progesterone.

The hormones estrogen and progesterone have a number of functions. They stimulate the development of female reproductive organs and appearance of secondary sexual characters. They also prepare the uterus to receive and protect the implanted embryo.

Gastrointestinal hormones

The gastrointestinal hormones form an independent system which is not influenced by the endocrine glands studied so far. The digestive hormones are produced by endocrine tissues of the digestive tract, under mechanical or chemical stimuli.

The main digestive hormones, their origin stimuli, target organs and responses are shown in the table.

ORGANS WHICH MAY BE ENDOCRINE GLANDS

Pineal gland

It lies in the roof of the third ventricle. Recently it has been suggested that the pineal gland is the source of adrenoglomerulotropin, a substance which stimulates the zona glomerulosa of the adrenal cortex to secrete aldosterone.

TABLE: THE MAIN DIGESTIVE HORMONES

Hormones	Where formed	Stimuli	Target organ	Response of target organ	Remarks
1. Gastrin	Gastric mucosa of the stomach	Presence of digesting protein in stomach	Gastric mucosa	Secretion of hydrochloric acid	Atropine inhibits its secretion
2. Enterogastrone	Duodenal mucosa	Presence of fats or hypertonic sugar solutions in duodenum	Stomach	Inhibits secretion of HCl and the motility of stomach	No effect on secretion of pepsin or mucus
3. Secretin	Duodenal mucosa	Presence of HCl in digesting fat and bilesalts	Pancreas	Stimulates exocrine secretion of pancreas secretion of bilesalts	Active principle is claimed to have been isolated
4. Cholecystokinin	Duodenal mucosa	fats and hydrochloric acid	Gall bladder	Contraction of gall bladder and expulsion of bile	——

Thymus Gland

It is a lobulated organ lying anterior to the heart. It is large during the years of rapid growth and regresses after puberty. Its function is not definitely known. In man a disease called myasthenia grevis may be associated with a thymic tumour.

Placental Hormones

Placenta is formed during pregnancy. It is a special organ which facilitates exchange of material between the mother and the embryo. Placenta is an elaborate, although transitory endocrine organ, which plays, a major role in the maintenance of gestation and at the end of it initiates the labour.

The placenta secretes a placental gonadotropin known as chorionic gonadotropin under the influence of luteinizing hormone of the pituitary. Its action is similar to luteinizing hormone and it is essential to bring about the maximum development of the corpus luteum. It at first supplements, then eventually replaces the gonadotropic function of the pituitary gland as pregnancy proceeds. Thus in later pregnancy the pituitary gland is non essential for gestation.

Hormones Involved in Labour

Labour is a series of rhythmic muscular contractions of the uterus that lead to expulsion of the fetus and placenta The hormonal control of labour is still not fully understood. Estrogen secretion is increased at the end of pregnancy bringing about the contraction of the uterus and this is perhaps augmented by oxytocin and relaxin, secreted by the ovary and placenta causes relaxation of the cervix, distending the birth canal, facilitating delivery.

Estrus Cycle

The sexual cycle of the female is called the estrus cycle. The duration of the period is 28 days in the woman. Estrus is repeated at intervals till pregnancy occurs.

Function of the Estrus cycle

(1) to bring the reproductive tract of the female into a condition favourable for gestation.

(2) to synchronize this state with sexual receptivity, ovulation, fertilization and movement of fertilized eggs into the uterus.

Hormones involved : Pituitary gland, the ovary and reproductive tract.

There are two functional phases of the estrus cycles

(1) Follicular phase.

(2) Luteal phase.

(1) **Follicular phase :** During this phase, the young follicles grow under the influence of the pituitary follicle sitmulating hormone and reaches maturity and is ready for ovulation. Estrogen is the predominent ovarian hormone during the follicular phase (although some progesterone is also secreted) and as the estrogen is secreted the follicles grow to maturity. When the concentration of this hormone is high, it inhibits the secretion of follicle stimulating hormone thus blocking further growth of follicles and at the same time stimulates growth of reproductive tract, especially the endometrium of the uterus. This is augmented by the secretion of progesterone.

At the end of follicular phase, ovulation occurs.

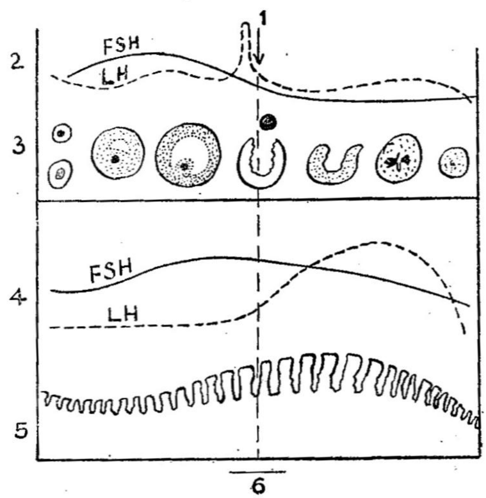


Fig. 18. The Neuroendocrine Control of Ovulation
1. Ovulation, 2. Gonadotropin hormones, 3. Follicle phase
4. Ovarian hormones, 5, Uterine wall cycle, 6. Heat.

(2) **Luteal phase:** Ovulation marks the beginning of the luteal phase of the estrus cycle. The empty follicle, after discharge of ovum, is transformed into a highly glandular structure, the corpus luteum. This is an important though transitory, endocrine organ that secretes large amounts of estrogen and progesterone under the influence of the pituitary luteinizing hormone. Progesterone is the predominent ovarian hormone of this phase. It acts on the uterus and causes the uterine endometrium to thicken and promotes growth of endometrial glands. It prepares the uterus to receive the fertilized egg for implantation. It inhibits contraction of the uterus. It also blocks the secretion of pituitary gonadotropins, especially luteinizing hormone, thus further growth of ovarian follicles are prevented till the corpus luteum ceases to function.

If implantation occurs, the corpus luteum functions through out pregnancy. Otherwise it ceases to function and the surface layers of uterine endothelium is sloughed off and discarded; and the uterus shrinks to its original size. The estrus cycle is then repeated.

Lactation

Lactation includes 3 phases, all of which are hormone dependent.

1. Development of the secretory cells and ducts of mammary gland is promoted by estrogen and progesterone. The lactogenic hormone (prolactin) also stimulates growth.

2. Milk secretion: Synthesis of milk is stimulated by growth hormone and prolactin. Continued secretion requires continued sucking, which provides a stimulus for secretion of prolactin.

3. Milk let-down: Ejection of milk is the result of neuro hormonal reflex that causes the secretion of oxytocin.

CHAPTER II

Ecology

An individual organism does not live alone. Each living organism is part of a biotic community, a group of organisms inhabiting a common environment and interacting with each other. Each species moreover fits into its community in a unique functional way-it has a specific habitat. The specific part of a biotic community in which each organism lives is called a habitat. Between the seashore and high mountain peaks, there are many different communities such as ponds, forests, lakes and deserts

The area of science concerned with the inter-relationship of organisms and to their environment is known as ecology. Recently man has become acutely aware of the consequences of his activities for natural environments and this awareness has led to an increased concern for human ecology.

1. HABIT ECOLOGY

There are three main habitats--viz. fresh water, marine and terrestrial.

Fresh water habitat : lakes and ponds.

Lakes and ponds are familiar features of the landscape and occur in practically every biome. They vary in size from less than an acre to many miles, and in depth from several feet to almost a mile. The origins of lakes are varied. Many are the direct or indirect result of glaciers, whereas natural or man-made dams may cause depression to fill with water. Parts of meandering rivers, cut off from the main stream, can also result in lakes.

Lakes are often classified on the basis of the amount of organic matter they contain.

1. Eutrophic lakes are relatively shallow with a rich accumulation of organic products.
2. Oligotrophic lakes, on the other hand, are generally deep and often have rocky, steep sides. The supply of nutrients such as phosphates are low in these lakes.

Ponds are small bodies of water with a large **littoral** zone Ponds are of different types.

1. Flood plain ponds are formed when a stream shifts its position, leaving the former bed isolated as a body of standing water.
2. Temporary ponds are those which remain dry for part of a year.
3. Artificial ponds are the result of formation of a dam of a stream or basin, by man.
4. Permanent ponds are those which contain water throughout the whole year.

Stratification : Lakes and ponds (as well as oceans have two basic layers. (1) The upper sunlight or euphotic zone is dominated by autotrophic organisms (producers). (2) Lower regenerating consumer zone inhabited by heterotrophic organisms.

Also, stratification is possible depending on light intensity, wave-length absorption, **hydrostatic** pressure and temperature. Accordingly the following zones are recognised in ponds.

1. **The littoral zone**—where the light penetrates upto the bottom. It is occupied by rooted plants.
2. **The limnetic zone**—upto the depth of effective light penetration.

   It is occupied by planktons, nektons (swimming forms) and sometimes neustons (surface dwellers).
3. **The profundal zone**—bottom and deep water area which are beyond the depth of effective light penetration.

In a lake, the limnetic and profundal zones are relatively larger than the littoral zone and the limnetic zone is the main producer region; whereas in a pond, the limnetic and profundal zones are generally absent and the littoral region is the chief producer region.

Stratification is also possible with regard to temperature. During summer lakes often have at the bottom a region of cold water (the hypolimnion) which is of greater volume than that of the upper region of warm water (the epilimnion). The hypolimnion in the oligotrophic lakes contains considerable oxygen at all times. Separating the epilimnion and hypolimnion is the metalimnion, a layer in which the temperature of the water falls very rapidly with increasing depth. Within the metalimnion is a zone of maximum rate of decrease in temperature called the thermocline. In this zone the decrease in temperature must be at least 1°C per meter of increase in depth.

Food relationships: The food relationships common in all communities, are also seen here.

Producers----consumers----decomposers.

A special group of organism found in aquatic environments is the plankton, a large and varied group of mostly small, free floating organisms. Some plankton, the phytoplankton contain chlorophyll, and therefore are capable of synthesizing food. Other types of plankton, the zooplankton must depend on the phytoplankton as their food source. The plankton are essential members of all aquatic chains since they are the producers and primary consumers. One common chain found in many lakes is: Phytoplankton-zooplankton--small fish--large fish. Diatoms are one of the most important members of the phytoplankton group and it can be said that all animal life in the sea depends ultimatel- on diatoms.

Lentic Biota: (Flora and fauna in lakes and ponds)

(a) Littoral zone: Flora include rooted plants and phytoplanktons eg. diatoms, green algae, blue-green algae and filay mentous green algae. Fauna include zooplanktons such as water fleas, copepods, damsel fly nymphs, dragon fly nymphs, flatworms, rotifers, ostracods. Some burrowing worms, larvae of midges, mosquitoes, fishes, frogs etc.,

(b) Profundal zone: There is no light in this zone and the organisms found here depend on the organisms of littoral zone for food. Blood worms, some clam phantom larvae, bacteria etc , are found here.

Lotic Biota: (Flora and fauna in rivers, streams etc., having running water)

The organisms in this habitat must be able to withstand the current of the water. Temperature of the water fluctuates and because there is through mixing, the temperature and concentration of nutrients are usually the same from top to bottom. The streams generally contain an abundant supply of oxygen.

The organisms of this habitat exhibit adaptations for maintaining their life.

1. Permanent attachment to a firm substrate. eg. algae attached to stones, logs; caddis fly larvae cement their cases to stones.
2. Presence of hooks and suckers for attachment with smooth surfaces. eg. some diptera larva, cadis larvae.
3. Sticky under surfaces. eg.snails and flatworms.
4. Stream lined bodies--eg. fish, insect larvae.
5. Flattened body enables them to find retuge under stones and crevices eg., nymphs of stone fly, may fly.
6. Positive rheotaxis (rheocurrent and taxis-arrangement some animals are adapted to move upstream).
7. Positive thigmotaxis (thigmotouch or contact) stream animals cling close to the surface or keep the body in close contact with the surface.

The Marine Environment

Today more and more attention is being focussed on the sea, not only as a biome of interesting plants and animals but also as a source of food, minerals, petroleum, and even as a habitat for mankind's booming population. The study of the sea is known as oceanography.

Perhaps the most well known characteristic of the ocean is its high concentration of salt and mineral ions. The most abundant ions in sea water are sodium and chlorine followed by sulphur magnesium, and calcium. In addition all the naturally occurring elements known to man are found in the sea. The dissolved ions in seawater occur in very stable proportions, and the total salinity often is calculated from the determination of the amount of chloride ion. The total salt concentration or salinity is considered to be the total grams o solids, excluding organic material, found in one kilogram of sea water. It averages 35 parts per thousand (g/kg). Salinity varies the most, in surface water which is affected by land run-off, precipitation, evaporation, and melting polar ice. Salinity is highest in the tropical regions owing to the greater rate of evaporation.

The five major oceans of the earth are the Pacific, Atlantic, Indian, Arctic and the Antarctic. The oceans are shaped generally like a wash basin in which the rim of the basin represents the continental shelf or the edge of the continents. A relatively shallow area of water, the neritic province, covers the continental shelf. The oceanic province, the deeper region of the sea, lies off the continental shelf (the major portion of the basin in our analogy). The continental shelves extend from the shore an average of 100 miles and from the continental slope, a gradual slope downward to the ocean bottom. The profiles of the Pacific and Atlantic show an irregular topography of ridges, basins and deep trenches. In 1960, the manned bathyscaph Tricste II descended to a depth of 35,802 feet, mans deepest penetration. Although there are several deep trenches, the average depth of the oceans is two and a half miles (12,000 feet).

Since the amount of photosynthesis is determined by the availability of light the ocean is often zoned according to light penetration. The upper 600 feet, the lighted open-water or photic zone contains the largest number of organisms, and planktons are specially abundant in this zone. The phytoplankton dinoflagellates, blue green algae and green algae are the important groups. Crustaceans form most of the zooplankton. Another category of organisms, the necton, are free swimming organisms such as fish, squid and whales which live not only in the photic zone but in all parts of the ócean. Below the depth of photosynthatic activity, the rate of food utilizations greater than food production and consequently more oxygen is consumed than is produced by photosynthesis. The depth at which the respiratory and photosynthetic rates are equal is termed the compensation depth.

Although the upper 600 feet of the ocean is generally referred to as the photic zone, some light does penetrate to 1200 feet. The light between 600 and 1200 feet is insufficient for photosynthesis, however and thus the area below 600 feet is generally called aphotic. Below 4200 feet is the dark openwater zone which is always dark. The animals living here are primarily predators with special adaptation such as enormous jaws, sharp teeth etc., Some utilize luminescent organs to attract prey. Below 6,000 feet is the bottom or benthic zone. Bacteria, silicious sponges, seacucumbers, bivalves, polychaete worms, variou-crustaceans, and brittle stars inhabit this zone.

The major temperature variations in theocean occur in the upper 3,000 feet. The Arctic and Antarctic regions are always near O°C, the Antarctic being somewhat colder. The deeper water below 6000 feet varies only 2 to 3°C throughout the seasons.

A seasonal thermocline can also exist in the oceans. The influence of warm or cold current, the geographical location and the amount of mixing produced by wave action and upwelling are some of the factors which influence the temperature of the oceans. Vertical mixing and upwelling allows a recirculation of minerals necessary to maintain the phytoplankton. Consequently the greatest amount of plankton and therefore the best fishing are found in the higher northern and southern latitudes.

The Intertidal Zones

Tide refers to the vertical rise and fall of coastal waters resulting primarily from the gravitational effects of the moon and sun. The horizontal movements of water, the currents, are a consequence of tide, wind, temperature and salinity. Plants and animals that live in the intertidal zones are repeatedly covered and uncovered by the cyclical tides. In general, four intertidal zones may be recognized: (1) spray zone (2) high tide zone (3) mid tide zone (4) low-tide zone.

The physical nature of the beach is significant in determining which species of plants and animals can survive there. The most common beach types are rocky, sandy and mudflat. In many areas, nearby fresh water sources may produce brackish or estuarine conditions. Organisms living in the estuarine habitat must be able to withstand extreme fluctuations in salinity. Several mechanisms exist in the organism for regulation of internal salt concentration, when the salt concentration changes in the environment. Other factors which determine the population of a beach include the amount of protection available from the pounding surf and the length of tidal exposure.

The animals living in the tidezones show definite zone preferences and physiological adaptations. On the rocky, unprotected beaches, the air breathing isopods (Ligia) and the small periwinkle snail (Littorina) live on the rocks and crevices in the spray zone; the acorn barnacle and shore crab inhabit high tide zone, the sea urchins, green anemone, and black turban snail are common in the mid-tide zone and the giant red seaurchins, chiton, live in the low tide zone. By far, the greatest number and variety of plants and animals are found on the rocky beaches.

Sandy beaches abound with clams, worms, sand dollars and certain crabs. Since distribution of life on the sandy beach is limited principally by the lack of shelter, attachment sites and permanent tide pools, the burrowing animals are best suited to this environment.

In the mud-flat habitat large expanses of mud and green eelgrass may be exposed by even minor tidal fluctuations. Clams worms, snails, crabs, shrimps and isopods are the most common organisms. The muddy bottom is characteristically peopled with burrowing filter feeders and scavengers.

The Terrestrial Habitat

The terrestial regions of the earth are sometimes classified according to the dominant plant and animal life inhabiting them. Each area, with a unique group of climax plants and related animal species is termed a biome 6 principal biomes are recogni zed: tundra, northern coniferous forest, deciduous forest, tropical, forest, grassland and desert.

Tundra : This biome stretches across the continents generally above 60° north latitude. It is characterized by snow, ice and frozen soil most of the year and the plants and animals that live here have high resistance to cold. The tundra is virtually treeless and consists primarily of lichens, mosses, sedges, heaths, dwarfed willows, and a few grasses. Seasonal thawing is of considerable importance to plant distribution and only shallow-rooted plants can survive. Caribou, arctic hares, foxes, lemmings and migratory birds are common.

Northern coniferous forest : It is characterised by coniferous trees. These evergreen trees consist of pine, fir, cedar, hemlock, and spruce. In some areas these trees grow so dense that little light reaches the forest floor, and few shrubs are around. Another characteristic of this region is the numerous lakes and peat bogs. The plants of this region must be able to withstand some freezing temperatures and often heavy snowfall. The coniferous forest is an excellant habitat for elk deer, grouse rabbits, squirrels, mountain lions and birds.

Deciduous forest : Deciduous hardwood trees are the dominant vegetation in this biome. These forests are usually formed of oak, elm, beach and maple trees. Frogs, salamanders, turtles. many snakes, lizards, squirrels, foxes, songbirds, rabbits. deer and raccoons are representative animals.

Tropical forests: This is characterized by high rainfall during most of the year. The major regions include central Africa, southern Asia, and northern central America. The climate is warm and humid with broadleaf ever green plants. The tallest trees form an open canopy but the second and third crown levels cut out most of the available light to the jungle floor. Ferns and herbaceous plants are common on the jungle floor. The animals include monkeys, various snakes, ant eater, tropical birds and large carnivores such as lions, tigers and leopards.

Grassland: It covers much of the world extending through north central Eurasia. north central and southern Africa, central United States, central South America and Northern half of Australia. The rainfall is irregular and the strong winds, common throughout the grasslands help to increase dryness and discourage the establishment of trees. Large herds of bison, and antelope once roamed the grasslands. With the arrival of man, however the herds were restricted and destroyed by hunters. Grazing animals dominate this biome. Jack rabbits, antelope and prairie dogs are common.

Desert: Deserts are geographic regions characterized by extremely low and uneven rainflall. The major deserts are found in North Africa, Southern Europe, interior of Australia, the South Western United States, Mexico. Both plants and animals show adaptations for desert life. Some plants lose their leaves during the hottest months whereas others have small, waxy or having leaves which retard evaporation. Most flowers are perennial and can withstand seed losses due to drought. Deep taproot, extensive, spreading root systems are common. Some animals such as the kangaroo rat never drink water. Insects, rabbitss quails, doves, rattle snakes, scorpions, lizards,coyotes are common animals.

2. THE ECOSYSTEM

Each living community depends on energy for its structure and function, and these energy relationships follow a silmiar pattern in each community. The flow of energy is always in one direction, whereas the chemical nutrients involved circulate in cycles. Energy flows from organism to organism whereas the cycling of chemicals involves not only living forms (the biotic) but also the non-living (the abiotic) environment. The biotic and non-biotic together form an ecosystem, and through this integrated system of energy flow and the cycling of materials, the ecosystem is maintained.

Energy flow: In any ecosystem, chemicals must be converted into living matter and energy storage products. In general, large molecules, such as $C_6 H_{12} O_6$, are synthesized from smaller molecules which are available in soil, air and water. Organisms that are capable of preparing their own food from such raw materials are

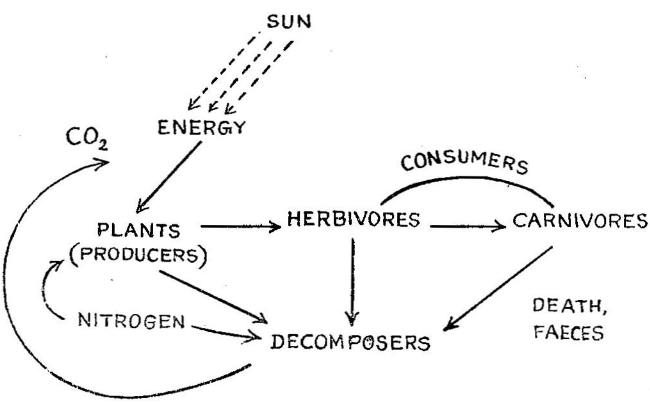


Fig. 19 Relationship among members of an ecosystem

called producers and autotrophs. They derive the necessary energy from the sun and have devices such as chlorophyll or other light trapping compounds that permit the utilization of the sun's energy. The organisms which feed on the producers are called consumers and heterotrophs. They are unable to produce food from raw materials and are dependent on producers and other consumers for food. Heterotrophs are classified into herbivores and carnivores.

Although there is a constant source of energy from the sun. the chemical substances are not in such constant supply. Therefore the group of bacteria and fungi form an important element of the ecosystem for they break down and decompose dead organisms. It is through decomposition that the necessary chemical nutrients are returned to the environment and without it all

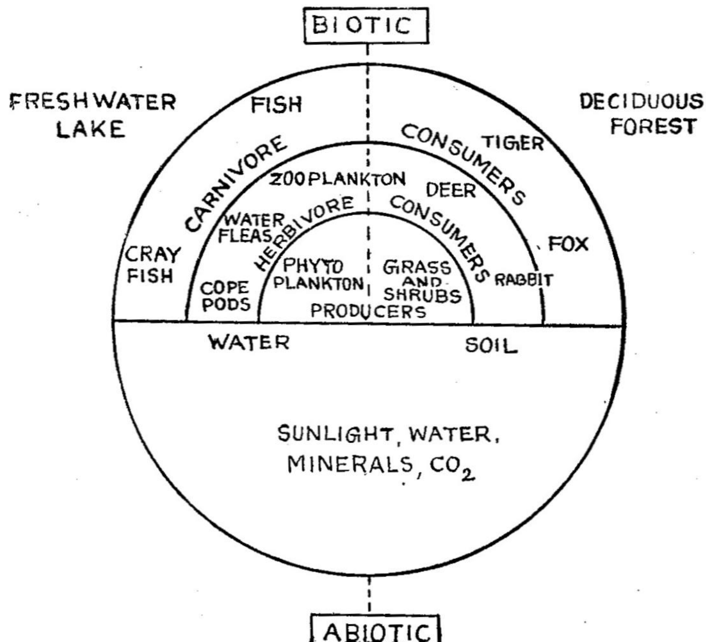


Fig. 20 Raincipol Topiclurls in fresh water and terrestrial

life would eventually cease to exist. Thus, the structural and functional organization within an ecosystem begins with the producers, which provide food (and energy) for the consumers. The consumers, as well as many producers, are broken down by decomposers which return raw materials to the producers. Each group of organisms in the community derives energy from the group producing it in this chain of events, and these represent the trophic levels. The principal trophic levels in two ecosystems, a fresh water lake and a deciduous forest illustrate trophic levels and their relationship to the abiotic. Principal trophic levels in two ecosystems-fresh water and terrestrial. A pyramid is frequently used to show the relative meshes of the various components of an ecosystem. In the movement from one trophic level to another, 100 percent efficiency is not achieved and energy is lost from the system along the way.

Food Chains and Webs

The flow of energy from one trophic level to another is called a food chain, for example, the follwing food relationship is important to game management experts :

Plants → Dear → Tiger

To farmers in some areas the following food chain is important-

Crops → Field mice → Hawks.

Serious results can occur when one element of the food chain is disturbed. If there is excessive tiger shooting, a deer population in a specific area may increase to the point where insufficient food is available to sustain the herd. Nutritional problems and crowding result so that a large herd of deer is produced which contains mostly weak and emaciated members. If foxes and wolves around a farming area are poisoned because they have killed a few sheep, the field mice population may increase and severely damage the grain crop which may cause the death of many more sheep.

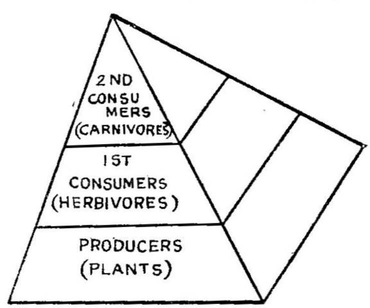


Fig. 21 The Biomass Relationship in an Ecosystem

Many instances are known in which man has imported a predator to control nuisance animals such as rats. Soon the predator may destroy the pests to the point that he must feed on some of the more desirable animals. Men must be very careful when he interferes with a natural order and must realize that it is impossible to change the entire ecological relationship by tampering with one element of a particular ecosystem. It is often necessary to correct a situation in which the activities of man and some of his domesticated animals have disturbed what were once natural conditions.

Most animals do not rely on one species for their food source but usually feed on several different organisms. A hawk, for example, will eat squirrels, mice, rabbits and large insects Because consumers do not rely solely on one plant or animal for food, there are many interrelated food chains These make up a food web which can be very complex.

Bio-geo Chemical Cycles and Ecosystems

In addition to the one way flow of energy through the ecosystem (from producers through consumers to decomposers) life also depends on nutrients and other chemical compounds that are cycled from the soil through atmosphere and living organisms, and back to the soil. The pest studies are those of water, oxygen, carbon, nitrogen, phosphorus, sulphr and calcium.

Oxygen

Oxygen is important not only as a structural component of sugar, fat, and protein molecules but also as a necessary agent

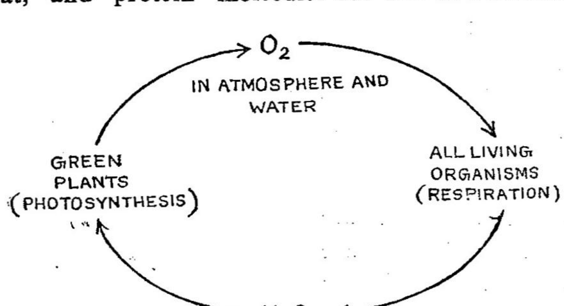


Fig. 22 (a) The Oxygen cycle

for the process called oxidation, by which energy is released from foods. Oxygen is released as green plants manufacture food. Oxygen from atmosphere is used in the process of respiration of all living organisms. Within cells the oxygen unite with hydrogen from sugar molecules to produce water. The water can be used again by green plants in photosynthesis and the cycle continues [Fig. 22 (a)]

Carbon

The general pattern of the movement of carbon is from the atmosphere to green plants, where organic carbon compounds are produced and used by both animals and plants, then back to the atmosphere as a by product of respiration from plants and animals. CO_2 is the form in which carbon circulates in most places of the cycle. Through decomposition of dead organisms and the waste products of plants and animals, some CO_2 is returned to the

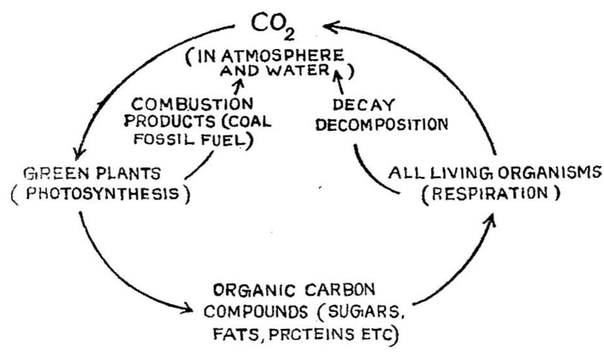


Fig. 22 (b) The Carbon cycle

atmosphere. In addition, the burning of coal and other fossil fuels releases considerable quantities of CO_2. In this process carbon may be stored for sometime before it is returned to the cycle via the atmosphere or water.

In recent times, considerable amounts of CO_2 as well as highly toxic compounds such as sulphurdioxide are being added to the environment by industry and automobiles. The consequences of this are quite dramatic in the smog-filled atmospheres of most major cities. In fact, even CO_2, may be hazardous in excessive amounts since many control centres in the living systems are dependent on a balance between CO_2 and O_2.

Nitrogen

The process by which nitrogen is made available to living systems is somewhat more complex than the oxygen and carbon cycles. Nitrogen is an essential element in such compounds as aminoacids, purines and pyrimidines. These compounds are usually produced first in green plants and then made available to animals. Although nitrogen makes up 78% of the atmosphere, it is not directly available to the majority of living organisms as much of the nitrogen used by green plants must be in the

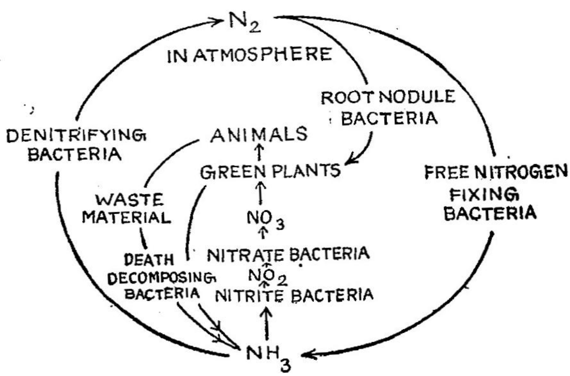


Fig. 22 (c) Nitrogen Cycle

form of nitrates. A slight amount of direct nitrogen fixing takes place in a small number of bacteria (Azotobacter, Clostridium) blue-green algae (Anabaena) and fungi. Lightening can also fix a small amount of nitrogen. Most of the organisms however, make use of nitrogen through two principal routes-(1) through the production of nitrate and (2) through the action of module bacteria (Rhizobium) on the roots of legume plants.

Some free living micro organisms in the soil and water can convert atmospheric nitrogen to ammonia (NH_3). This ammonia is either used by these organisms or given off to the environment. Another group of bacteria can convert the ammonia to nitrite (NO_2) (eg:Nitrosomonas) and a third group can convert the nitrite to nitrate (NO_3) (eg:Nitrobacter). In the form of nitrates, nitrogen can be used by green plants. The ammonia, nitrites and nitrates are usually present as ions (NH^+_4, NO_2-NO^-_3 which can unite with other ions of opposite charges to produce salts. Other sources of ammonia are also available to nitrite-forming bacteria such as the ammonia produced in animal wastes (urine) and in decomposition.

Decomposing organisms ↓

N_2 fixing bacteria→ NH_3→NO_2→NO_3

(available to green plants)

Waste products——↑

Certain plants, such as members of the pea family (Legu mes) have bacteria (sp.Rhizobium) attached to nodules on the root structure which can take free nitrogen directly from the soil and convert it into organic nitrogen. These bacteria penetrate root hairs of the legume, invade the cell wall and membrane and then multiply; the root hairs respond to this invasion by a differential growth resulting in the enlargement, the nodule. Nitrogen fixation occurs within the module.

Although some bacteria are required for supplying nitrogen in usable form to living organisms, others are responsible for an opposite processes known as denitrification (eg. Pseudomonas). These bacteria can convert ammonia, nitrites and nitrates to free nitrogen which is released to the atmosphere. Although it is unnecessary for Nitrogen to return to the atmosphere to complete its cycle (as in the carbon cycle) some, nevertheless is released as free nitrogen. [Fig. 22 (c)]

Phosphorus

The major reservoirs of phosphorus are the rock formations of the earth's crust. Slowly, through the process of weathering and leaching, phosphates are returned to the soil and the sea. Dissolved phosphate can be incorporated into living organisms usually into plants and then animals [Fig. 22 (d)]

Phosphorus, in this form is essential to the functioning of the metabolic processes that convert food into usable energy,

energy transfer and the structure of DNA. In addition it is a major component of bones and teeth.. In some aquatic en-

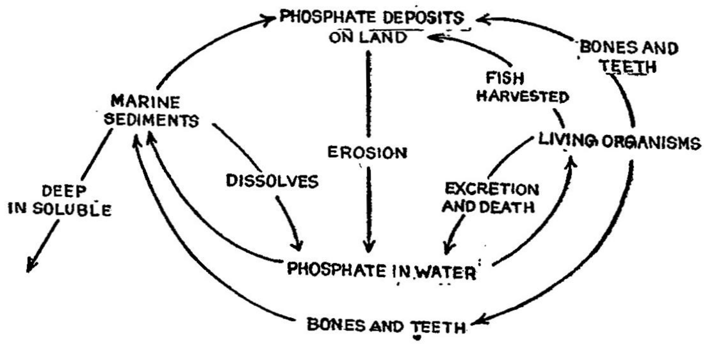


Fig. 22 (d). Phosphorus Cycle

vironments, phosphates may be the "limiting factor" for growth and reproduction at certain times of the year. Since phosphorus is eroded away, phosphates are often added to lawns and farmland when the soil has become depleted.

When organisms excrete or decompose, phosphates are put back into circulation. Some phosphate, however, is deposited in sediments, and the deep, rather insoluble sediments are lost to living organisms until an upheaval occurs. Eventually these will be returned to the cycle, although some concern has been expressed that gradually we are permanently losing more phosphates to the deep sediments. Shallow sediments often redissolve and may be brought up by the currents and waves of the oceans. Land-dwelling organisms contribute to the terrestrial phosphate deposit and thereby assist in maintaining the cycle. Fish eaten by man and birds help to return phosphorus from the sea to the land.

The ecosystem, therefore is comprised of the abiotic physicochemical environment and the biotic assemblage of plants, animals and microbes. These components have a close knit relationship it is energy oriented. The direction of energy is unidirectional and non cyclic while that of minerals is cyclic. At every step of the trophic levels, energy is lost where as the mineral nutrients are not lost but they are potentially available for reuse. The manifestation of the abiotic processes takes place through the vehicle of organisms. Since each species has unique morphological, physiological and behavioural attributes, no two ecosystems are alike. Further ecosystems are not discrete entities delimited sharply from other systems; but influence one another.

3. GROWTH AND REGULATION OF POPULATIONS

The members of a species form a population in a commu nity. Populations of many species interact to form communities and communities form parts of everchanging entity, affected by every factor in its environment, and in turn affecting them.

The growth of populations : There is not a species of living thing that could not completely fill its habitat with its kind if unlimited food were available to it and if the other physical and biotic factors in its environment were favourable. All populations possess certain characteristics such as birth rate, relative age structure, numbers (density), distribution pattern and death rate.Once a population is established, it undergoes a rather specific growth pattern if conditions remain favourable and the habitat is free from a competitor. Although population growth is slow at first, it soon increases and the expansion is geometrical and steady until it reaches carrying capacity. This capacity of any particular habitat depends not only on the amount of food available but also on the nutritional value of the food which in turn depends on the nature of the water and soil, shelter or cover provided by the habitat etc., when this limit is reached, the population density usually fluctuates about this level.

Checks on population growth : Physical and biotic factors in the environment eventually check further population growth. The check arises from either or both of two factors.

(1) The capacity of the enviornment to supply the needs of the species is limited. A point is always reached when the amount of food or sunlight nutrients, and water in the case of plants, is insufficient to support any further increase in the population. This is not just a matter of an absolute limit to the resources available, it also involves the fact that other species are competing for these same necessities of life. Each species has its own ecological niche in a community. When two species have exactly the

same niche, we would expect that one would be more efficient than the other and eventually replace the less adapted species. This principle of **Competition exclusion** may not always hold, however. The limited capacity of the environment to furnish energy establishes an absolute limit to population size. However, this limit is not apt to be reached under natural conditions. Competition for food keeps the populations in check.

(2) The second major check on the size of populations is predation and parasitism.

(a) **Predation:** The majority of heterotrophic species secure their food by preying on other organisms. Although exceptions exist, most predators are larger than the prey they consume. Their relationship with their prey is usually a temporary one, just long enough to consume it or at least part of it. Animals which prey upon other animals almost always kill their prey.

Many adaptations are seen, which increase the effectiveness of predation. The keen eyes of the eagle, the sharp ears of the owl, the keen sense of smell of the wolf, the echolocation of the bat, and the value of wings and legs to predators are a few examples. Strong jaws, cutting teeth, sharp claws, hooked beaks, the long tongue of the frog, the fangs of the rattle-snake, and the mandibles of insects are other examples of structural modifications which assist predation.

On the other side of the coin, there are also devices to avoid being eaten. Eyes, cars and a keen sense of smell are just as effective at discovering predators as prey. The ability to run, fly or swim away from a predator when it is detected is of great survival value. Camouflage is another way of minimizing attack by predators. The inky smokescreen expelled by the startled squid hides its escape route. Weapons such as teeth and jaws, a sting, poison fangs and the pincer legs of the cray fish can be used defensively as well as offensively. The quills of the porcupine, the scent glands of the skunk, poisonous hydrocyanic-acid secreted by millipedes are other familiar examples. Some animals are often able to escape from predators by sacrificing a portion of their body (lizard). Many a sea cucumber has escaped consumption by expelling its sticky, offensive swelling viscera when molested.

Co-operation between members of the same species often reduces the severity of predation. Grazing ungulates are usually organized so that the strong are on the outside of the herd, the weak within. The presence of many sets of eyes and ears in the herd makes the predator more easily detected and his approach more difficult.

Among plants there are a few predatory plants like venus fly trap. Spines, thorns, ability to produce toxic chemicals are some of the devices to avoid predation.

The balance between prey and predator is a delicate one and self regulating.

(b) **Parasitism** : A parasite is an organism which lives at the expense of another organism (the host) from whose tissues it derives its nourishment and to whom it does some degree of damage. A parasite usually does not kill its hosts, though there are exceptions. The well adapted parasite consumes just enough host tissue to supply its own needs without destroying the host. It has been said that a parasite lives on the host's income while a predator lives on the host's capital.

Thus, populations remain stable inspite of the enormous potentiality to reproduce.

4. ANIMAL ASSOCIATIONS

In most communities very close relationships may exist between two or more species. These intimate associations are called symbiosis, (living together). Three categories of symbiosis are commensalism, mutualism and parasitism.

Symbiosis refers to a situations in which the niche of one species happens to be more or less closely associated with the body of another organism. The organism whose niche it is, always benefits from the relationship. The organism who supplies the niche may be injured by it, as in parasitism. In many cases however, the organism that supplies the niche may be relatively unaffected by the relationship. This situation is called commensalism.

Commensalism : Is a relationship between two organisms in which one member of the pair receives direct benefit while the other is neither benefitted nor harmed. The relationship between the remora (Sucker fish) and the shark is a classic example of commensalism. The dorsal fin of the remora is modified into a sucker by means of which the remora can form a temporary attachment to the shark. The shark does not seem to be inconvenienced by this and makes no attempt to prey upon the remora. When the shark does feed however, the remora is in a position to pick up scraps the shark fails to consume. There are certain species of barnacles that are found only as commensals on the jaws of whales. Many of the bacteria living in our large intestine should be classed as commensals. They feed on undigested food materials and generally do not harm us.

Mutualism : Symbiotic relationships in which each species benefits are called mutualistic. The relationship between Rhizobia and their legume hosts is an example. Although each organism is able to survive independently growth together is clearly beneficial to them both. Lichens are an example of mutualism between a fungus and an alga. Although the alga may be able to survive alone in nature the fungal partner is never found to do so. The heterotrophic fungus receives carbohydrates from the alga; while the alga is protected from dehydration by the tough gelatinous walls of the fungus. Acids secreted by the fungus may also aid the algal partner by liberating minerals from the substrate.

Algae are often found living within the bodies of heterotrophic organisms. Their presence provides an internal supply of food and oxygen. The former may be sufficient to enable the animal host to go without eating for long periods. The alga benefits by the availability of CO_2, the protected location and the fact that it can be transported to a spot where ample light is present. The cellulose digesting bacteria in the cow's **rumen** and in the intestines of termites are other examples.

Mutualistic relationships may be the evolutionary outcome of what began as parasitism. Structural adaptations are often found in mutualistic relationships.

Parasitism: is the relationship in which one member benefits while the other is harmed. Parasites that inhabit the outer surfaces of their hosts are ectoparasites; those that live within the host organism are endoparasites. Ectoparasite examples are fleas, ticks etc., which suck blood from their hosts. Internal parasites are tapeworms, malarial parasite etc.

Almost all parasites are relatively small invertebrates or microorganisms. There is probably not an organism on this earth that is not parasitized at some time during its life. Almost all locations on the host's body may become occupied by parasites. Viruses, some bacteria and the malarial parasites invade and multiply right within the very cells of the host (intracellular). Most parasitic bacteria and protozoans as well as many round worms and flukes invade the tissues of their host. Tapeworms are found within the intestines of the host.

One problem faced by all parasites is how to invade the host. For animals, four routes are used. (1) Many bacteria and viruses gain entrance to the body by being inhaled. These may cause respiratory tract diseases. (e. g. colds) (2) During coughing or sneezing, parasite-laden droplets are discharged into the air and can readily be inhaled by others. (3) Venerial diseases are caused by microorganisms which gain entrance during copulation. (4) Insect and tick bites often transmit protozoan parasites, bacteria and virus.

Once the parasite has gained entrance into the body of the host, there are three possible outcomes. The host may be killed, or the host may tolerate the parasite or the host may destroy the parasite. The host's defensive mechanism to invasion by parasites is to produce antibodies. Man supplements these by drugs.

5. Eugenics

The term eugenics (Gr. eugenes-well born) was coined by an English scientist Francis Galton in 1885. The science of eugenics is a science dealing with all influences that improve the inborn qualities of a race, also with those that develop them to the utmost advantage.

Eugenics and Euthenics

The betterment of human society can be achieved by following two interrelated methods:

(1) Euthenics—In one method, called euthenics, the improvement of already existing human beings can be achieved by improving the environment conditions. e,g., by subjecting them to better nutrition, better unpolluted ecological conditions, better education and sufficient amount of medical facilities.

(2) Eugenics—By another method, called eugenics, the future generations can be improved by improving the **germplasm** of already existing individuals. Eugenics believes in artificial selection of physically and mentally sound individuals and discouragement of defective individuals for the inheritanee of the defective germplasm to the future generations. In other words, eugenics seeks the measures to preserve the best type of germplasm and to eliminate defective germplasm from the human population by applying the laws of human genetics to man.

Pedigree Analysis

Studies of human families have revealed the fact that desirable or undesirable traits depend for their expression on the genes carried by the germ cells of the parents. By pedigree analysis the mode of inheritance of a number of diseases and traits have been studied. Various diseases and defects like haemophilia, red-green-colour blindness, syphilis, insanity, rheumatism, hysteria, cretinism, polydactylism, syndactylism etc., are all inherited from the parents. Beside the defects and diseases the good qualities such as memory, intelligence, ability of speech, mechanical skill, musical ability and various body characters are transmitted from one generation to another.

Eugenics and Human Betterment

Eugenics can be applicable by adopting following two methods:

(a) By encouraging the marriages between desirable persons (constructive methods or positive eugenics)

(b) By discouraging the marriages between undesirable persons (restrictive method or negative eugenics)

(a) Positive Eugenics

Positive Eugenics attempts to increase consistantly better or desirable germplasm and thus to preserve best germplasm of the society. The percentage of desirable traits can be increased by adopting following measures:

(1) Early marriage of those having desirable traits-It is a most commonly observed fact that the highly placed persons of the society often have great ambitions for the future life. In achieving their ambitious goals, they often devote the best part or their youth and they remain able to get married in their mature age (i.e. 30 to 35 years).

(2) Subsidizing the fit-Because the highly endowed persons lead a well planned life and to avoid unnecessary difficulties in nursing the children they often prefer to have small number of children. Therefore, the selected young men and women of best eugenic value should be encouraged to increase their birth rate.

(3) Education-For the eugenically oriented reform in society, people should be educated about the basic principles of human biology, human genetics, eugenics and sex. Children should be instructed about the basic laws of health and they should be encouraged to develop a physically and mentally healthy body.

(b) Negative Eugenics

Negative eugenics attempts to eliminate the defective germplasm of the society by adopting following measures :

(1) Sexual separation of the defectives—The defective persons may have various sex-linked diseases such as nightblindness, haemophilia, colour blindness, etc., and various other defective traits which may be regulated by dominant or recessive genes. The increase of germplasm of the persons having such defective traits in the population can be checked by keeping them away and separated from society.

(2) Sterilization—Sterilization is the best means to deprive an individual from his power of reproduction without interfering with any of his normal functions. The sterilization method is based on surgical operation of sperm duct or vas deferens in males and oviducts or fallopian tubes in females. The former is known as vasectomy and the latter is splangectomy.

6. Pollution

The ultimate cause of pollution is people, and as the number of people increases there is a corresponding increase in the amount of pollution. From an ecological point of view, there are two types of pollution.

(i) Pollution involving biodegradable pollutants.

(ii) Pollution involving nondegradable pollutants.

Biodegradable pollutants such as domestic sewage can be decomposed rapidly by natural processes or by carefully engineered systems, such as a community's sewage treatment plant. Problems arise when the input of degradable pollutants into the environment exceeds the environment's capacity to decompose or dispense them. The problems with disposable sewage result in general from the fact that urban populations have grown much faster than their sewage treatment facilities. Degradable pollutants can be dealt with by a combination of mechanical and biological treatment; but there are limits to the total amount of organic matter that can be decomposed in a given area, and there is an overall limit to the amount of carbondioxide that can be released into the air.

The nondegradable pollutants include metals such as mercury, trace metals, aluminium cans and organic chemicals such as DDT that are degraded only very slowly. Dealing with these pollutants is a much more difficult and expensive problem. Some of these pollutants are actually a resource for recycling.

The pollution of the air in industrialized countries is of great importance. When air is trapped under a warm upper layer a vertical rise of pollutants is prevented. Certain combination of pollutants may react in the environment to produce additional pollution. Certain components in automobile exhaust can combine in the presence of sunlight to produce more toxic substances, called photochemical smog. One such, blocks a key reaction in photosynthesis and will kill plants by inhibiting their production of food.

The industrialization of agriculture that has occured within the last few decades has introduced pesticides and herbicides. When these are used much too enthusiastically, they cause pollution, for these poisons are persistent and are degraded very slowly. They accumulate in many parts of the environment that they can no longer be used.

Two highly undesirable effects of the saturation of the environment with DDT and other organochlorides are the development of strains of insects that are resistant to the DDT and the accumulation of these toxic substances in the food chain. Most of the pollution problems can be traced to the fact that new insecticides are tested, usually superficially, at the level of the organism without controlled tests of their effects on the entire ecosystem.

(1) Water pollution

A rapidly increasing proportion of the earth's fresh water is being used to meet the needs of man; for irrigation of crops and in industrial processes. The manufacture of paper and the generating of electricity are two major industrial uses of water. Only about 10% of our water used is devoted to domestic needs. Water is used also for washing or flushing away wastes. The problem is that many water using processes add materials to the water that make it unfit for other uses, especially for drinking and recreation.

Water Pollution through industries- E.g. Hoogly River Bank (159 industries) : The wastes that industry adds to water are as varied as industry itself. They include a great variety of organic molecules that nourish aquatic bacteria. In breaking down these substances by cellular respiration, the bacteria are in effect purifying the water. If the system becomes overloaded however, bacterial respiration may so deplete the dissolved oxygen content of the water that most higher forms of aquatic life (eg.fish) cannot survive. Untreated domestic sewage also places great oxygen demands upon any water supply in which it is dumped.

Some industries also pollute water with inorganic materials and with heat. Mercury discharge by certain manufacturing processes have caused serious mercury pollution in parts of the United States, Canada and Japan.

(2) Thermal Pollution

80% of the water used by industry is used simply for cooling. And the lions share of this is used in the generation of electricity. Nuclear power is especially wasteful of heat. A nuclear generating plant uses 372,000 gallons of cooling water each minute and discharges it back to the river 22°F warmer. While the ecological efforts of such thermal pollution as yet are insignificant, the projected growth of the nuclear generating industry suggests that caution be observed that no aquatic ecosystem becomes loaded with heat to the point where serious ecological consequences follow. Eg. Basin Bridge area.

(3) Water Pollution Due to Eutrophication

Domestic sewage adds substantial quantities of nirtrates and phosphates to our fresh water supply. The heavy use of fertilizer may also present a problem during rainy season when they are washed away into streams. Phosphorus is generally found in negligent quantities in fresh water ecosystems and is therefore a limiting factor for blue green alga. Adding phosphorus and nitrates to water makes the blue green alga and green algae to grow abundantly which has an undesirable effect in the ecosystem. The respiratory needs of the algae may so deplete the oxygen content of the water during the night that fish suffocate. Further more, rapid algal growth may temporarily exhaust the nutrient supply, leading to a rapid dying off, of the algae. The products of the decay may add such unpleasant tastes and odours to the water as to degrade its attractiveness. The increased productivity of lakes and streams brought about by nutrient enrichment is known as eutrophication. It has become a wide spread problem in most countries with large population and intensive agriculture.

(4) Air Pollution

The alveolar surface of the human lung provides a large and intimate interface between the internal environment and the air. Over a period of 24 hours we breath in some 15,000 litres of air. The purity of this air is a matter of considerable concern.

Primary Air pollutants

A number of ingredients find their way into air, chiefly as a result of man's activities, and these may be considered as contaminants or air pollutants. The sources of air pollution are exceedingly varied but can be divided into 2 categories. One is our industrial and technological activities. Petroleum refineries, smellers. fuel-fired electrical generating plants and the ubiquitous automobile; all release enormous quantities of pollutants into the air. Eg. Ennore area & Agra. These include:

(1) Soot (from unburned fuel) and industrial fly ashes of other sorts (Eg. Bhilai area).

(2) Sulphur dioxide (SO_2) from the oxidation of fuel (eg. coal, oil), containing sulphur compounds (Eg. Trombay area, Calcutta).

(3) Various hydrocarbons (from the incomplete combustion of gasoline). Among these is benzopyrene a notorious carcinogen (cancer causing agent). Ammonia from urea plants (Eg. Neyveli.)

(4) Oxides of nitrogen (eg. NO_2) produced by the chemical union of O_2 and N_2 in the cylinders of internal combustion engines.

Secondary Pollutants

In bright sunlight, nitrogen oxides, hydrocarbons, and oxygen interact chemically to produce powerful oxidants like Ozone (O_3) and peroxyacetyl nitrate (PAN). These secondary pollutants are exceedingly damaging to plant life and lead to the formation of smog, which irritates the eye. Eg. Indra Prastha power station at Delhi.

The other major category of air pollution is cigarette smoke. Cigarette smoke contains a number of hydrocarbons, including benzopyrene.

How far these pollutants affect humans is difficult to asses. The most promising approach is to study the rate of human illness in populations differing in their exposure to air pollutants. In Great Britain, it has been shown that the rate of lung cancer is substantially higher in urban areas where there is plenty of heavy industries.

Chronic bronchitis, asthma, several circulatory disorders and lung cancers are some of the diseases which are more common among persons exposed to air pollution of urban life and cigarette smoking.

(5) Pollution on Land

One of the major pollution problems of large cities is disposal of solid waste material, including garbage, leaves, containers and other discarded manufactured products. (Eg.) tannery waste at Vaniambadi.

Many of the chemicals, emitted into the air such as radioactive minerals, sulphur and lead eventually come to earth to pollute the soil. Many pesticides and herbicides are applied by spray mechanism and they find their way into the soil. These chemicals may have significant effects on plants and animals causing a disruption in species composition of communities. DDT and other contaminated hydrocarbon pesticides may upset the normal food chains starting with soil animals. Pollutants on land are more harmful in forests, where they may inhibit-processes of soil formation and reduce the capacity of the forest to maintain fertility of the soil.

Pollution Control

Pollution control is a gigantic task. Antipollution measures are taken by the State and the Union Governments. Technological know-how exists in the country and most of the equipments necessary for installing control devices are also manufactured within the countries. National Environmental Engineering Research Institute (NEERI) at Nagpur (branches at other major cities), Bhabha Atomic Research Centre (BARC) at Bombay, National Committee on Environmental Planning and Co-ordination (NCEPC) New Delhi have both skilled personnel and know-how to tackle the difficult problems arising from air, water and land pollutions in India.

CHAPTER III

EMBRYOLOGY

The science of Embryology is the study of the development of animals and plants. The process of development starts before fertilization of the egg, when a set of genes is set apart for the formation of gametes. In both sexes, the first step in the production of gametes (**gametogenesis**) is a rapid proliferation of cells by ordinary mitosis resulting in **spermatogonia** and **oogonia.**— Once proliferation stops, the cells are called **spermatocytes** and **oocytes.** They enter a stage of growth and maturation forming the **spermatozoa** and **ova.**

The second phase of development is **fertilization** which involves the union of the male and female pronuclei.

The third phase of development is the period of **cleavage.** This is the mitotic division of the fertilized ovum to give rise to a large number of blastomeres, without any remarkable change in the size of the embryo. The result of cleavage is the **blastula-** with a layar of cells the **blastoderm,** surrounding a cavity, the **blastocoel.**

The fourth phase of development is **gastrulation.** During this phase, the single layer of blastoderm givers ise to two or more layers of cells known as germinal **layers.** The resulting embryo is now called the **gastrula.**

The fifth phase of development is **organogenesis** (organ formation). The cells of the three germinal layers become split up into smaller groups of cells, each of which is destined to produce a certain organ or part of the animal.

The sixth phase of development is **the period of growth** and **histological differentiation.**

After the organ rudiments are formed they begin to grow and greatly increase their volume. In this way the animal gradually achieves the size of the parents.

The seventh phase comprises of all morphological changes that occur after the larval stage (where it is present) or after adult stage has been reached.

1. Gametogenesis in frog

The essence of life, the most characteristic feature of every living system, is the ability to reproduce its kind, to perpetuate the species. The reproductive process includes a wide range of phenomena from the simple fission of cells in bactaria and unicellular organisms, to a highly complex pattern in higher plants and animals. It involves genetic phenomena, the transfer of biological information from one generation to the next, the endocrine regulation of gamete formation and intricate behaviour patterns of adults, to ensure that the male and female gametes are released at the same time and meet to form a fertilized egg or zygote which undergoes a complex sequence of events to develop and differentiate into an adult organism.

Gametogenesis is the formation of **gametes**; the male gamete is known as the **sperm** and the female gamete is known as the **ovum.** They develop in the **gonads; testis** in the case of male and **ovary** in the case of female. The development of the sperm is called **spermatogenesis** and the development of the ovum is called **oogenesis.** Fundamentally, these processes occur by **meiosis** during which the chromosome number is reduced to one-half, so that the gametes receive only half as many chromosomes **(haploid)** as other cells **(diploid).** When the two gametes unite in fertilization, the fusion of their nuclei reconstitutes the diploid number of chromosomes.

Spermatogenesis

The testis is made up of thousands of cylindrical sperm tubules, in each of which millions of sperms develop. The walls of these tubules are lined with unspecialized germ cells, **spermatogonia.** Throughout embryonic development, the spermatogonia divide mitotically, giving rise to additional spermatogonia to provide for the growth of the testis. After sexual maturity, some of the spermatogonia undergo spermatogenesis, the formation of mature sperms.

Spermatogenesis begins with the growth of spermatogonia into larger cells known as **primary spermatocytes.** These divide, (first meiotic division) into two equal sized cells, the **secondary spermatocytes,** which in turn undergo the second meiotic division to form four equal sized **spermatids.**

The spermatid is a spherical cell with large amount of cytoplasm, with haploid number of chromosomes. A complicated process of growth and change converts the spermatid into a functional sperm. These changes can be summarised as follows:

1. Shrinkage of nucleus in size and formation of head of the sperm.
2. Shedding of most of the cytoplasm.
3. Concentration of Golgi at the front end of the sperm to form **acrosome,** which plays a vital role in penetration into egg cell.
4. Formation of axial filament from the centriole.
5. Formation of middle piece, with mitochondria, which provides energy.

Structure of a Mature Spermatozoan

The average size of a spermatozoan of frog is about 0.03 mm in length. It has an elongated, solid-staining **head** (nucleus) with an anterior **acrosome,** pointing outwardly toward the periphery of

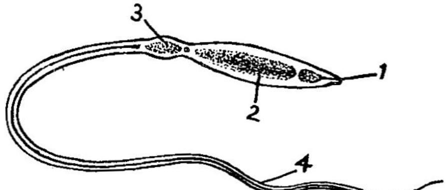


Fig. 23 Sperm

1. Acrosome
2. Head
3. Middle piece
4. Tail

the seminiferous tubule. The middle piece is generally not visible but the tail appears as a gray filament, about four or more times the length of the sperm head.

The mature spermatozoan is dependent upon external sources of nutrition so that it joins from 25 to 40 other spermatozoa, all of whose heads may be seen to converge into the cytoplasm of columnar cells known as **sertoli cells.** These are functionally nurse cells, supplying nourishment to the cluster of spermatozoa.

Oogenesis

The ova or eggs develop in the ovary from immature, colourless sex cells called **oogonia.** Early in development, the oogonia undergo many mitotic divisions and proliferate. They then become **oocytes** and enter a period of growth. Since the egg provides the greater part of substances required for development, growth plays a much greater role in oogenesis than in spermatogenesis. Also, the differentiation of the egg occurs simultaneously with growth, rather than after maturation as it occurs in spermatogenesis.

The period of growth in the female gametes of **Rana pipiens** is 3 years and it increases in size from 50 μ to between 1000 μ and 2000 μ in diameter. Simultaneously with the growth of the oocyte, its nucleus enter into the prophase of meiotic divisions and the homologous chromosomes pair together as it occurs in primary spermatocytes. But the subsequent stages of meiosis, are postponed until the period of growth is over. During this time, **yolkplatelets** are formed and the cytoplasm becomes densely packed with them. The yolk of amphibians contains two main proteinaceous substances; phosvitin and lipovitellin. In addition lipid and glycogen are also found.

In mature amphibian egg, protein in yolk constitutes roughly 45% of the dry weight, lipids 25% and glycogen 8.1%. Only about 20% of the dry weight of the mature egg is active cytoplasm.

As the oocyte grows and various inclusions are produced in its cytoplasm, a pattern of organization gradually emerges, which will be of importance when the eggs start developing. Unequal distribution of cellular constituents mark the **animal pole,** where the nucleus is present and **vegetal pole** where there is accumulation of yolk. The **pigment granules** begin to appear in oocytes which have grown to about one half of the final diameter. The distribution of pigment in the amphibian egg is not uniform; there is much more pigment in the animal hemisphere than in the vegetal hemisphere. Though the pigment granules in themselves may not vary in embryo, the uneven distribution may be considered as an indicator of qualitatively different areas in the cytoplasm of the egg.

After the oocyte completes its growth, it is ready for the reduction divisions. The events in the nucleus are the same as in spermatogenesis, but the division of the cytoplasm is unequal-

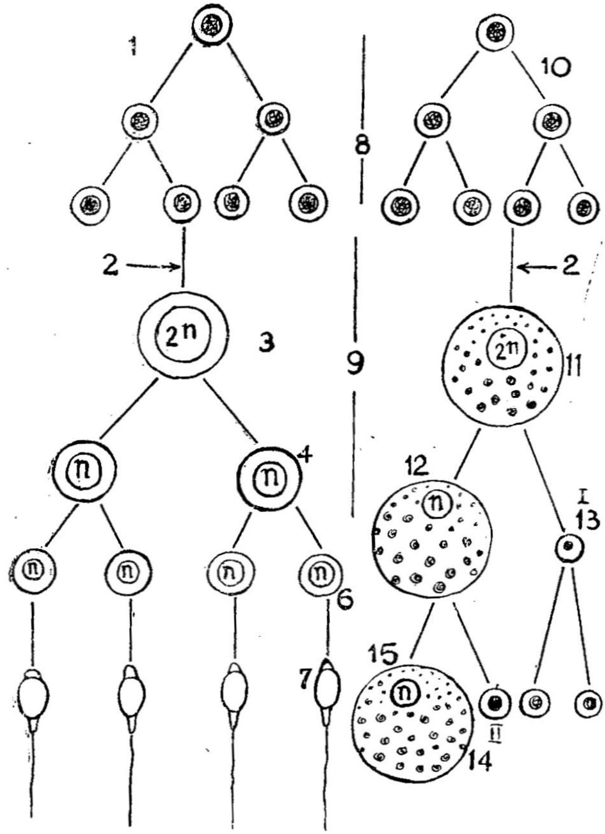


Fig. 24
Gametogenesis
1. Spermatogonia, 2. Growth, 3. Primary spermatocyte, 4. Secondary spermatocyte, 5. 6. Spermatid, 7. Sperm, 8. Mitosis, 9. Meiotic divisions, 10. Oogonia, 11, Primary Oocyte, 12. Secondary Oocyte, 13. I Polar body, 14. II Polar body, 15, Ootid.

resulting in one large cell, the secondary oocyte, which contains the yolk and nearly all the cytoplasm and one small cell, the first polar body, which consists of practically nothing but a nucleus.

The second meiotic division, proceeds as the ovum moves down the oviduct in some animals; in others it occurs only at fertilisation. The secondary oocyte divides unequally into a large **ootid and a small second polar body,** both of which have haploid number of chromosomes. The first polar body may divide into two additional second polar bodies. The ootid then becomes the **mature ovum.** The three small polar bodies soon disintegrate so that each primary oocyte gives rise to just one ovum, in contrast to the four sperms formed from each primary spermatocyte. The unequal cytoplasmic division insures that the mature egg will have enough cytoplasm and stored yolk to survive if fertilized.

The similarities (and differences) between oogenesis and spermatogenesis are illustrated in figure 24.

It should be pointed out, that, after maturation (reduction divisions) the spermatids must still undergo differentiation before they become spermatozoa, the functional male gametes. On the other hand the egg, after reduction divisions, does not undergo any further changes, it is quite ready to start developing.

A further distinction between the male and female gemetes is that the male gametes, the spermatozoa, become capable of fertilizing the egg sometime after they have completed reduction divisions and further differentiation. The eggs become capable of being fertilized some times **before** they have completed reduction divisions and before they have given off the polar bodies.

2. Types of Eggs in Vertebrates

As a general rule, mature eggs are spherical in shape, consisting of nucleus, cytoplasm and reserve food.

1. Reserve Food

The amount of yolk, or stored nutrients present in the egg plays an important role in determining the pattern of development of eggs af fertilization. The yolk granules vary in composition in deferent vertebrates but usually they are composed of protein, phospholipids and neutral fats.

In the prochordate Amphioxus (Fig. 25) the yolk is predominantly, protein. The amount of yolk is relatively small and the yolk granules are fine and fairly evenly distributed in the cytoplasm of the egg. Eggs with a small amount of yolk are called **oligolecithal** (microlecithal, isolecithal).

In frog's egg (fig. 26) the yolk is found in the from of large granules, known as yolk **plateles.** The cytoplasm is **densely**

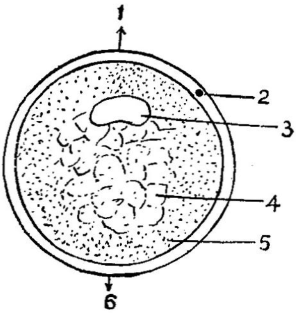


Fig. 25
Amphioxus-Egg

1. Animalpole, 2. I polar body, 3. Nucleus (germinal vesicle), 4. Yolk eytoplasm, 5. Peripheral cytoplasm, 6. Vegetal pole.

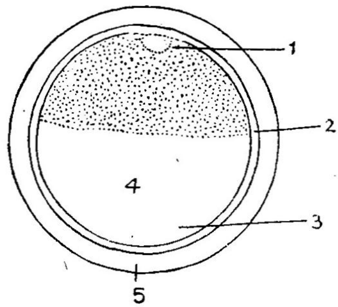


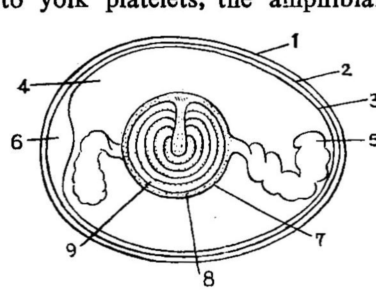
Fig. 26
Frog's Egg

1. Animal hemisphere
2. Vitelline membrane
3. Vegetal hemisphere
4. Yolk
5 Jelly coat

packed with them (mesolecithal). The distribution of yolk is distinctly unequal; densest in the lower part of the egg and there is relatively more cytoplasm in the upper part of the egg. Eggs of this type are known as **telolecithal.** The yolk platelets of amphibians contain mostly two types of protein: phosvitin and lipovitellin. In addition to yolk platelets, the amphibian

Fig. 27
Hen's Egg

1. Shell 2. Outer 3. Inner shell membrane 4. Albumin 5. Chalaza 6. Air space 7. Vitelline membrane 8. Yellow yolk 9. White yolk.



eggs contain stored supplies in the form of lipid and glycogen. In a mature amphibian egg, protein yolk is roughly 45% of the dry weight lipids 25% and glycogen 8.1%.

The yolk of a bird's egg (fig. 27) is of large quantity (macro-lecithal) and lies in a compact mass in the interior of the egg and the cytoplasm is restricted to a thin layer on the surface, with a thickened cap of cytoplasm on the upper side, in which lies the nucleus of the egg cell. The yolk as a whole contains 48.7% of water, 16.6% proteins, 32.6% phospholipids and fats and 1% carbohydrates. The proteins are phosvitin and lipovitellin as in frog's egg. The yolk can be distinguished into yellow and white yolk.

In mammals, the egg is isolecithal and is called the graafian follicle. The oocyte is surrounded by a vitelline membrane (zona pellucida) and zona radiata, which is secreted by follicle cells (secondary membrane). Other follicle cells surround the ovary and the whole structure is enclosed within a protective membrane called theca.

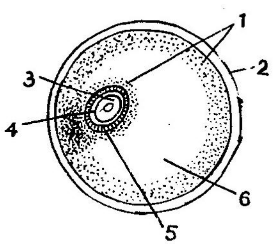


Fig. 28
Egg of mammal

I. Follicle cells
2. Outer protective layer
3, Oocyte
4. Zone pellucida
5. Corona radiata
6. Fluid

2. Cytoplasm

The superficial layer of cytoplasm of eggs differs from the rest of the cytoplasm, in its physical properties. It is more viscous and its components are not readily displaced. This superficial layer is known as **cortex**. It serves to fix the position of oocyte and also bears **cortical granules**. These however are not found in all animals.

3. The Nucleus

The nucleus of the eggs is generally large, due to a very large amount of nuclear sap, so that it appears to be bloated with fluid. It is often referred to as **germinal vesicle**.

4. Polarity of the Eggs

The arrangement of the various cytoplasmic substances in the egg, position of the nucleus and yolk determine the polarity of the egg, the animal and vegetal poles. Many efforts have been made to elucidate what factors are responsible for the unequal distribution of these parts but it is not possible to find a common factor which could be held responsible for the origin of polarity of the egg.

5. The Egg Membranes

All eggs are covered by the cell membrane, or plasmalemma. In addition, the eggs are surrounded by special egg membranes. Depending on their origin these may be subdivided into three groups: the primary membranes. the secondary membranes and the tertiary membranes.

The Primary Egg membranes are the membranes which develop in the ovary between the oocytes and the surrounding follicle cells. This membrane is known as the **Vitelline Membrane** in amphioxus, frog and bird ; in mammal it is known as **Zona pellucida.** The primary egg membranes usually are closely applied to the surface of the egg, but later a space filled with fiuid may appear between the cytoplasm and the membrane; this space is called perivitelline space. In mammals, another layer of follicle cells are formed on the surface of zona pellucida called the corona radiata, which are peeled off later, when the ovum descends the oviduct.

The Secondary Membranes are secreted by a layer of follicle cells surrounding the ovum. In the frog a jelly like substance is seereted as the eggs pass through oviduct. It protects the egg and serves to make them stick to one another and to any object in water. When the amphibian egg is deposited in water, the jelly absorbs water and swells.

The most complicated egg membranes are found in the eggs of birds, where no less than five membranes, can be distinguished.

These are secreted by oviducts. The **viteline membrane** is very thin and is composed of two layers of double origin. The inner layer is formed in the ovary and the outer layer in the oviductal funnel. The next membrane is the **white of the egg.** This is composed mostly (85%) of water and the remaining is a mixture of several proteins, mostly albumen. A denser part of the egg white forms strands, known as **chalazae,** as the egg travels down the oviduct. It helps to keep the egg cell in the centre of the egg white. Next to the egg white comes two layers of the **shell membranes** composed of keratin fibres matted together. Over most of the surface of the egg, the shell membranes are in contact with each other but at the blunt end of the egg they are separated. The inner membrane adheres to the egg white, and the outer membrane adheres to the shell. In between there is a space filled with air. The outermost membrane is the **shell.** This consists chiefly of calcium carbonate and is porous; the pores are filled by an organic substance related to collagen. The shell membrane and shell are secreted in the lowest portion of the oviduct.

6. Cleidoic and Non-cleidoic Eggs

Eggs which are laid on land and which are provided with a shell are known as cleidoic eggs (eg. bird) Non cleidoic eggs have no shell and are laid in water. (egg of Amphioxus and frog).

7. Mosaic and Regnlative Eggs

Mosaic eggs are those in which fate of all parts are fixed at an early stage, Regulative eggs are those in which fate of all parts are fixed at much later stage.

8. Size of Eggs

The size of the eggs are correlated with the number of eggs produced. The number is correlated with the mortality rata of the eggs and embryos and the necessity of distribusion of the progeny beyond the territory of the parent population. The larger the size the fewer the number. Few eggs are produced also in cases where special means have been evolved to ensure survival through difficult periods of early development by means of protective devices or by retaining developing eggs within the maternal body.

The larger the egg and the greater the amount of yolk, the more cells it is able to produce before development. In small sized eggs, embryonic period is short and in heavily yolked eggs-embryonic period is longer.

An animal egg is thus a reproductive cell that not only has the innate potential to develop into a complex, multicellular organism but has to be prepared to undergo subsequent development. It has to be **packed** with sufficient material for future growth and should be **programmed** with directional information to follow a special developmental course.

3. Fertilization

Fertilization is a complex process involving the fusion of a male and female gamete (the sperm and the ovum). Fusion of the male and female pronuclei restores the diploid number of chromosomes and introduces genetic variation.

It has two functions : (1) to cause the egg to start developing (2) to inject a male haploid nucleus within the egg cytoplasm.

Most aquatic animals simply liberate their sperms and eggs into the water and their union occurs by chance. No accessory structures are needed. This type of rudimentary and uncertain method of fertilization is called **External Fertilization.** Other animals, especially those living on land have accessory sex organs for transferring the sperm from the body of the male to that of the female, so that fertilization occurs within the female. This method is called **internal fertilization.** It requires the cooperation of both sexes and many species have evolved eleborate behavioural patterns to insure that the two sexes are brought together for mating.

Fertilization involves two physiological events, penetration of sperm into egg, and **activation** of the egg to undergo cleavage and development. The egg may be in any stage from primary oocyte to mature ovum when the sperm enters it, but the fusion of egg and sperm nuclei can occur only after the egg nucleus has completed the two meiotic divisions and has become a mature ovum.

The eggs of some species secrete a substance called **fertilizin.** This diffuses into the surrounding medium and the sperm cells are attracted to the egg by means of chemotaxis, and causes the sperms to clump together and stick to the surface of the egg. A substance called **antifertilizin,** located on the surface of the spermatozoa responds to fertilizin and brings about the fertilization phenomena.

The penetration of the egg coverings by the sperm enzymes has been widely accepted. The enzymes (Hyaluronidase) produced by coats at the point of entry, to which the egg responds by forming a **fertilization cone** and by various physiological changes collectively called **activation. (Fig. 29)**

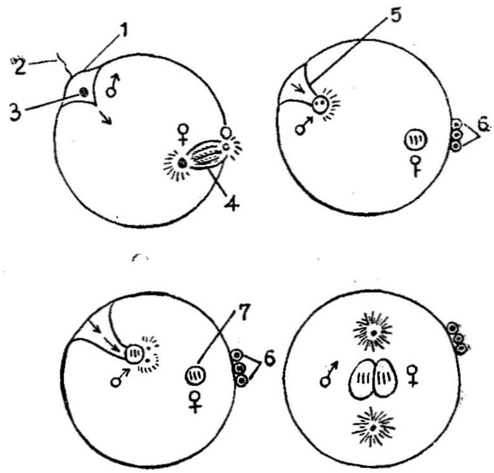


Fig. 29
Fertilization

1, Entrance cone 2. Tail 3. Head of sperm 4. II Meiotic division
5. Entrance path 6. Polar bodies 7. Female pronucleus

After one sperm enters the egg, the egg undergoes its first fertilization reaction namely, the granules in the cortex are discharged into perivitelline space, the space enlarges and two layers of the cortex join the vitelline membrane transforming it into the **fertilisation membrane.** It prevents the entrance of other sperms. The sperm nucleus and other sperm structures (except the tail) pass into the cone. Now the zygote is formed.

The sperm nucleus moves inward from the site of the fertilization cone, it soon rotates through 180° so that the mitochondria and centrosome of the midpiece assume the leading position. The sperm aster is formed in the egg cytoplasm and it leads the male pronucleus to the site where union of the two pro-nuclei occur. At once it begins to undergo mitotic divisions.

Significance of Fertilization

1. The egg is activated by the touch of the sperm and maturation is completed.
2. Metabolic changes occur in the egg increasing in oxygen consumption.
3. Sperm entry restores the diploid number of chromosomes.
4. Brings about a new combination of genetic factors.
5. Very often a new plane or axis is established.

Cleavage

The successive divisions of the fertilized egg, which divide the substances of the egg into an increasing number of cells of decreasing size is called **cleavage.** The divisions are at first rapid and then they are slowed down as the cell sizes of mature somatic tissues are reached.

Cleavage in Isolecithal Eggs

The first cleavage division of an isolecithal egg passes through both animal and vegetal poles and splits the egg into two equal cells (holoblastic and equal). The second cleavage division also passes through both poles of the egg but at right angles to the first and separates the two cells into four equal cells. The third division is horizontal at right angles to the other two, and separates the four cells into eight, four above and four below the line of cleavage. Further divisions result in embryos containing 16,32,64,128 cells and so on until a hollow ball of cells, **blastula** is formed. The wall of the blastula is formed of **blastomeres,** forming a single layer, the **blastoderm,** surrounding a cavity in the **centre, the blastocoel.**

Cleavage in Telolecithal Eggs

The cleavage pattern is modified in teleolecithal eggs by the large amount of yolk present. The first cleavage division passes through the axis but is faster at the animal pole than in the vegetal pole, where the yolk retards rapid cleavage (Holoblastic, unequal) 2nd and 3rd cleavages are similar to amphioxus but faster in animal pole and slower in vegetal pole. Thus many small sized cells are formed at the animal pole and the cells at the other pole are larger. The smaller cells are called **micromeres** and the larger cells are called **macromeres.** The blastocoel is displaced upward.

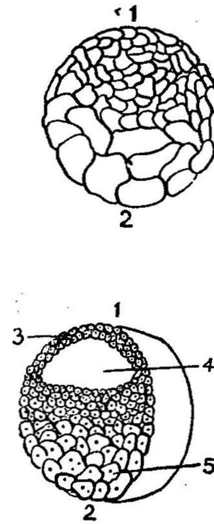


Fig. 30 (b)
1. Animal hemisphere
2. Vegetal hemisphere
Section

1. Animal hemisphere
2. Vegal hemisphere
3. Micromeres
4. Blastocoel
5. Yolk cells

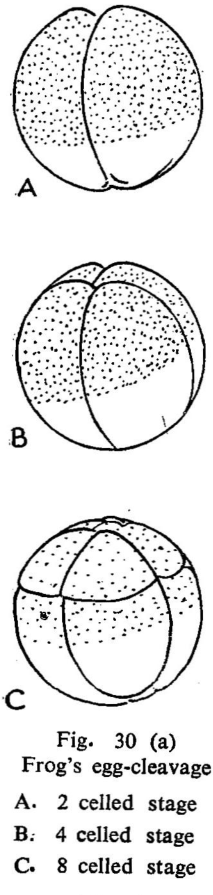


Fig. 30 (a)
Frog's egg-cleavage

A. 2 celled stage
B. 4 celled stage
C. 8 celled stage

In eggs with a larger amount of yolk, such as a hen's egg,cleavage occurs only in small the disc of cytoplasm at the animalpole. At first, all the cleavage planes are vertical and all the blastomeres lie in a single plane. The cleavage furrows separate the blastomeres from each other but not from the yolk. The central blastomeres are continuous with the yolk at their lower ends and the blastomeres at periphery are continuous both with the yolk beneath them and with uncleared cytoplasm at their outer edge. As cleavage continues more cells become cut off to join the ones in the centre but the new blastomeres are also continuous with the uncleaved underlying yolk. The central blastomeres eventually become separated from the underlying yolk either by horizontal cleavages or by splitting.

Now the blastomeres of the central area can be distinguished into (a) cells with complete plasma membrane and seperated from its neighbours and from the yolk **(epiblast)** and (b) lower cells which remain connected with yolk **(hypoblast)** and (c) marginal cells which form a syncytium with many nuclei **(periblast).** There is a small space between the epiblast and hypoblast called **subgerminal cavity** which appears only under the central portion of the blastoderm. This area is more transparent and is called **area pellucida** whereas the more opaque part which rests directly on the yolk is called the **area opaca.**

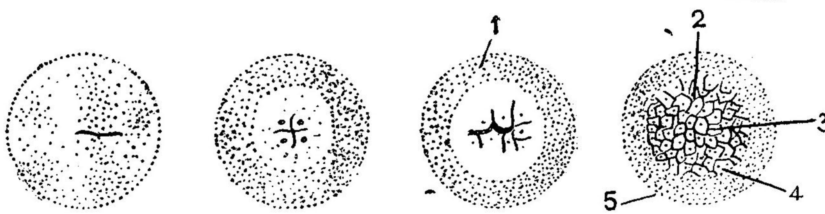


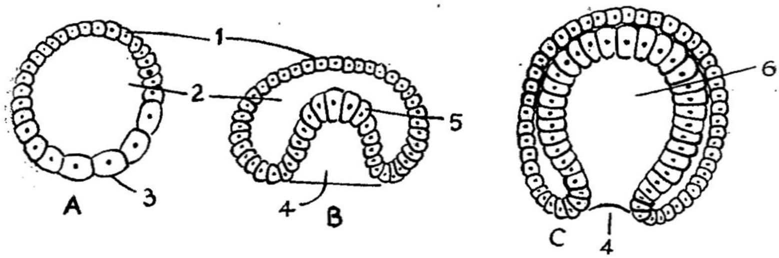
Fig. 31
Hen's egg cleavage

1. Periblast. 2. Area pellucida, 3. Central mass, 4. Marginal cells, 5. Area opaca

4. Gastrulation

Gastrulation involves the movement or migration of cells which occur in specifice ways and lead to specific arrangements of cells. These **morphogenetic movements** involve considerable parts of the embryo which stretch, fold, contract or expand. By these migrations of cells the single layered blastula is converted into a two or three layered gastrula. The three germinal layers, the ectoderm, endoderm, and mesoderm take their respective positions by the end of gastrulation.

In Isolecithal eggs (eg. Amphioxus) gastrulation occurs by a simple process of **invagination** or intucking of the egg surface. The blastoderm at the vegetal pole becomes flattened and then



Fig, 32.
Gastrulation in Amphioxus

1. Small blastomeres, 2, Blastocoel, 3, Large blastomeres, 4. Blastopore, 5. Invaginating cells, 6. Archenteron.

concave, and sinks inwards as if pushed in by some invisible finger. Thus the spherical gastrula is converted into a cup shaped structure with a large cavity in open communication to the exterior. This large cavity is called the **archenteron** and its opening is known as **blastopore.** The blastocoel eventually disappears. The outer layer of cells forms the future ectoderm and the inne- layer of cells forms the future endoderm.

In telolecithal eggs (eg. frog) simple invagination of the above type is not possible because the vegetal region of the blastula is far too thick and overlaiden with yolk and is therefore passive in its behaviour. The gastrulation in frog occurs by the active cells of the marginal zone, where a pocket-like depression (dorsal lip of blastopore) is formed (Fig. 33) superficial cells roll over the rim of the blastopore end into the interior while new portions of cells approach the rim in their place. The thinning out, extension and rolling of superficial cells of animal half over the vegetal half is called epiboly and the rolllng inwards of cells at the dorsal lip is called **involution,** The dorsal lip of the blastopore extends downwards; and a ventral lip is also formed. Due to the progressive epiboly of the pigmented cells of the animal half, the gastrula appears black except for a circular area (yolk plug) bordered by the blastoporal lips. Involution occurs at all points of the blastoporal lips, thus at the end of the gastrulation, the endodermal cells are not distinguishable from one another but later, by the time the blastopore closes, the meso-

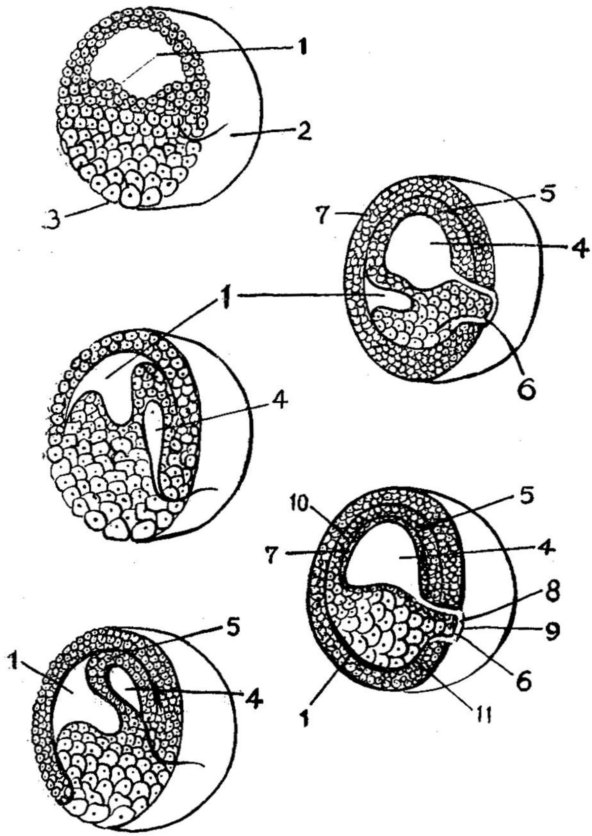


Fig. 33
Frog-gastrulation

1. Blastocoal 2. Dorsal lip 3. Vegetal hemisphere 4. Archenteron 5. Endoderm, 6. Ventral lip, 7. Ectoderm, 8. Lateral lip, 9. Yolk plug, 10. Mesoderm & Notochord, 11. Mesoderm.

dermal cells separate from the endodermal cells and form notochordal cells. The process of splitting or separation of mesodermal cells from endodermal cells is called **delamination.** Delamination also occurs within mesoderm, to split it into visceral mesodermal layer and parietal mesodermal layer.

Thus gastrulation is essentially a process of movement of parts of the embryo. These movements are irreversible. As a result of these varied types of movements such as invagination, involution, epiboly, delamination etc., the structure of the embryo is changed.

5. Embryonic Nutrition

Yolk and Placenta

Special structures which serve to satisfy the requirements of the embryo in respect to nutrition are the yolk and placenta.

The yolk in the egg cannot be considered as part of the embryo in this sense, although it supplies nourishment to the embryo in early stager of development, as in frog. In animals with large amount of yolk, as in the hen's egg, special organs are evolved in order to store the yolk, digest it and to utilize it for the growth of the embryo. The utilization of the yolk is through a special structure called yolk sac.

In birds, the yolk becomes enclosed within a sac called the yolk sac in which a network of blood vessels develop and become connected to the blood vessels of the embryo. By the second day of incubation, the heart of the embryo begins to beat and by 38th and 40th hours of incubation, the blood starts circulating through the network of the yolk sac. The inner wall of the yolk sac develops outgrowths, which are supplied by blood vessels. They penetrate deep into the yolk and facilitate its absorption. The yolk however is not completely absorbed during embryonic life. Shortly before hatching, the yolk sac is retracted into the abdominal cavity of the embryo and the walls of the abdominal cavity close behind it.

In mammal, the embryo develops in the uterus of the mother where it is implanted. The outer surface of the extra embryonic membrane, the chorion, is thin but at a certain place it develops a number of finger like projections called villi, which grow into the tissues of the uterine wall in which they are embedded. These make up the organ known as the **placenta**, by means of which the developing embryo obtains nutrients and oxygen and get, rid of carbondioxide and metabolic wastes.

The villi contain many blood capillaries. The uterine wall of the mother is also thick and vascular. The bloods of the mother and embryo do not mix at all in the placenta or any other place, but are always separated by a membrane through which substances diffuse. As the embryo grows, the placenta grows also. At birth, the placenta and other embryonic membranes are loosened from the lining of the uterus by a series of contractions and expelled.

CHAPTER IV

EVOLUTION

1. ORIGIN OF LIFE

The different forms of life that are seen today are explained by the theory of evolution as descent of each and every species from common ancestors. The fossil record tells us that in earlier times, there were fewer species on the earth and that they were less complex than our modern species. In theory, then, the study of evolution should lead us back to the first form of life from which all others have been descended. We do not know what this first form was. The best we can do is make intelligent guesses about its characteristics.

Theories On The Origin of Life

Various theories have been advanced to account for the existence of life.

(1) **Special Creation Theory:** Among the first attempts at answering this question in our civilization were the stories of creation that are found in the Bible and other scriptures. These stories share two features in common. First, they were created long before man had gained any knowledge of the physical, chemical and biological principles that are basis of life. Second, they invoke divine intervention in the creation of life and thus fall outside the scope of scientific inquiry.

(2) **The Cosmozoic Theory :** The Cosmozoic Theory of origin of life explains the presence of life on our earth by assuming it was brought here from elsewhere in the universe, perhaps incorporated in a falling meteorite. This theory is not satisfactory

as it simply removes the problem from this planet to some other location.

(3) **Abiogenesis or Spontaneous Generation and Biogenesis:** The theory of spontaneous generation was popular till about a century ago. In fact, Van Helmont even gave a recipe-grains of wheat and a dirty shirt in a dark container-for producing mice spontaneously. In 1668, the Italian physician Francesco Redi performed an experiment to show that maggots do not arise spontaneously in decaying meat but are produced from the eggs of flies. Although the spontaneous generation of large forms of life began to be doubted after this, Van Leuwenhoek's discovery of micro organisms reopened the question. The Italian Priest Lazzaro Spallanzani tried to show that even the microorganisms did not appear spontaneously in rotting food. He boiled nutritious broth in glass flasks and then sealed them so that nothing could get into the broth from outside. The broth remained lear and sterile. Even then sceptics argued that heating the air within the flask had so altered it that spontaneous generation could not occur.

It was the immortal French biochemist and microbiologist Louis Pasteur who one hundred years ago finally proved that spontaneous generation or abiogenesis cannot occur. He, too, boiled flasks of broth, but instead of sealing the necks of the flasks, he drew them into a S. shape leaving the ends open. Now fresh air could reach the interior of the flask, but, Pasteur reasoned, any bacteria or other micro organisms floating in it would be trapped in the long neck. Sure enough, the broth usually stayed sterile until he tipped a little into the neck of the flask and then allowed it to run back. Only after doing this, did micro organisms begin to grow in it. Some of the flasks that Pasteur prepared are still in existence (now sealed) their contents of broth clear and pure. Yet, though we have good reasons for thinking that life is not created spontaneously, we have no rigid proof of this.

(4) **Chemical Origin Theory (Modern concept) Oparin's Theory:** The Russian biochemist, A. J. Oparin proposed a theory in 1936. While agreeing that life does not arise spontaneously now, he felt that it might have arisen spontaneously under the conditions that existed earlier in the history of the earth. According to this

theory, the oceans of the early earth contained a rich supply of organic molecules. Over a period of long time, these molecules, became associated with one another in temporary complexes. Ultimately one such complex developed: (1) some sort of membrane to seperate it from the "soup" of organic molecules around it (2) the ability to take in molecules from this soup and discharge other molecules into it. (3) the ability to incorporate the absorbed molecules into the characteristic pattern of the complex' and (4) the ability to split apart portions of itself that had all these features too. Such a complex could have been the first living thing.

The theory of Oparin depends greately on the earth's being somewhat different then than it is now. In order that the organic molecular complex' should develop, there must have been substantial concentrations of the inorganic ingredients out of which they could be synthesized and there should have been a source of energy to bring about this synthesis. Analysis of the atmosphere of the large cold planets, Jupiter and Saturn, reveals the presence of methane (CH_4) and ammonia (NH_3). If these two gases, together with water vapour (H_2O) were present in the atmosphere of the early earth, all the elements would have been present (C,H,O,N) for the synthesis of most aminoacids, the carbohydrates and fats and the purines and pyrimidines. Radio activity ultra-violet radiation from the sun, heat from volcanos and electrical discharge—all might have provided energy for the synthesis of various organic molecules from these gases.

Could such a system really work? In 1953, Stanley Miller a biochemist, built an apparatus and filled it with water, methane, ammonia and hydrogen. The mixure was kept circulating by continuously boiling and then condencing the water. The gases passed through a chamber containing electrodes with a spark passing continously between them. At a end of a week, chemical analysis of the contents of the flask revealed the presence of several aminoacids (eg. glycine, alanine) succinic acid (organic molecule involved in the citric acid cycle).

Muller's results encouraged others to vary the procedures and modify them. Most of the amino acids, some small polypeptidies, purines and pyrimidines, sugar and a vitamin nicotinamide have been produced in these latter experiments.

None of these experimented recreations however produced anything alive. Some molecules associated with life like proteins, sugars were produced, could these have eventually associated themselves into a complex attributes of life ?. we may never know : Sidney W. Fox and several of his co-workers have shown that by subjecting a mixture of amino acids to intense heat (160-200°C) for several hours, a protein like compound (Proteinoids) could be produced. By pouring water over a mixture of hot proteinoids, Fox produced tiny spherical bodies(microsphere) which had a double walled membrane typical of living cells. Simple sugars have been produced by iradiating solutions of formaldehyde ($H_2C=O$) with ultraviolet or gamma rays. Later sugar molecules have been produced by heating mixtures of simple sugars. Compounds of fat, purines and pyrimidines can also be prepared in the lab. However, efforts to synthesize nucleic acids (DNA, RNA) under the hypothetical primitive earth conditions have not been completely successful.

Life required even larger molecules than nucleotides and further construction of such molecules must have occured at some times. Life can be simply defined as "cells containing nucleic acids" and protein.

Viruses have a similar composition-that is, either RNA or DNA and protein. It is tempting to speculate that they are similar to the early structures formed when nucleic acid and protein molecules first evolved. This is only one hypothesis, howevere, to explain the existense of viruses. Some biologists believe that viruses have evolved to an extreme state of parasitism, with the gradual loss of all cellular structures except nucleic acid and protein. Since viruses do not posses the necessary cell parts for reproduction and other life processes, they must invade living cells and utilize the host's cellular machinery.

The proposed chemical events leading to the development of life are summarized as follows :

Primitive atmosphere :	NH_3, CH_4, HCN, H_2O
Small organic molecules:	Amino acids, glycerine, fatty acids, 5-C sugars, 6-C sugars, purines and pyrimidines

Large organic molecules	Proteins, fats, compound sugars, nucleotides
Larger organic molecules	Nucleic acids (DNA and RNA)
Macromolecules	Chromosomes
Life	Chromosomes in cells
Diversity of life	Natural selection and the variety of cells produced

2. Geological Time Scale

Not until little more than a century ago did men begin to appreciate just how old the earth is. One of the first estimates was based on the increasing salinity of the oceans. Dividing the salt concentration of our present oceans by their annual increase in salinity, one arrives at a figure of about 50 million years for their age. There is no proof however for the assumption that oceans have been getting saltier at a constant rate through the years. A similar attempt was made to establish the age of the earth by measuring the total thickness of sedimentary rock deposits and dividing this by the estimated annual increase in the thickness of ocean sediments. This method is also not satisfactory and there is no continuous record of sedimentary rock.

The discovery of the radioactive elements has provided us with a clue regarding the geologic process which proceeds at a constant rate. Radioactive elements contain unstable isotopes, which by emitting subatomic particles such as electrons and alpha particles (helium nuclei) become "transmuted" into other isotopes Atoms of U-238, the most abundent, istope of uranium, undergo a series of transmutations as the "decay" radioactively till an isotope of lead (Pb 206) is formed. These transformations take place at a definite, measurable rate. (half life of isotope). This is not affected by temperature, gravity, magnetism electricity or any other force. Here then is geological clock which keeps perfect time and whose elapsed running time can be simply 'computed from the ratio of isotope of lead (Pb. 206)(the stable isotope)atoms to U:238 atoms in a rock sample. By this method, the oldest rock is dated as 2.7 billion years old, (in Southern Rhodesia). However they surely were not formed at the time the earth itself was formed. The study of other isotopes in other minerals (as well as in meterite) indicates that the earth (and the solar system) was formed some 4-7 billion years ago.

The Dawn Of Life

No one knows exactly when life first appeared on the earth. Fossils that resemble bacteria have been found in sedimentary rocks over 3 billion years old, in South Africa. It is above 0.5 mm. long and has been named eobacterium isolatum.

Nourishment for the first form of life was no problem as it was surrounded by the soup of organic molecules. It only required energy and we assume that the first living organism secured this by fermenting the organic molecules. Fermentation could not have gone on indefinitely. Some organisms must have evolved a means of sy nthesizing new organic molecules from the inorganic substances found in the environment. Such synthesis require energy which probably came from the sun. These photosynthetic organisms not only provided an inexhaustible supply of organic molecules to meet the needs of life but ultimately provided oxygen as well. With the accumulation of oxygen in the atmosphere, the way was open for heterotrophic organisms. to secure their energy requirements by cellular respiration. Then with an inexhaustible supply of energy from the sun and an efficient method for extracting energy from them, the full potentialities of life could be realized.

Though it is possible that life arose spontaneously from organic molecules, it cannot occur now. For one thing, there are no longer appreciable quantities of organic molecules in the waters of the earth. Second, any complex of organic molecules that might form spontaneously would quickly be destroyed by the oxygen that is now present in the atmosphere, and which is a powerful oxidizing agent and the already existing forms of life (for example bacteria) would consume the complex before it developed to the point where we could consider it to be alive.

The Geological Eras

The geological and biological history of the earth since the first appearance of abundent fossils is divided into three major eras, namely, the Palaeozoic, Mesozoic and Caenozoic. Each of these is further subdivided into periods, and epochs. This

GEOLOGICAL TIME SCALE

Eras	Period	Epochs	Duration in million years	Million of years ago to the present	Important plants	Important animals
1	2	3	4	5	6	7
Caenozoic (Age of Angio-sperms and Mammals)	Quarternaiy	Recent	0.025	0.025	Decline of woody plants; rise of herbaceous ones	Age of man;
		pleistocene	1	1	Great extinction of species	Extinction of great mammals; first human social life
	Tertiary	Pliocene	10	11	Decline of forests;spread of grasslands. Monocotyle-dons developed.	Man evolved from manlike apes;elephants, horses,camels almost like modern species.
		Miocene	14	25		Mammals at height of evolu-tion; first man like apes.
		Oligocene	15	40	Maximum spread of forests; rise of monocotyledons	Early mammals extinct rise of Arthropods. Forerunners of most living genera of mammals
		Eocene	20	60		Placental mammals diversified and specialised hoofed mam-mals and carnivores established
		Paleocene	10	70		Spread of early placental mammals and modern birds.
Mesozoic (Age of gymno-sperms and Reptiles	cretaceous		65	135	First monocotyledons; oak & maple Forests; Gymno-sperms declined.	Dinosaurs reached peak, be-came extinct. Toothed birds became extinct. First modern mammals.
	Jurassic		45	180	Increase of dicotyledons cycads, conifers, ferns common	Fish toothed birds lizards; dinosaur larger & specialized [illegible]ctivorous marsupials

Eras	Period	Epochs	Duration in million years	Millions of years ago to the present	Important plants	Important animals
1	2	3	4	5	6	7
	Triassic		45	225	Gymnosperms dominant Decline towards end. angiosperms. Extinction of pteridophytes & seed ferns	First dinosaurs & egg laying mammals Extinction of pri. mitive mammals.
Palaeozoic Age of ferns & Amphibians	Permian		45	270	Decline ot lycopods and horsetails	Many ancient animals died out; mammal like reptiles modern insects arose
	Pennsylvanian		30	300	Great forests of seed, ferns & gymnosperms	First reptiles. Insects common-spread of ancient amphibians.
	Mississippian		50	350	Ferns, lycopods and horsetails dominant: Gymnosperms increasingly widespread.	Insects increase. Amphibians develop rapidly spread of ancient sharks.
	Devonian		50	400	First forests, ferns well established: seed ferns and first gymnosperms	First amphibians Fishes wide spread. Lungfishes and sharks abundant
	Silurian		40	440	First land plants with stele, algae dominant	Marine Arachnids dominant. rise of fishes
	Ordovician		60	500	Seaweeds abundant	First fishes, corals, trilobites & Molluscs abundant
	Cambrian		100	600	Seaweeds	Invertebrates, shelled animals dominant
Proterozoic			1,500 ?	2,000 ?	Primitive aquatic plants	Marine Protozoa
Archaeozoic			???	???	No recognisable fossils, life from deposits of	Indirect evidence graphites etc.,

is based on the formation of strata due to accumulation of sediment-sand and mud-at the bottom of lakes, seas or oceans. The duration of each period ofepoch can be estimated from the relative thickness of the sedimentary deposits, although, the rate of deposition varied at different times and in different places.

3. Fossils And Their Significance

There are overwhelming evidences which indicate that during the course of time, all species of organisms have changed. The fossil record affords the best direct evidence for the theory of evolution.

Fossilization is the process which permits us to see the living forms that existed at various times in the history of the earth. Most fossils are formed when organisms containing hard, mineralized parts are buried in mud or sand before they have decayed. After burial, decay stops and fossilization can occur in many ways. Thus a fossil can be defined as any sort of remains of a once-living organism.

A variety of kinds of fossils are available. Under special circumstances, the entire body of an organism may be preserved after death. Insects trapped in the sticky pitch of conifers growing along the Baltic Coast over 30million years ago, can now be studied, entombed in amber as easily as if they had just died. The frozen woolly mammoths found in Siberia are other examples.

Such total preservations of dead organisms is very rare. Usually, the soft portions of the body are quickly destroyed after death by scavengers or decomposed by decay bacteria. Hard parts, such as bones or shells, are more resistant to such destruction and hence more likely to be fossilized. If surrounded by sediments of clay or sand, they may yield easily recognizable fossils 500 million years later, long after the enclosing sediments have turned to rock such as shale or sandstone. These fossils may even retain traces of organic matter for surprisingly long periods. Aminoacids and small peptides have been recovered from some, that are over 300 million years old

Another common fossil is the petrifaction. This is a copy in stone of some plant or animal part. As the original remains dis-integrated, they were replaced bit by bit with mineral deposits. This process can proceed so slowly that the original specimen is reproduced in all its detail. Fossil wood of this type show preserved annual rings. Some of the original material is present in this specimen. It is not made of cellulose but silica. Nevertheless the faithfulness of the copy makes the fossil as useful as the actual specimen would be. In fossil bones, silicates and other minerals present in the water associated with the sand or mud have entered porous materials such as the bone marrow or spaces left by the decay of softer parts.

If fossil-bearing rocks of approximate known dates are exposed scientists can gain some knowledge of the plants and animals that existed in those times. Such a source is the Grand Canyon, where the Colorodo river has exposed a series of rock layers a mile deep representing a two-billion year period of time. Here we have a story book of our earth and a record of some of the organisms that lived in the various eras over this period of time. The oldest rock is found at the bottom of the Canyon, whereas the youngest rock occurs at the top. The fossils of the most simple living forms are found near the bottom of the Canyon and the fossils of more complex organisms are found progressively nearer the top of the Canyon. In Tamil Nadu, invertebrate marine fossils are found in Ariyalur taluk of Tiruchirrappalli district. From these observations it may be generalized that this represents the developmental pattern of life.

Another way in which the fossil record can be utilized is to trace the development of a specific family of plants or animals. From such studies general patterns of evolution can be determined. The excellent fossils produced by vertebrate animals make this group a good subject for such study, and perhaps the most well known group is the horse family. The horse family has been traced back approximately 55 million years although the early members of this family were very different, from modern horses.

It must be noted that one never finds an unbroken fossil history in one location. Geological upheavals of the land are always followed by erosion and hence erasure of part are noticeable also among soft bodied animals since they decay quickly.

However, though we may never be able to trace the fossil history of all animal groups, the presence and distribution of fossil already discovered provide us with some of the most direct evidence of the theory of evolution.

4. Theory Of Organic Evolution

"Evolution is the gradual development from the simple unorganised condition of the primal matter to the complex structure of the physical universe and in like manner, from the beginning of the organic life on the habitable planet a gradual unfolding and branching out into all the varied forms of beings which constituted the animal and plant kingdom. The first is called the inorganic, the last organic evolution of descent with modification (Richard Swan Lulls).

According to modern concept, evolution is defined as theory dealing with the changes that occur in living organisms as a result of slight genetic variations through successive generations. This implies that present day organisms have developed from preexisting forms and that the visible changes were produced by changes in genes and genes frequencies. Evolution, therefore can be defined as a change in gene frequencies. Evolution is a generally accepted concept in society today and modern biology recognizes its foundation in genetic mechanisms.

Man has attempted to find out the mechanism that governs Evolution. Man has been aware of relationships and development among living forms for some time. Aristotle, Linnaeus, Hutton, Lamarck and Charles Darwin have contributed greatly to our present concept of evolution.

5. Theory Of Natural Selection

Charles Darwin was the most important figure in the development of the theory of evolution. He was able to add to the concept of an evolutionary process and to propose a mechanism 'to account for it which was to gain almost universal acceptance'.

Born in 1809 in England, Darwin was the son of a physician and the grandson of a famous natural philosopher, Erasmus Darwin. Charles Darwin was interested in pursuing a medical career but soon dropped this programme at Edinburg and turned to theology at cambridge. His real interests however were in geology and natural history and he was strongly influenced by the geologist Lyell. Another influence on Darwin was the Essay on Population written by Malthus, which stated the now well-known concept that populations increase at a geometric rate although resources for living are generally limited. Malthus believed that populations must be held in check or they may soon run out of subsistance, and this suggested to Darwin the idea of competition and a struggle for existence in populations.

That species could and did in fact change was a certainty to Darwin. The production of new varieties of domestic animals seemed to illustrate the point very well and Darwin became extremely interested in animal breeding. His trip on H. M. S. Beagle during the years 1831 to 1836 was the most important aspect of his education which prepared him to formulate the theory of Evolution. His studies of the fauna and flora of the Galapagos Islands, located 650 miles west of Equator, specially his detailed study of the fourteen species of finches in those islands was responsible for his theory on origin of the species in 1859. His book entitled **'on the origin of species by means of Natural Selection'** threw the world into a controversy over the mechanism of the development of life.

It is necessary to note here that another biologist, Alfred Wallace, had arrived at conclusions identical to Darwins' and had in fact sent to Darwin a copy of his theory in 1858. Wallace had arrived at his concept independently through his studies on the fauna and flora of Malaya. However the theory is referred to as Darwinism, though it should be rightly called Darwin-Wallace Theory.

Darwin's theory can be briefly summarized as:

Fact No.1 : All species have a high reproductory potential. From oysters to elephants, they are capable of filling the earth with their kind.

Fact No. 2 : Except for minor fluctuations, the population of any given species remains fairly constant from year to year.

Conclusion No. 1: Therefore, we must conclude that all creatures face a continual struggle for existence.

Fact No. 3: There is inherited variation among the individuals of any species.

Conclusion No. 2: Therefore we may conclude that those individuals whose variations best fit them for their environment will be the most likely to survive. This idea of the survival of the fittest is what we call Darwin's theory of natural selection. It is the mechanism Darwin thought accomplishes in nature what man's selective breeding accomplishes in domestication.

Darwin failed to recognize the source of the variations in organisms, and he looked to a modification of Lamarckism for the answer. He used a theory called pangenesis in which it was supposed that tiny units called "pangenes" pass from each part of the body into the gametes to determine what the offspring will inherit in the next generation.

Darwin's theory of natural selection has often been seriously misunderstood. To many people it implied that a "dog eat-dog" existence is natural and that the survival of the fittest means "might is right". Fitness is not measured in terms of aggressiveness but in terms of the ability to produce mature offspring. The fittest organisms in any population are those that leave the largest number of mature offspring. A variety of mechanisms may play a role in this.

(i) Survival: The most important is simply the ability to stay alive till one's reproductive age is over. Any trait that increases the organism's chances of surviving to and through this period makes that orgnanism more "fit" than the others of its species. We call such traits adaptations. They may involve a change in body structure, a change in body physiology, a change in behaviour or all of these. Some adaptations (like claws, fangs) are aggressive. Others are inconspicuous but play important roles in promoting survival. (eg.) Mimicry of the Indian dead-leaf butterfly, the twig caterpillar show morphological adaptations that make their owners more fit by reducing the likelihood of their being eaten by predators.

Physiological and behavioural adaptations go hand in hand with morphological ones. For (eg.) the mimicry of the Indian dead-leaf butterfly would be useless if this creature did not make a practice of resting quietly on twigs with its wings closed.

(ii) Sexual selection: This is another factor affecting "fitness". Any inherited trait that makes some individuals more desirable to the opposite sex than others will thus make them more successful in mating. Consequently, larger proportion of the next generation will have inherited this trait (e.g.) brilliant plumage in male birds.

(iii) Family size: Any trait resulting in the production of larger mature families is also a measure of fitness..

The Modern Concept — Neo Darwinism

Since the time of the Darwin Wallace theory discoveries in biology have contributed greatly to our knowledge of the process of evolution. So, the modern concept of evolution is based on the labours and research of many.

Modern biology attributes variation in living organisms to inheritable chromosomal units, called genes. Since the genes are on the chromosomes, variations are produced in the events of meiosis (crossovers and recombination). The role of the environment then is not to **Produce** the variations but to select the variations. A particular environment acts as a "screen" permitting certain genotypes to inhabit it and "selecting out" other genotypes. Natural selection, as used by Darwin and most modern biologists, refers to the selecting role and function of the environment upon genotypes living in it. We speak of those organisms selected by a particular environment as being adapted to that habitat, and those characteristics they display, which are of value in that environment as adaptations. Because heritable adaptaions increase the probable success of a species, adaptive changes are beneficial. Many changes can occur in a species and all of these are evolutionary; all changes, however, are not necessarily adaptive.

Since better-adapted organisms in a particular environment reproduce at a higher rate than the less adapted, biologists currently use the term **differential reproduction** to denote the success of favoured forms rather than the survival of the fittest. As a result of differential reproduction, the frequency of certain genotypes increases in the population while the frequency of others decreases. If the environment should change, the overall frequency of genotypes could change and organisms of different appearance and function may result. Therefore, evolution is a change in gene frequencies.

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