CHAPTER I

CHARACTERISTICS OF THE LIVING MATTER

Living matter shows certain characteristics which mark them off from the **non-living.** Living matter essentially consists of a body composed of **protoplasm.** Even in the case of unicellular animal or plant, there must be *protoplasm.* Protoplasm has got complex chemical composition, namely, it is composed of proteins which are absent from the non-living matter. Living matter shows movement *i.e.,* capable of moving to and fro. This movement is more pronounced in the animal kingdom but not so in the plant kingdom but the roots of plants have to move constantly in search of food. Another factor peculiar to the living is the method of nutrition which means the taking in of food. The food is then digested with the help of certain juices known as digestive juices. Then absorption takes place and the animal grows. Growth as a result of nutrition and digestion is peculiar to the living. This type of growth is known as growth by intercalation. The plants take in inorganic salts in solution from the soil and organic food is prepared but that food has to be digested by plants. As a result of digestion, a plant grows. Therefore in the living, growth takes place as a result of internal process in other words, it is *intrinsic* but growth also takes place in the non-living which will be discussed in the course of this chapter.

Living matter is always undergoing loss of its substance but it is not visible because the loss is made good

by nutrition. The loss is generally a process of oxidation *i.e.*, combination with oxygen and as a result of this, energy is liberated which manifests itself in the activities of the organism. The process is called *respiration* which takes place both in animals and plants and externally oxygen is taken in and co_2 is given out.

The sum total of chemical changes as results of nutrition, digestion and respiration is known as *metabolism*. The constructive processes like nutrition and digestion are known as *Anabolism* whereas destructive processes like respiration, excretion are called *Katabolism*. Metabolism is the sum total of **Anabolism** and **Katabolism.**

Living matter shows *irritability i.e.*, it is capable of answering to external stimuli.

Over and above the power of responding to external stimuli, living matter has the power of automatic movement. This is known as automaticism.

Living matter ultimately attains old age, which is known as Senescence, and dies.

Reproduction *i.e.* to say bringing forth individuals similar to the parents is one of the most important manifestations of life. In fact, life from preexisting life is the rule in the living world, this is known as the law of biogenesis.

The above are the peculiarities of the living matter.

Difference between Living and Non-Living—

Living :	Non-living :
1. Presence of protoplasm.	1. Absence of protoplasm.
2. Nutrition occurs.	2. No nutrition.

3. Growth takes place by intercalation and intersusception of new materials.	3. Growth occurs simply by deposition or accretion of new materials on the outside.
4. Respiration and excretion occur.	4. No respiration or excretion.
5. Metabolic activities always present.	5. No metabolic activity.
6. Living matters are irritable and automatic.	6. Irritability is present upto a limited extent but automaticism is totally absent.
7. Reproduction occurs according to Biogenetic law.	7. No true reproductive activity.
8. Senescence and death occur.	8. There is no senile decay or death.

The points which have been noticed in the living are not found in the non-living but there are certain points which are common and require some special explanation. Growth takes place in the non-living also, as a stone by gradual collection of debris on it. They can form a larger lump but there is fundamental difference in the growth of non-living. This growth takes place not as a result of nutrition and digestion but on account of external deposit of lifeless matter. This is known as *extrinsic growth*.

Non-living matter does not show any protoplasm, or any method of organic reproduction, rhythmicity etc. In addition to the above, there are certain border-line cases which are hard to solve. A piece of sodium chloride is dead and a dog is living but when a piece of frog's muscle is kept in Ringer's solution and is capable of answering to stimulus we are confronted with the question that the frog as a unit is dead but the muscle is living or dead.

The answer can be given by bringing the characters of the living to its test.

Difference between Animal and Plant—

There are characters which are peculiar to plants while others are peculiar to animals but in the lowest groups they seem to merge with one another. Ordinarily, the source of organic food is the plant because it can convert inorganic food into organic compounds with the help of solar energy and with the help of this organic food, animals specially herbivorous animals nourish and the animals either directly take these organic food or they live upon herbivorous animals but whatever be the food, it is ultimately the animals that have to depend upon plants directly or indirectly. As an example, man might take fruits, plants etc., or he may live upon meat but the meat comes from such animals as goat, sheep etc., which can take only small herbs and grass *i.e.*, plants, so the ultimate traceable food is plant-food. The main differences are :—

(1) Plants can manufacture organic food with the help of chlorophyll stored either in soft parts as stems but specially in green leaves whereas animals have no chlorophyll and are entirely dependent upon plants. Plants are therefore called *holophytic* and animals are called *holozoic*.

(2) Plant cells are generally provided with distinct *cell-walls* composed of *cellulose* or in fungi, of fungus cellulose. The cellulose wall is absent from animal cells. In plants, naked cells are exceptionally found as in reproductive stages.

(3) Centrosome is generally found in animal cells but in plant cells with rare exceptions, it is absent.

(4) Respiration occurs both in plants and animals. The protoplasm undergoes oxidation with the liberation of co_2 and energy in both. In the lowest plants and animals, this interchange of gases occurs throughout the entire body surface. In higher plants, interchange of respiratory gases takes place through minute apertures called stomata ; in higher animals, the principal respiratory organs are the gills or lungs found respectively in aquatic and terrestrial forms.

(5) Plants take in simple inorganic substances from the soil in solution with water through the root-hairs for manufacturing organic food in the leaves but animals take prepared organic food through an aperture, the mouth and then inside a digestive cavity. Fungi serve as exception among plants for they live upon organic food.

(6) Plants have no special system to drive away waste products from the body. Animals have a definite excretory system ; the principal excretory organs in higher forms being the kidneys and skin. There is an apology for such a system in the plants. as often excretory products are eliminated with the fall of Bark or outer rind of plants.

(7) Plants and animals both show movements but the movement of the former is less and ordinarily, the movement of the root in the soil is the highest movement but in the special adaptation of winged seeds, the plants conquer the material difficulties in their movement by travelling miles and miles. The animals are without any

restriction in their movements. With a few exceptions, most plants are sessile whereas most animals are motile.

Although the higher animals and plants show well-marked differences, the unicellular animals or the unicellular plant seems to merge with one another in their lowest ranks and a special name is coined for them *e.g.*, the *Protista.*

Summary of difference between animals and plants.

Animals :	Plants :
1. Animals depend on plant either directly or indirectly for their food, in that sense the animal's body is a less equipped chemical laboratory than the body of a plant.	1. Plants can utilise simple inorganic substances from which they elaborate complex organic substances which are used as food.
2. Chlorophyll absent except when acquired from another plant.	2. Chlorophyll present.
3. In animals there is almost a limiting cell membrane which is often protoplasmic and rarely made of cellulose.	3. Cellulose cell wall present except in fungi.
4. Centrosome or attraction sphere is present.	4. Centrosome is rarely present.
5. Respiration in higher forms through gills or lungs.	5. Respiration in higher forms through stomata.
6. Definite excretory organs in the form of nephridia or kidneys in higher animals.	6. No definite excretory organ.
7. Most animals are motile excepting a few such as the sponges, sea anemones, corals and ascidians etc.	7. Most plants are sessile excepting a few aquatic forms such as Chlamydomonas, protococcus, desmids etc.

CHAPTER II

THE PHYSICAL AND CHEMICAL NATURE OF PROTOPLASM

Protoplasm—

Huxley defined protoplasm as the physical basis of life. Without protoplasm there cannot be any life. The protoplasm is a highly complex substance and is not possible to be analysed in the living state. The protoplasm that is studied by biologists is dead because as soon as it is treated with stains and reagents, it loses its living properties.

Properties of protoplasm—

A. **Physical**—protoplasm is a jelly-like substance. It is readily coagulated *i.e.*, it becomes solid just like the hardening of egg-albumen when boiled. It has the capacity to absorb substances of lower concentration *i.e.* it shows the phenomenon of osmosis.

The miscroscopical appearance has been described as :—

(1) **Reticular,** (2) **Fibrillar,** (3) **Alveolar** and (4) **Granular.**

Reticular—protoplasm has been described to be in the form of net work or reticulum.

Fibrillar—protoplasm has been said to be in the form of threads called fibrils connected by other threads.

Alveolar—when there are empty spaces in the protoplasm known as alveolus.

Granular—it states that protoplasm is in the form of minute granules.

B. Chemical—protoplasm is chemically regarded as very rich in proteins. Proteins are always associated with organic life. As the commonest example of proteinaceous substance, egg, fish, meat may be cited. The analysis of dead protoplasm has shown that it is composed of a variety of proteins. They have within them the following elements *e.g.* H, O, N, C, S and some inorganic salts of sodium, calcium, potassium, iron, chlorine and phosphorus.

C. Physiological—protoplasm is responsible for all the life—processes in the organism. Protoplasm carries out the following functions :—

(1) **Nutrition,** (2) **Reproduction,** (3) **Respiration,** (4) **Excretion** etc.

Nutrition—means the taking in of food or food-material and by a series of processes capable of converting them into the life-substance, the protoplasm.

Reproduction—every organism will ultimately die and in order that the kind may not be exterminated from the face of the earth, representatives must be left in the world which in turn will repeat the process by separating a part of the body and thus the series will go on and live in the world. This process is called Reproduction.

Respiration—this process always takes place and essentially consists in the interchange of oxygen of the

atmosphere with the CO_2 (carbon dioxide) formed in the body as a result of some vital activity within the body.

Excretion—this process means the discharge of waste-products from the body. In the plant, the system of excretory organs is not so well developed as in the animal kingdom, which carry on this process.

Protoplasmic movement—

Protoplasm is always in a state of movement. The movement of protoplasm :—

(1) **Rotation**—when the movement is in a definite direction *e.g.*, Vallisneria.

(2) **Circulation**—when the movements are in several directions *e.g.* in the hairs on the stamens of Tradescantia.

(3) **Amœboid**—when the movement takes place by the throwing out of blunt processes called Pseudopodia *e.g.* Amœba.

(4) **Ciliary**—when the movement takes place with the help of fine hair-like processes called Cilia *e.g.* Spermatozoids of Fern and Moss.

Tests for protoplasm—

(1) It coagulates with the application of heat and alcohol.

(2) It turns yellowish-brown when treated with iodine.

(3) It turns yellow with Nitric Acid and the yellow colour becomes deeper with the addition of ammonia.

Average percentage composition of protoplasm.

Carbon	.. ..	50 to 55 %
Hydrogen	.. ..	6·5 to 7·3 %
Nitrogen	.. ..	15 to 17·6 %
Oxygen	.. ..	19 to 24 %
Sulphur	.. ..	·3 to 2·4 %

Protoplasm is regarded to be in the colloidal state. Colloidal substance consists of ultra-microscopic particles suspended in a medium of fluid or semifluid consistency. The particles form the disperse phase and the solute, the continuous phase. All such structure is invisible to the naked eye, being of ultra-microscopic size, but always within the protoplasm small microscopic granules or drops are visible and these do not form part of the essential permanent protoplasmic structure but are small aggregations of fats, carbohydrates or proteins which have been temporarily formed as a result of the protoplasmic activity. They may be referred to as "*metabolites.*" Such a substance may be an **Emulsion.**

The protein part of protoplasmic colloid is readily and irreversibly coagulated by high temperatures and with this coagulation, the life of the cell comes to an end.

Within fairly wide limits, the protoplasm can lose or gain water in the manner of gelatine, passing from one condition to the other readily and reversibly according to conditions.

A colloid which looks like a solution is called a *sol,* and that which is semi-solid in consistency is known as *Gel. Cytoplasm* is an example of Sol, while the *nucleus* is Gel.

Above 40°C, the structure of the protein molecules is affected and the irreversible coagulation changes set in. Thus the protoplasm can be said to exist normally in a state intermediate between that of a sol and a gel and a change in either direction is very readily caused by temperature, changed water-content, changed salt concentrations and by different hydrogen-ion concentrations.

If protoplasm is subjected to a solution of salt or sugar, it will allow the water to pass but not the substances with larger molecules. Thus protoplasm is said to be *semipermeable.*

The nuclear composition has an additional element namely *phosphorus*. The different kinds of proteins which are abundantly found in it are nucleo-albumin, globulin and peptones.

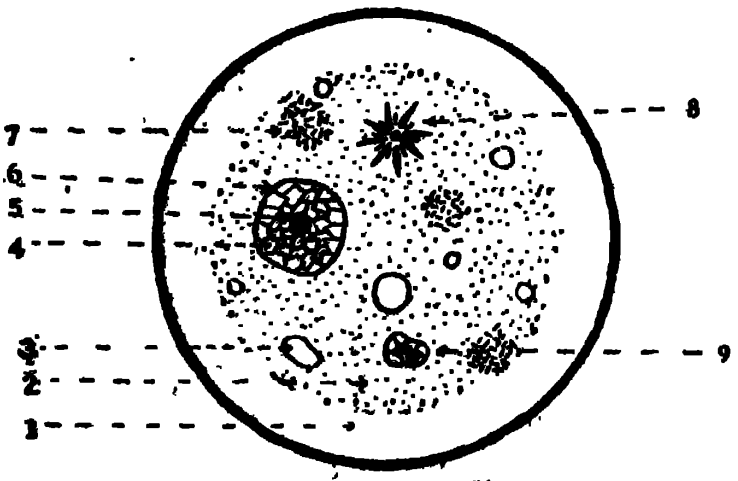
Cells—

Cells are the structural and functional units of the animal body. In the case of a unicellular animal, the single cell has to carry out all the functions but in a multicellular animal, several cells combine to form a tissue and tissues are in their turn specialised to perform definite functions of the body. The **animal cell** is peculiar in this respect that the definite **cel-wall** is absent. It consists of a spec of protoplasm differentiated into (*a*) **Cell-membrane,** (*b*) **Cytoplasm** and (*c*) **Nucleus.**

Cell-membrane—This is the limiting membrane of the cell and occurs in the form of a thin pellicle. In most animal-cell this is a specialised part of the protoplasm and hence a living structure.

Cytoplasm—The portion of the protoplasm within the cell-membrane and surrounding the nucleus is known as cytoplasm. The cytoplasm consists of an outer transparent **Ectoplasm** and an inner granular **Endoplasm.** Embedded in the cytoplasm and lying close to the nucleus is a star-shaped body known as **Centrosphere.** Within which are one or two granules called **Centrosomes.** The centrosphere plays a very important part during cell-division. The cytoplasm also contains **Mitochondria** in the form of rods and cones and **Golgi-bodies** which can only be demonstrated by treatment with special stains and reagents.

Cavities or gaps are often met with in the cytoplasm. These contain a fluid called cell-sap and are known as **Vacuoles.**



Animal cell.

1. Ectoplasm.
2. Endoplasm.
3. Vacuole.
4. Nuclear reticulum.
5. Nucleolus.
7. Mitochondria.
6. Nuclear membrane.
8. Centrosphere.
9. Golgi body.

Nucleus—It is the most dense part of the cell-protoplasm and is bounded by the **Nuclear-membrane** within which lie the **Nucleoplasm.** The latter is made up of a network of **linin-threads** containing thick corners of **Chromatin granules.** Within the meshwork there is a fluid called **Nuclear-sap** or **Karyolymph.** Here and there chromatin granules are aggregated to form bodies called **Nucleoli.**

Cell division—

The growth of an animal or plant results from the division of its cells. There are some unicellular animals which also must divide to give rise to new animals. There are several methods of cell division. Some are very simple, others are complicated in their process of division.

The principal types are :—

(*a*) **Direct division,** (*b*) **Indirect division** or **Mitosis** or **Karyokinesis,** (*c*) **Reduction division** or **Meiosis,** (*d*) **Free cell formation.**

Direct division—

Direct division occurs in the lowest group of animals namely the *protozoa.* The nucleus first elongates and assumes the form of a dumb-bell and the cytoplasm also constricts and separates into two cells, *e.g.,* Transverse division of Paramoecium specially the meganucleus, Amoeba.

Indirect division or Karyokinesis or Mitosis—

(*After Dr. Hans Grüneberg, Ph.D., M.D.*)

Nuclear division of the sort almost universally found in plants and animals is called Mitosis. The resting nucleus of a cell is a vesicle of varying shape surrounded by a nuclear membrane. It consists of fine threads in a tightly coiled bundle. The threads are the **Chromosomes** and to one or two of them, a darkly staining body, the nucleolus may be attached. Chromosomes can be distinguished from other constituents of the cell by a specific chemical test (Feulgen) and are stainable with basic dyestuffs such as haematoxylin and gentian-violet.

The stages of mitosis which can be followed in living cells or fixed preparations, are :—

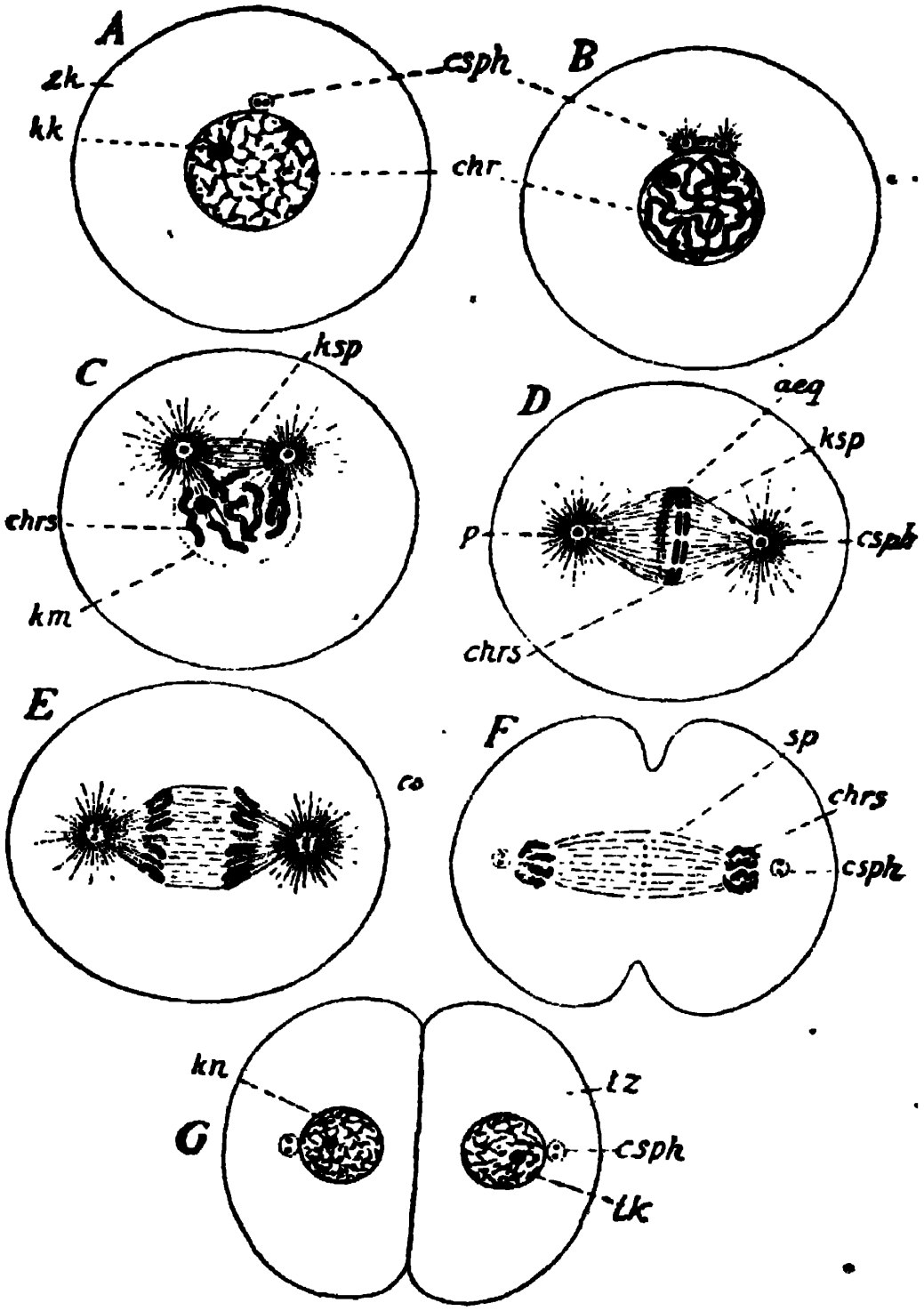
(1) **Prophase**—Separate chromosomes become visible as fine long threads. They consist of little granules called **Chromomeres,** connected by a fine thread like beads on

string. Each chromosome is a double thread, a longitudinal split having occurred prior to prophase in the resting nucleus. Each half is called a **Chromatid** but the two daughter-chromatids of each chromosome are still connected at one point. At later stages of Prophase, the chromosomes contract by forming a close spiral thereby getting thicker and shorter and staining darker in preparations.

(2) **Pro-metaphase**—The nuclear membrane becomes dissolved at the end of prophase so that the chromosomes are lying free in the cytoplasm of the cell. A spindle of denser cytoplasm is being formed, parts of which are contributed by the nuclear sap. The poles of the spindle which in some organisms emanate from a darkly staining body, the centriole or centrosome, are at opposite sides of the nucleus. The chromosomes have contracted lengthwise considerably. That part of each chromosome which was not yet divided at prophase attaches itself to the spindle; it is called the spindle attachment or Centromere. Now this Centromere also divides.

(3) **Metaphase**—The chromosomes arrange themselves in the equatorial plane of the spindle to make a flat circular "plate."

(4) **Anaphase**—The two daughter chromatids of each chromosome move towards opposite poles of the spindle. This disjunction starts at the Centromere which therefore is responsible for the separation of the chromatids. Since the two groups resulting from this separation each receives a daughter chromatid of every chromosome, two complete and exactly corresponding sets of chromosomes are formed.



Karyokinesis or Somatic type of nuclear division.

A. Resting cell,
B. Centrosphere dividing into two, prophase.
C. Nuclear Spindle formed
D. Metaphase,
E. Anaphase,
F. Telophase.
G. Daughter cells.

Zk. Cytoplasm,
Csph. Centrosphere,
Kk. Nucleolus,
Chr. Chromatin,
Ksp. Spindle,
Chrs. Chromosomes,
Km. Nuclear membrane.
Cs. Centrosome.
Tz. Daughter cell.

(5) **Telophase**—New nuclear membranes are formed round the two new nuclei. New nucleoli are formed, replacing the one dissolved during mitosis in each daughter-cell, and a division of the cytoplasm between the nuclei marks the end of mitotic cell division.

The number of Chromosomes is constant in a given species—

Each animal or plant species has in all its body cells a constant number of chromosomes visible at every somatic cell division. In a few groups, the two sexes differ as to chromosome number.

Species	Number of Chromosomes.
Entamoeba histolytica	6
Culex pipiens (mosquito)	6
Anopheles	6
Drosophila melanogaster (fruit fly)	8
Musca domestica (house fly)	12
Lucilia (green-bottle)	12
Calliphora (blue-bottle)	12
Pisum sativum (garden pea)	14
Zea mays (maize)	20
Rana temporaria (frog)	26
Mus musculus (house mouse)	40
Man	48
Bombyx mori (silk-worm)	56
Rumex hydrolapathum (great water dock) ..	200
Cambarus sp. (crayfish)	208

The chromosome number is usually even, suggesting that the chromosomes are present in pairs. Some exceptions to this rule do occur.

The shape of the Metaphase Chromosomes—

The shape of the chromosomes at metaphase may be rod-like, or **V-shaped** with two equal arms, or **L-shaped** with a long and

short arm, or very short ovoid or globular. Often a chromosome has a little knob attached to one end called a **Trabant** or **Satellite.** In the chromosome complement of any given species, several types of chromosomes may be present simultaneously. So in Drosophila melanogaster (fruit fly) four out of eight chromosomes, are always V-shaped, and two others are always dot-like and very small. So not only the number of chromosomes, but also their shape is characteristic for each species. **Each chromosome has an individuality,** and in many species with not too numerous chromosomes and sufficient differences in chromosome shape and size, individual chromosomes are easily identifiable at every cell-division.

In such cases it is seen that **chromosomes are present in pairs, the partners of which correspond to each other.** So in Drosophila melanagaster females, there is one pair of rod-like chromosomes, two pairs of V-shaped chromosomes and one pair of very small globular chromosomes. The members of such pairs which are usually (with one important exception) of very similar shape and size, are called **Homologous chromosomes.** The homology of chromosomes in pairs becomes very obvious at the maturation divisions preceding the formation of sex-cells, even when that homology is not so striking in somatic divisions.

MEIOSIS

The two nuclear divisions preceding the formation of functioning sex-cells are called the **first and second meiotic divisions,** the whole process is called **Meiosis.** In animals the process leading to the formation of male gametes or spermatozoa is called **Spermatogenesis** and that leading to female gametes is called **oogenesis.** In plants the corresponding terms are **Micro and Megasporogenesis.**

Spermatogenesis—

The prophase of the first meiotic division is characterised by a number of complicated processes not found in any other cell division. The following stages are distinguished:—

(1) **Leptotene**—The chromosomes appear as fine coiled threads within the nucleus. Their number is, of course, that characteristic of the species.

(2) **Zygotene—Homologous Chromosomes** start pairing in such a way that the two threads lie parallel to each other. This intimate pairing brings corresponding parts of the chromosomes side by side. Thus at this stage, the number of chromosome pairs or **Bivalents** is just half the number of single chromosomes of the set seen at mitosis.

(3) **Pachytene**—The chromosomes get somewhat thicker and it becomes obvious that each of the paired chromosomes (A and a) has divided longitudinally into two daughter chromatids, so that the whole group now consists of four threads (A′ A″ a′ a″). Each homologue is represented by two identical daughter chromatids, which, however, are still connected at the spindle attachment.

(4) **Diplotene**—As soon as the splitting of chromosomes into two daughter chromatids has taken place at pachytene, the attractive force which brought homologous chromosomes parallel to each other ceases to exist. Homologues open out again and would separate completely, if they were not held together at one or several points by what are called **chiasmata.** A **chiasma** is a crosswise connection between two chromatids of a bivalent which are not the daughter strands of one original chromosome. So either of the two A strands may form a chiasma with either of the "a" strands. At any given level of the bivatent only two of the four strands are involved in a chiasma; but if several chiasmata are formed, other strands than those forming the first one may contribute to the second or third chiasma.

After the formation of chiasmata has taken place, chromosomes contract, getting shorter, but much thicker. This contraction reaches a maximum at metaphase when the bivalents have arranged themselves in an equatorial plane.

At the anaphase of the first meiotic division the bivalents separate in such a way that at the spindle attachment which initiates disjunction, the two daughter chromatids of each homologue remain together since the spindle attachment point, unlike the rest of the chromosome, has not undergone division at pachytene. So A′ and A″ go into one cell, while a′ and a″ pass into the other. It is to be clearly understood that this applies only to the region of the spindle attachment. The failure of the spindle attachment to divide

is peculiar to the first meiotic division and does not occur at any other cell division. The concluding phase of the first meiotic division is usually at once followed by the beginning of the second meiotic division. Each of the two nuclei resulting from the first division divides again. No new division of chromosomes takes place at this division, but the two chromatids left together at the previous division now pass to opposite poles of the spindle. So altogether four cells are being formed which now differentiate into mature spermatozoa.

Result of the two Meiotic divisions—

There are two cell-divisions, but during these divisions the two homologues of a pair, A and a, have divided only once (at pachytene of the first division) forming the bivalent A′ A″ a′ a″. The four strands of the bivalent are now distributed to four cells. Each of the resulting cells, therefore, receives only one of the chromatids, either A′ or A″ or a′ or a″. Since this applies to all the bivalents, the net result is the formation of cells which do not contain the full set of chromosomes, but only half that number. They, therefore, carry only one member of each pair of homologues

The result of meiosis is therefore reduction of chromosome number. If the somatic number of chromosomes is $2n$, each spermatozoon contains only n chromosomes. We call the somatic number ($2n$) **diploid,** while the gametic chromosome number (n) is called **Haploid.** Drosophila, for instance, has Diploid 8, haploid 4 chromosomes, man respectively 48 and 24. This halving of the chromosome number is called **Reduction.**

Free cell formation—

Sometimes the nucleus is divided into a number of parts and later on cytoplasm collects to each bit of nucleus to form a number of naked cells. This is known as free cell formation *e.g.* gametes of Monocystis.

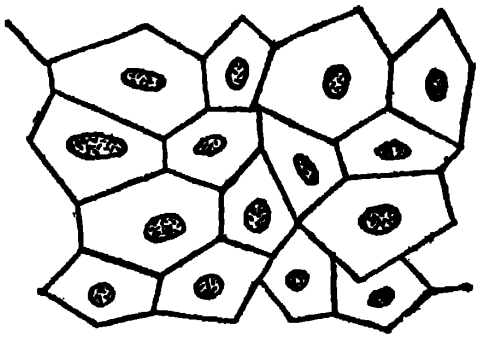
Tissue and Tissue-system in animals—

Tissue means a collection of similar cells performing a definite function in the body. There are various tissues

in the body of an animal. These tissues combine to form **organs.** Example of organ is the eye, tongue, liver etc. Practically organs also combine to carry out different functions of the body, such a combination of organs is known as a **system.** Thus urine is manufactured inside the kidney, from the kidney it passes by a passage called ureter and collects inside a sac called urinary bladder, now the whole work is accomplished through these organs namely kidney, ureter and bladder and they form a system called **urinary system.**

There are four kinds of *tissues* :—(*a*) **Epithelial,** (*b*) **Muscular,** (*c*) ***Connective*** and (*d*) **Nervous.**

Epithelium means a boundary and epithelial tissues are found to cover the external and internal surfaces of

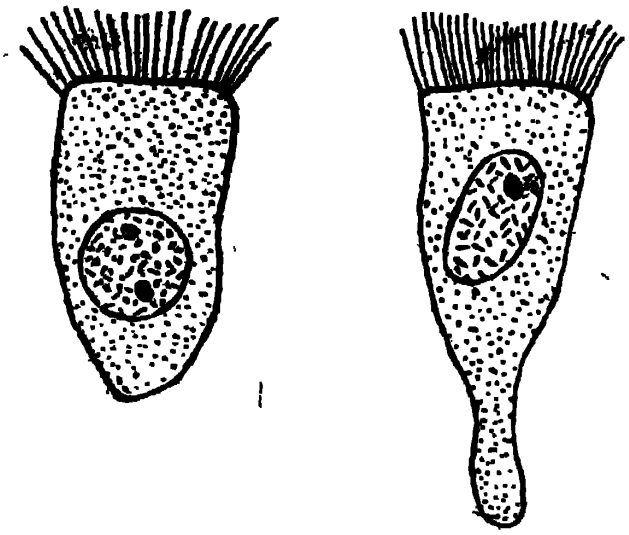


Squamous epithelium,
surface view.

the animal. There may be **simple epithelium** consisting of a single layer of cells or **compound epithelium** consisting of two or more layers of cells. According to the shape of the cell, the epithelial tissues are of the following kinds :—

(*a*) **Columnar**—In this the cells are tall, lying side by side like columns. Between the cells, there are fine

crevices which communicate with lymph-spaces; found in the lining of the intestine of Toad.



Cilated epithelium from toad's mouth. Cell with cilia.

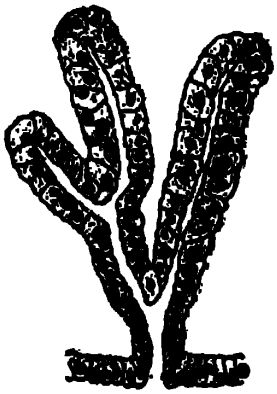
(b) **Ciliated,** this is a modification of columnar epithelium and has a lining of fine protoplasmic hairs on the outer borders of the cells. The hairs are called **cilia** and are in constant motion in one direction found in the roof of the mouth of Toad.

(c) **Glandular epithelium** is a kind of epithelium, in which the cells become specialised for the secretion of chemical substances. The glands might be simple or compound. This is found in the stomach of Toad.

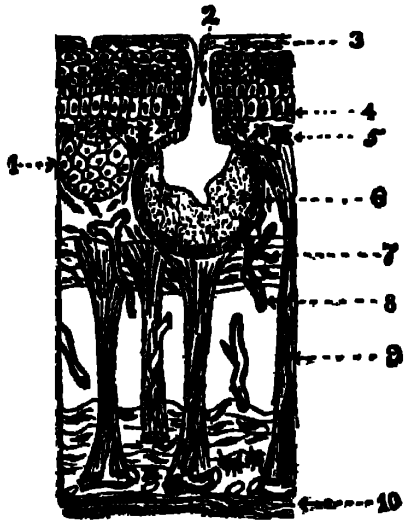
(*d*) **Squamous** epithelium is a kind of simple epithelium. The surface of this tissue seems to be composed of flat tiles like a pavement found in the lining of blood-vessels, coelome, toad's skin.

(*e*) **Stratified** or **compound epithelium**—In this several layers of cells are found. The innermost layer is generally soft and is known as **Malpighian layer.** The outer layers become more and more flat and horny, as in

the skin or epidermis of toad. The outer cells fall off and are renewed by new cells from the soft layer.



Glandular epithelium from the alimentary canal of Toad-stomach.



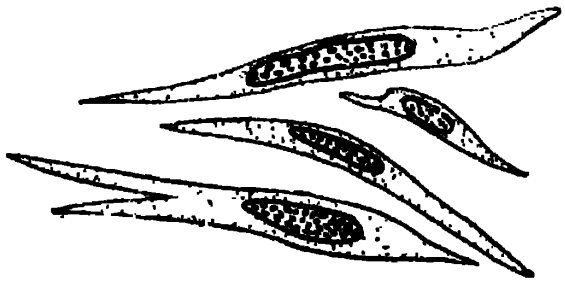
Stratified epithelium from toad's skin. (*Section*)
1. Cutaneous gland. 2. Duct. 3. Epithelial cells. 4. Malpighian layer. 5. Pigment cells. 6. Gland. 7. Connective tissue. 8. Blood-vessel. 9. Connective tissue. 10. Connective tis-

(*f*) **Cubical epithelium**—This consists of cubical cells. They are found in the gonads where they give rise to germ cells.

Muscular tissue—

The movements of the body are generally controlled by the contraction of this tissue. This tissue consists of elongated cells which are highly elastic and contractile. Muscle fibres are of two kinds, (*a*) **Striated** or **Striped** and (*b*) **Plain** or **unstriped** or **unstriated.**

Some of the muscles are under the control of the will *i. e.* the animal can control the movement which is generally called **voluntary** type and is striated. Others are not under the control of the will and are called **involuntary.** They are generally unstriated. Exception —heart muscle though striated is involuntary. The fibres of plain muscle have elongated cells with nuclei in the middle *i. e.* each cell has a single nucleus *e. g.* muscular lining of intestine.



Unstriped muscle fibres with nuclei.

Striped muscle fibre dark and light bands from toad's leg.

The fibres of the striped variety are cœnocytes *i. e.* each fibre contains several nuclei and their cytoplasm exibit alternate light and dark stripes. The nuclei are scattered along the length of the fibre. The fibres are surrounded by a sheath called **sarcolemma** which adheres to the adjacent fibre or tendon as in the leg muscles of Toad.

Heart muscle—

The heart muscle although of the striped variety is an exception. Each cell has a nucleus and is striped but it is not under the control of the will; the automatism lies

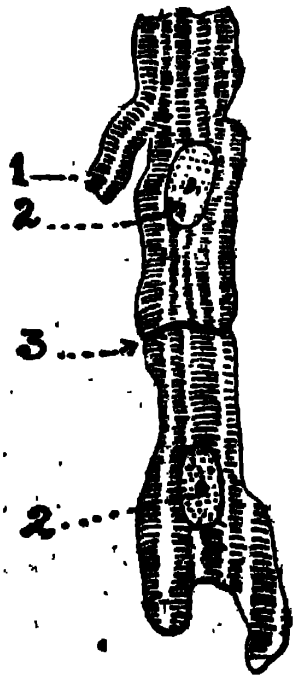
within its own tissue which has slightly less distinct striations than ordinary muscle.

Connective tissue—

This tissue develops plenty of intercellular substance to bind together or support other tissues. The connective tissues may be of the following types :—(1) **Connective tissue proper,** (2) **Cartilage,** (3) **Bone** and (4) **Blood.**

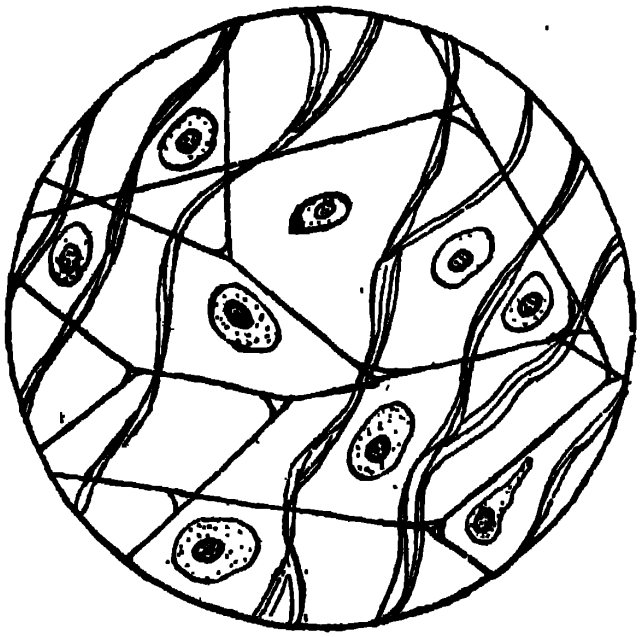
(1) **Connective tissue proper**—As the name indicates it connects other tissues. They contain fibres of two kinds *e.g.* **white fibres** which may branch and have

Heart muscle of Toad.



1. Fibre-branch.
2. Nucleus.
3. Partition.

Connective tissue.



Cells, yellow fibres—run singly, white fibres—in bundles.

a wavy course but never join with one another and are composed of fine fibrils. The yellow fibres or elastic fibres join up to form a network but are not composed of fibrils.

When connective tissue is boiled, the ground substance gives **gelatin.** In the ground substance of connective tissue, spaces are found which are occupied by scattered connective tissue **corpuscles.** Connective tissue almost penetrates every part of the body holding the softer tissues in position; under the skin it forms a continuous layer called **dermis.** The dermis is covered by epithelial layer called **epidermis.** **Tendon** is a modification of connective tissue and serves to connect muscles to bones.

Cartilage is found in the pinna of external ear. It has a homogeneous ground substance. The cells are found in pairs in the ground substance which separate due to the secretion of the cells. There are two kinds of cartilage. One kind shows abundant development of fibres and is known as **fibrous cartilage.** The other kind

Cartilage.

Ground substance, cells are dividing.

Section of decalcified bone

1. Haversian canal. 2. Bone-cell. 3. Lamellae.

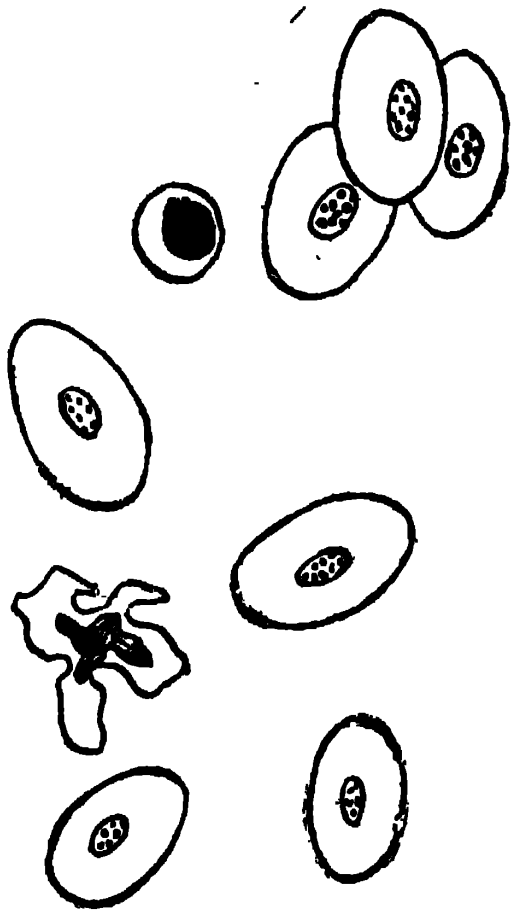
does not show any fibre but has a hyaline ground substance and is called **hyaline cartilage.**

Bone—

The ground substance of this tissue consists of animal matter on which calcium phosphate or carbonate is

deposited. A thin section of frog's bone shows that it is composed of many thin layers or **lamellæ** surrounding the **marrow cavity.** In the lamellæ are found numerous cavities called **lacunæ** with delicate branching tubes called **canaliculi** which run in all directions. The cavities in sections appear black owing to the presence of air in them. The lacunæ contain the *bone cells.*

Blood is a kind of liquid connective tissue, for it has liquid ground substance. Mainly two kinds of cells are



Blood of Toad. Oval—Red blood corpuscle, Round and irregular—white blood corpuscles.

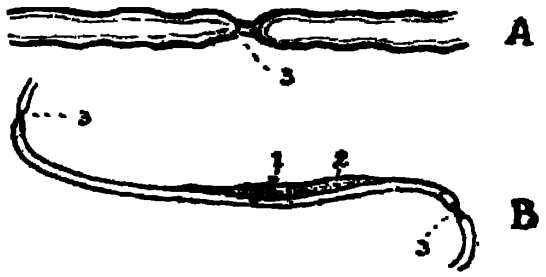
found in blood. They are called **corpuscles** e.g., *white* and *red blood corpuscles.* The white blood corpuscles play a very important part in the body because they can

devour disease producing bacteria introduced into the body of the animal. The red blood corpuscles supply nutrition to the tissues and are also carriers of a colouring matter called *Hæmoglobin* which play an important role in respiration. The liquid ground substance of the blood is called **Plasma.** Blood when shed, sets into a jelly-like substance, this is called **clotting** or **coagulation** of blood.

Nervous tissue—

The body of the animal is traversed by fine thread-like structures called **Nerves.** These nerves carry

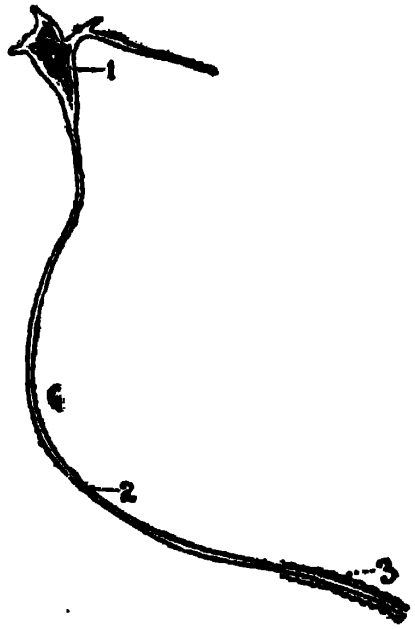
Nerve fibres.



1. Nucleus of sheath. 2. Neurolemma.
3. Node of Ranvier.

messages of the body. The nerves give us the power to discriminate the hot from the cold substance and various other sensory intelligence. Suppose a substance is hot, the feeling of hotness is carried by nerves to the brain and immediately another set of nerves coming from the brain order the part of our body to remove from the hot substance. Therefore a central station is seen *e.g.*, the **brain** which is called **the central nervous system** and there are two sets of nerves, one is **efferent** and the second is **afferent.** The sensation is carried from the outside to the brain by ***afferent*** or *sensory nerve* while

the reverse order, that is, from the brain to the tissues is by *efferent* or *motor nerve*. The nervous tissue is composed of cells or **neurons.** Each cell has a cell-body containing the **nucleus,** a long process called the **Axon** and a branching end called the **Dendron** or **dendrite.**



Nerve cell.

1. Nucleus. 2. Axon. 3. Process of medullary sheath.

The **axon** often is very long and takes the form of a **fibre.** The nervous tissue run in bundles enclosed by a sheath of connective tissue. While examining a nerve, this sheath must be torn off with needles to expose the nerve fibres.

Each nerve fibre has a central axis called **Neuraxis** or **axisfibre.** Around this, is a *sheath* called *medullary sheath* and finally covering the whole is a membrane called **neurolemma.** At intervals, nodes are produced due to the absence of medullary sheath called **Nodes of Ranvier.**

A collection of nervous tissue is known as *Ganglion* where nerve fibres and nerve cells are found.

The *brain* and *spinal cord* form the central nervous system while the nerves both efferent and afferent form the *peripheral system.*

In the autonomic-nervous system, the nerve fibres are devoid of any medullary sheath. These fibres constitute the non-medullated nerve fibres as distinguished from the medullated fibres just described.

CHAPTER III

NUTRITION AND GROWTH

The living organism takes in food or food-material for its nourishment, that process is called nutrition. The animals take their prepared food either from plants or from animals. The plants, however, have to take their food material in the form of solution through root-hairs except in the case of Fungi or in the case of insectivorous plants which live upon organic life.

The simplest animal like the Protozoa and specially the amoeba, gets hold of food through pseudopodia or false feet and then transfer them to the food vacuole for digestion. The next higher animal namely the Hydra gets hold of the food through tentacles and transfers them to the coelenteron for digestion. In the third higher group in complexity of structure namely the Leech, the food is sucked and then transferred into the alimentary canal for digestion. The freshwater prawn, the fourth higher group and almost the highest among Invertebrata, nutrition is in the form of engulfing food with the help of appendages and legs.

The vertebrata or the back-boned animals generally live upon organic food but that food must be digested with the help of certain secretions from glands like liver, pancreas etc., which make them fit to be absorbed into the blood stream to supply nourishment to the tissues of the body.

The lowest plants simply absorb water through their body and generally with the help of sunlight and chlorophyll can manufacture their food.

The fundamental difference in nutrition in the two kingdoms of animals and plants lies in the fact that the former is only capable of taking organic food whereas the latter takes in inorganic food-material. The nutrition of animals is holozoic whereas plants have holophytic mode of nourishment.

When the food has been digested, it enters into the body and supplies every living cell. In the higher animals, the nutritive material enters the blood stream and supplies different organs and tissues of the body. If there is extra amount of food after compensating the loss which always occurs in the body for the production of energy, growth takes place. Growth always occurs whenever there is extra amount of nourishment and the second factor is the healthy condition of cells.

The higher plants also grow when there is additional amount of nourishment after meeting the immediate amounts necessary for the loss undergone by the plant in the production of energy. As a matter of fact, every living cell whether it is a unicellular organism or a multicellular one, has to burn part of the protoplasm for the production of energy. Nutrition is necessary to make good this loss and the additional amount is utilised for its growth. Growth means, in the higher organism, addition of new cells manifested outwardly by increase in size.

The higher animals take the food but that food as it is, cannot be absorbed by the tissues so a detailed

process is gone through known as digestion. Digestion takes place by several stages, the first stage takes place with a juice called salivary juice secreted by salivary glands situated in the mouth. The next stage is inside the stomach, where the walls secrete a juice known as Gastric juice and the final digestion is brought about in the small intestine where juices from pancreas and liver make the food fit to be passed into the blood stream. Without entering into details, it will be useful to remember that certain chemical agents known as Enzymes help digestion but they are not themselves used up in the process.

Higher plants also have to digest before the food can be used for the welfare of the plant body.

Circulation of Nutritive Materials—

The nutritive materials enter the plants through root-hairs by a process of osmosis. Osmosis means that the substances of higher concentration always attract substances of lower concentration when separated by permeable membranes. In the case of plants by osmosis, water and dissolved inorganic substances enter the roots and by a second process called root-pressure which is generated in the roots, the water is pumped up the stem through xylem vessels. There are other factors which help the rise of water in the xylem vessels. Therefore, it is seen that the material enters and passes through the xylem vessels and finally reaches the leaves. In the leaves, the manufacture of organic food takes place. When the organic food is prepared, the easily available form is sugar; this sugar immediately passes through

another set of tissue called phloem. Therefore in the plants, there is extreme specialisation regarding the path for food-material and food. The phloem carries the food generally in the form of sugar to parts where there is immediate necessity. The extra amount of food is stored up inside the plant for future use in the form of starch.

The lower plants like Spirogyra absorb nutrition through their surface and as they live in water, dissolved substances have easy access to their cells.

The fungi which are either parasitic or saprophytic, absorb nourishment through mycelium. As the fungi can live only upon organic matter, the process of absorption is direct and that serves as food.

The higher animals take the food through the mouth, after a brief process of chewing or mastication when salivary juice mixes with the food, it passes into the stomach. In herbivorous animals, the digestion is delayed in the stomach, because in some animals, the stomach has several chambers. When the animal first takes its food, it passes into the first chamber, then it is again brought to the mouth for chewing when the animal feels leisurely and finally it is passed into the other chamber to be transferred to the intestine. The first part of intestine namely the small intestine not only carries out the remaining process of digestion but the actual absorption into the bloodstream takes place in this part. The residue mainly consisting of waste products pass out through the large intestine to the outside world in the form of faeces. The carnivorous animals have the process of digestion much simplified and it begins in the mouth, continues in the stomach and finally sent into the small intestine where juices come from glands like

liver, pancreas and nourishment is sent to the blood. The lower animals like protozoa have nourishment from the surface and with the help of food-vacuole digest them. In Hydra, there is only one aperture through which food enters the coelenteron where digestion takes place. The leech takes nutrition in the form of blood and gradually digest drop by drop which may last for one year *i.e.*, one meal may be digested in one year. The prawn has digestive glands and alimentary tube which may be compared to digestion of higher animals although not so specialised.

Respiration—

Respiration means the interchange of CO_2 (carbon dioxide) for oxygen, in other words, the taking in of oxygen and giving out of carbon dioxide. The animals and plants always undergo some loss in the form of oxidation. The protoplasm is undergoing combustion to produce energy. This process of combustion occurs both in animals and plants. It essentially consists in the use of oxygen by tissues and the resultant production of carbon dioxide which must be eliminated. This process is responsible for the production of energy which gives the power to work.

The higher animals like man, tiger, guineapig etc. respire through special organs, called the lungs. Air enters through the nostrils, passes to the back of the mouth, enters the glottis and thence to larynx and trachea and finally makes its way inside the lungs. The lungs have fine blood-vessels in the form of capillaries which absorb oxygen and eliminate CO_2. The impure blood with CO_2 is brought to the lungs from the heart and the impure

blood after purification again passes into the heart. The result of oxidative processes in the body is the gaseous substance CO_2, which acts as poison to the body, therefore the sooner it is got rid of, the better for the animal. The toad or frog in the adult stage respires through the lungs.

The fish has a peculiar method of respiration. The gills are the organs for respiration, here the current of water brings with it, the dissolved oxygen that is passed through the gills where there are capillaries to absorb it and give out CO_2 from the blood which is circulating inside them.

The simple animals like protozoa, give out CO_2 through their surface. The prawn have gills which eliminate CO_2 to the outgoing current of water.

The plants also respire, CO_2 is given out and oxygen is taken in. In the higher plants, there is no such organ as the lungs but there are minute apertures on the leaves called stomata which perform the function of respiratory organ. Ordinarily, oxygen is taken in from the air and CO_2 is given out through the stomata. The process takes place day and night. The plants have a simultaneous process of photosynthesis which takes place at the day time only. Photosynthesis requires the presence of CO_2 which enters the plant-body through stomata. The association of plants is healthy for all animals in the day time because free oxygen is evolved due to this process of photosynthesis. There are some plants which can respire in the absence of atmospheric oxygen, their oxygen is derived by the disintegration of tissues, such plants are called anaerobic plants. There are other plants which can respire only in the presence of oxygen, they are called aerobes.

The anaerobic plants are yeasts while almost all plants are aerobic.

Experiment to show that plant respires.

A glass flask is filled with florets of sunflower and all green parts are rejected and some cotton wool supports the florets when the flask is inverted and fixed to a stand. The flask has also some sticks of caustic potash. The flask has a perforated rubber cork. The cork is sealed with the flask with paraffin wax so that no air can enter the flask. Through the perforation of the cork, a glass pipe of narrow bore passes into a dish of mercury at one end and the other end is inside the flask. The pipe is properly sealed with cork so that the apparatus is absolutely air-tight. After some 5 to 6 hours, the mercury rises in the tube. The significance is that the florets have respired and the CO_2 which is set free, is absorbed by the caustic sticks so that a diminution in volume of gas has occurred within the flask and as a result of that, mercury has risen inside the tube. This proves that respiration has taken place.

Excretion—

Animals and plants do not require all the substances introduced in their body. So everything which is useless to the organism must be eliminated which is known as **excretion.** Anything which is useless to the organism and has to be got rid of, is excretion. The higher animals take a large amount of food but the waste products which are not required for the body are rejected as faeces or excreta. The higher animals including fish, toad, reptile,

birds and mammals have a definite excretory system. The blood stream carries the waste products of the body derived as a result of metabolism in the tissues which pass out as gas from lungs or gills as the case may be, in the form of CO_2. On the other hand, the blood is filtered and the nitrogenous waste products dissolved in water, pass out from the kidney through a passage called ureter. Therefore the kidney acts as a filter and the waste products pass out in the form of urine.

Another example of the way by which excretory products are eliminated is through the pores of the skin. The perspiration takes away the waste products but at the same time, it has a beneficial effect namely the skin is kept moist and is prevented from breaking down.

The lowest animal like amoeba has a contractile vacuole by which excretory products are eliminated.

Hydra has to eliminate through any part of their surface. The leech has pairs of nephridia segmentally arranged for the discharge of waste-products. The prawn has a definite excretory system which has their openings at the base of antennae.

The plants have generally no definite excretory system but in the higher plants, excretory products are generally stored up in the cortical region of the stem. In the plants, where bark is formed, the falling off of the bark, takes away the excretory products stored up in that dead tissue.

Sometimes the plants utilise the excretory products as a means of protection from the attack of animals. The animals once they feel the unwholesome smell will never turn their attention to such plants.

In conclusion, it should be remembered that the excretion is a product derived from the organism as a result of destructive metabolism generally.

Secretion—

The organism has to give out something either through some organs or tissues to carry out some function *i.e.*, anything which is given out for the benefit of the organism is **secretion.** Secretion differs from excretion in that, the former is beneficial whereas the latter is nothing but waste product.

The higher animals including man, have various secretory organs. Inside the mouth, whenever food is taken in, a juice comes out which is a secretion of the salivary glands. In the stomach, there are glands which secrete gastric juice which helps digestion. The pancreas also secretes a juice for helping digestion. These juices either run directly or through definite passages to mix up with the food to help digestion. But there are some, secretions from glands which have no so-called passage. These organs are known as endocrine glands. The thyroid, thymus, suprarenal, pituitary, spleen are examples of endocrine glands. The secretion from these organs simply mixes with the blood-stream and performs some of the most important functions of the body.

In conclusion, there are chemical agents called Enzymes which are always associated with the secretion which helps digestion. These enzymes do not themselves take part in the chemical reactions of the body. Thus there are fat-splitting enzymes which make fatty food fit for digestion and absorption.

The plants also secrete through cells to help digestion. There are some glands namely honey secreting glands in flowers which help the plant in pollination. In the case of fern and moss, definite chemical substances are secreted by the archegonium to bring about fertilisation. The cellulose wall of plant cells is a result of secretion of protopasm.

Storage of Reserve Material in Animals and Plants—

The living organism shows a foresight as it were, for the storage of food for future use. The animals store up food in their tissues; if for any reason, the supply of food is stopped or hindered. The commonest form of storage in the higher animals is Glycogen which is stored up in the liver for future use. The toad stores up glycogen in summer and leisurely uses them in winter. The other form of storage is fat which is also kept in reserve in the subcutaneous tissue and mesentery. The snakes store up, a large amount of fat under the skin for use in their hibernating period. The fat bodies found within the toad are also storage products.

Thus the form of glycogen and fat are the storage products in animals. Glycogen is similar to starch but more easily convertible into sugar.

Plants store up food either in their underground stems *e.g.* Tuber, Corm, Bulb or in their roots *e.g.* Sweetpotato. The form of storage is a variety of starch, protein and fat. Plants store up food in their seeds, which may be exalbuminous or albuminous, but human beings make use of such storage and turn them to their own use, thus robbing nature and making the plants less plentiful on the face of earth. The eggs of birds store up food in

the form of yolk and albumin, is an instance where storage is found for the nourishment of the would-be developing embryo in animals.

Photosynthesis—

The word is derived from Photos meaning "light" and synthesis "to prepare." Photosynthesis means the preparation of organic food in the leaves with the help of chlorophyll and sunlight. The requisites for photosynthesis are sunlight, chlorophyll, carbon dioxide and water. Therefore photosynthesis can only take place in the chloroplastids which are always associated with green leaves. The carbon dioxide is supplied by the atmosphere and enters the leaves through the stomata. The water and inorganic substances come from the roots to the leaves. Therefore the leaf is the laboratory where organic substances are manufactured. The mesophyll of the leaves is richly supplied with cells containing chloroplastids and there is spongy parenchyma having plenty of intercellular spaces. The CO_2 of air enters through stomata and combines with the water which fill up the spaces of the mesophyll. The CO_2 readily combines with water forming an organic compound called formaldehyde and there is evolution of oxygen according to the equation :—

$$CO_2 + H_2O = CH_2O + O_2$$

carbon dioxide Water Formaldehyde + Oxygen.

The formaldehyde immediately forms a combination of 6 molecules and Sugar is formed according to the equation :—

$$6(CH_2O) = C_6H_{12}O_6$$

Formaldehyde Sugar.

This sugar loses a molecule of water and forms starch which is known as assimilatory starch.

$C_6H_{12}O_6$	—	H_2O	=	$C_6H_{10}O_5$
Sugar		Water		Starch

Whenever active growth is taking place, the starch is reconverted into sugar and supplies nourishment. The additional amount of sugar *i.e.* the amount that is not necessary for immediate use is stored up as starch and is known as **Reserved Starch.**

The chemical processes involved in the manufacture of the simple carbohydrates from the raw materials, carbon-dioxide and water, is a matter of great controversy. The process really consists of (1) a photochemical action, hence light is necessary; (2) a chemical action.

In 1843, Liebig suggested that there were several intermediate stages. In 1861, Butlerow gave a good hypothesis for the production of carbohydrates.

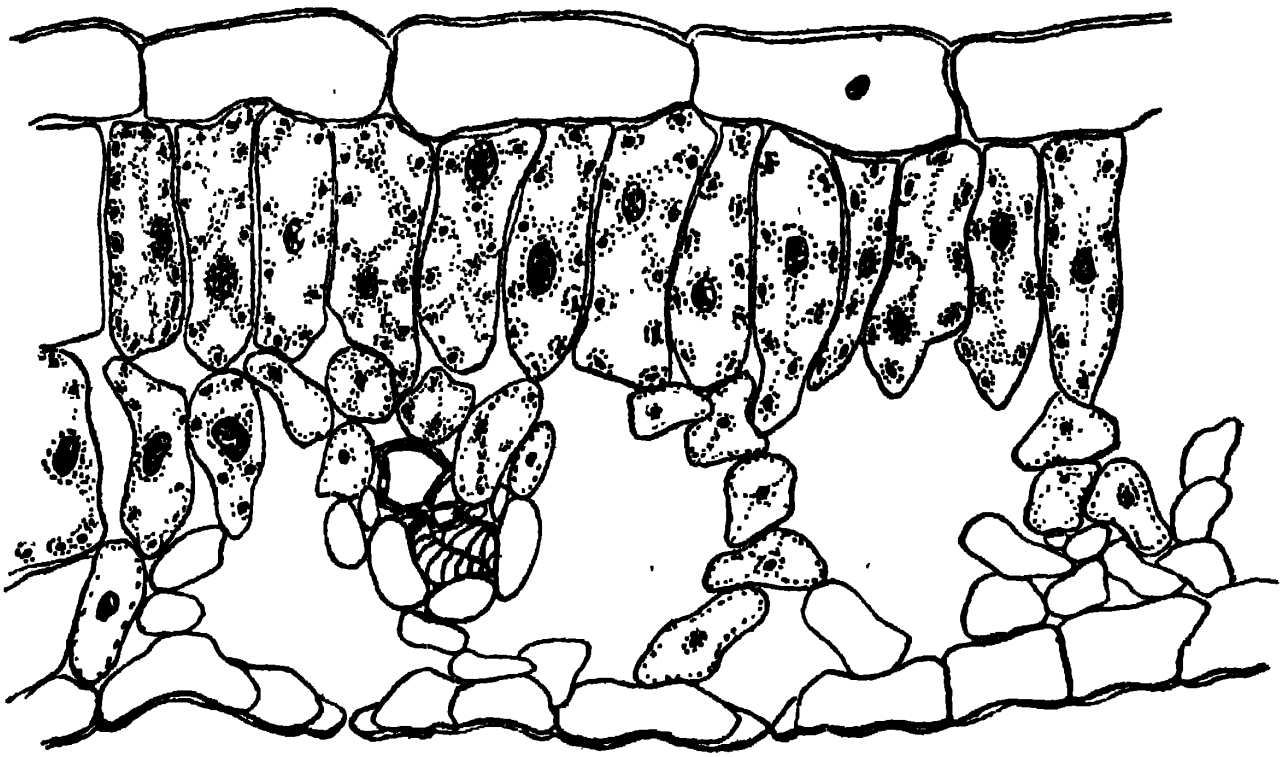
In 1870, Baeyer developed the observation into a theory of photosynthesis.

In 1918, Willstatter and Stoll postulated the hypothesis which includes the production of formaldehyde.

Experiment to show that Oxygen is given out during the process of Photosynthesis.

Take a glass beaker and place a number of the pondweed called Hydrilla in it with water. Cover the plants with an inverted funnel and take a test-tube after filling it with water. Close the mouth of the test-tube with thumb and place it on the funnel. Place the apparatus in bright sunlight. Bubbles are given off periodically from the cut ends of the weeds and gradually

the water of the test-tube is replaced by a gas.. Remove the test-tube and test the gas with a glowing splinter. The gas proves to be oxygen being a supporter of combustion.



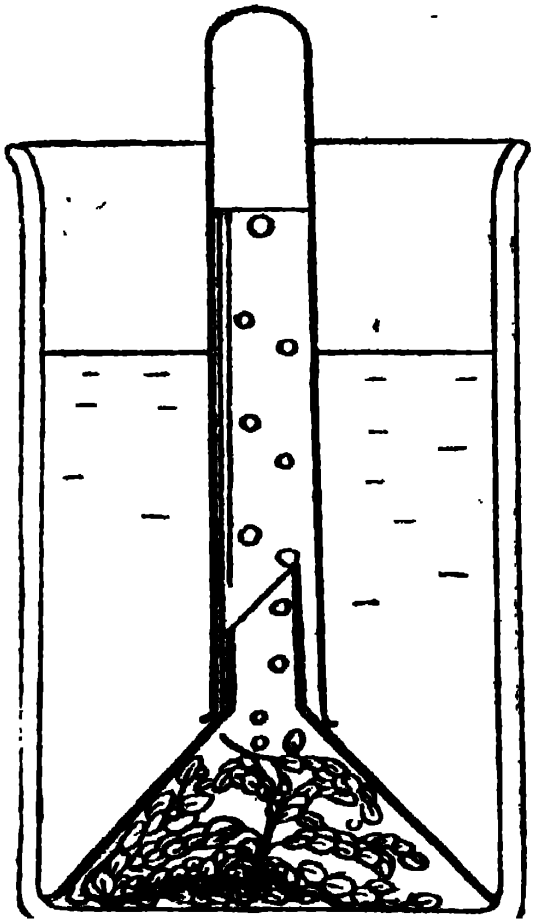
Section of green leaf showing chloroplasts in Mesophyll.

Normally, there is sufficient CO_2 in water and during photosynthesis, this gas is used up and O_2 is evolved.

Control experiment.

Set up another similar apparatus but boil the water before putting the water in the beaker. Cool it and put the plants and arrange like the previous experiment. The water in the test-tube should also be boiled and cooled. Place the apparatus in sunlight but no bubbles arise because by previous boiling all the dissolved CO_2 has been removed and so there is no evolution of oxygen as in the absence of CO_2, no organic matter is produced.

Take a green leaf which was exposed to sunlight. Wash it with warm alcohol to drive out chlorophyll. Then wash it with water and dip it in iodine solution. It turns blue showing the presence of starch. This proves that starch is manufactured by green plants during photosynthesis.



Experiment to Show evolution of oxygen during photosynthesis.

If the leaf was partly covered during its exposure to sunlight then the covered parts will not turn blue when placed in Iodine solution showing that the exposed parts are only able to manufacture starch which turn blue.

Comparison between Respiration and Photosynthesis.

	Respiration.		Photosynthesis.
	Takes place in all living cells.	1.	Takes place in cells containing chlorophyll.
2.	Raw materials are oxygen and food-stuffs.	2.	Raw materials are water and carbon dioxide.
3.	Takes place day and night.	3.	Takes place in day-time.
4.	Energy-releasing process.	4.	Energy absorbing process.
5.	Products are water and CO_2.	5.	Products are oxygen and food-stuffs.
6.	By this process, plant loses in weight.	6.	By this process, the plant gains in weight.
7.	It is a catabolic process.	7.	It is an anabolic process.

CHAPTER IV

STIMULUS AND RESPONSE IN PLANTS AND ANIMALS

The living protoplasm either in the animal or in the plant is capable of answering to any external change created in the form of stimulus. The protoplasm is said to respond to the stimulus. It is one of the characteristics of all living organisms. If the external conditions change also—the protoplasm is said to be sensitive. Thus in a dark room, a pot plant is placed and light is allowed to pass through a hole. The stem will try to move towards the source of light. The stem and leaves respond to the stimulus of light. If some algae be placed in water and at the bottom of the vessel, a light is placed, the plant will move towards the light.

The action of gravitation of the earth is manifested in the downward movement of the root. The root is sensitive to the stimulus of gravitation and moves towards the centre of the earth.

The stems of plants often turn towards the sun and this sensitiveness is known as heliotropism. The stem is called positively heliotropic while the root which moves away from the sun is known as negatively heliotropic.

The secretion of a chemical substance like Malic acid in the archegonium of fern acts as a stimulus and the antherozoids respond to it.

The more pronounced cases in plants is the stimulus of touch in the Telegraph plant (Bonchandal) which at

once dances and closes the leaflets as a result of such stimulus. In some plants, the leaves and flowers open with the rise of the sun, *i.e.* they are capable of answering to the stimulus of light and in the evening the leaves and flowers close down. Some flowers like "Krishnakali," Tuberose (Rajanigandha) on the other hand, open only in the evening.

Some insectivorous plants like Drosera and Nepenthes are capable of secreting substances when insects touch their bodies.

Sir J. C. Bose has shown by his researches that the plants are capable of answering to stimuli and as a matter of fact, he has invented a delicate needle by which he injects stimulants and poisons into the tissues of the plant. He has recorded the effects of stimulants and has shown that the plant tissues can be stimulated like the animals. The effects of poisons had been a lowering of the life processes ultimately resulting in the death of the plant.

Therefore plants can and do respond to stimuli.

The animals show a variety of response to stimuli. The lowest animal like amœba, sends out its pseudopodia when it receives the stimulus of food-particle.

The Hydra, when it meets its prey sends out its wire from cnidoblast cells.

The Leech can respond to stimuli and has got a rudimentary nervous system.

The freshwater prawn has got a special balancing organ at the base of 1st antennule.

The higher animals can respond very well. If the leg-muscle of toad be dissected out with its nerve and

a mild electric current is passed, it will respond by a series of movements which can be recorded.

There are some bats (Chiroptera) which are too sensitive to light. They can see only at night-fall and pass the daytime in hanging from trees like dead creatures.

The human body is sensitive to heat, cold and electric shocks. Drugs that are stimulants can stimulate animals whereas poisons can kill animals.

Movements in Plants and Animals—

The animals as already stated can move without any restriction but plants are more or less restricted in their movements.

The simplest amœba can move by pseudopodia. The Hydra can swim. The leech has looping movement and can freely swim in water. The prawn can swim and jump in water. The insects which are provided with wings are capable of moving for miles. The fish can swim indefinitely in water. The toad can move on land as well as swim in water and from their habitat both in land and water, they are called Amphibians. The mammals have their legs developed almost to a degree of perfection. The modern horse has got its limb specialised for movement. The birds generally are endowed with the highest form of movement for which their forelimbs have been modified into wings.

In the case of plants, movements are divisible into two sections :—

(*a*) **Taxism** and (*b*) **Tropism.**

Taxism means the movement of the whole organism. Sometimes plants mainly unicellular move bodily either

away or towards the source of stimulus. When chemical agents act for such stimulus, they are called chemotaxis *e.g.*, the movement of antherozoid towards the secreted malic acid of archegonium ; Phototaxis, is the movement of the organism towards the source of light. All algae show phototaxis, these are attracted by weak light but move away from strong light. There are certain movements which are known as Autonomic *i.e.*, they occur from within, such as the movement of young leaves and other growth movements.

Tropism—

Tropic movement means the movement of a part of the plant and is induced *i.e.* caused by some stimulus. The various tropic movements are :—

(1) **Heliotropism,** (2) **Geotropism,** (3) **Hydrotropism** and (4) **Chemotropism.**

Heliotropism—

The stems of plants move towards sunlight whereas the roots grow away from light. The former is called positively heliotropic while the latter is called negatively heliotropic.

Geotropism—

The movement of roots towards the gravitation of earth is called Geotropic movement. The root grows towards the earth and is called positively geotropic. The stem grows away from the earth and is called negatively geotropic. If by any contrivance, the action of gravity is eliminated, the plants grow quite independent of this factor *i.e.*, the root does not go down and the

stem does not go up. This can be manifested with the help of two instruments called Knight's wheel and Clinostat.

Hydrotropism—

This means the movement of parts of plants towards moisture or water. The root moves towards moisture and is called positively hydrotropic whereas the stem is negatively hydrotropic because it avoids moisture or water.

Chemotropism—

The movement due to chemical substances is known as chemotropism. The roots in such adverse situations like water-logged areas move towards the air for oxygen. The movement of pollen-tube towards the ovule by means of sugary solution is another example.

Nervous mechanism in Animals—

The animals have a very well organised system called the nervous system. It consists of a central station called the Brain which gains in complexity of structure as the animals evolve from lower to higher status. The highest development is attained by man, whose seat of intelligence in the brain has far surpassed that of any other animal. The central nervous system includes the Brain and the Spinal Cord. There is another system called the Peripheral system which includes the afferent and efferent nerves. The afferent nerves carry messages of the outside world to the brain which orders through the efferent system. The nerves are thread-like structures which ramify all over the body. The nervous system is

peculiar in this respect that they have got the power of regeneration *i.e.*, parts which are cut off are capable of growing into new ones. The brain usually consists of two olfactory lobes, two cerebral hemispheres, two or four optic lobes, cerebellum and medulla oblongata. The medulla oblongata is continued as the spinal cord. The spinal cord runs through a bony column called vertebral column and the brain is protected by a bony structure called the Cranium which contains it.

The lower animals like the Prawn have also a nervous system consisting of Cerebral ganglia, thoracic ganglia and a double ventral nerve cord. The different portions of the body are supplied by branches from one or other of these ganglia. The leech has also a similar nervous system. The Hydra has some special cells called nerve cells but no such system.

The animals by their nervous mechanism control the different organs and functions of the body.

CHAPTER V

CHEMICAL CO-ORDINATION

There are various chemical actions in the body of the animal or plant which are kept in due order and which go by the name of chemical co-ordination. The chemical actions are in harmony *i.e.*, one is controlled by the other and there is not much or less of any activity. Thus there is a secretion in the mouth which is called saliva. In the stomach, there is the secretion of Gastric juice in which there is free hydrochloric acid. These secretions are never more or less in the healthy animal. The glands like Liver and Pancreas also secrete chemical substances which help digestion. There are certain glands which also secrete and help the animal to discharge its function. There are certain substances produced as a result of various chemical activities of the body, some of them are useful while others are mere waste products. Useful substances which in any way help to perform the bodily functions are known as **Secretions** while the waste products are known as **Excretions.** The gastric juice of stomach is an example of secretion while urine is an example of excretion.

The body of the animal is always undergoing some decay. The first and foremost of this chemical process is respiration. During respiration, a part of protoplasm combines with oxygen and liberates energy for the animal. Such a process of oxidation is really a process of combustion. It may be compared with the supply of fuel to the engine; the engine is the body and bodily

protoplasm is the fuel. The loss of protoplasm is always compensated by a fresh supply of nutrition from the blood stream. While respiration goes on in the tissues, certain waste products are produced which are eliminated through different channels. The CO_2 is the most largely produced gaseous substance which readily dissolves in the blood and is carried by the venous blood to the lungs in the case of higher animals like the mammals, reptiles, birds, toads etc. to be exchanged for the atmospheric oxygen which again finds its way into the tissues through arterial blood. The fish has a different method of exchange namely they pass the CO_2 and absorb oxygen through their gills and the current of water which has dissolved in it these gases, supplies them with the necessary amount of oxygen and the outgoing current takes away the CO_2. Accumulation of too much CO_2 is poisonous for the animal as is exemplified by the process of suffocation felt when a large number of people are confined in small ill ventilated rooms or by people when they lie down in perfectly closed rooms for a period. They might die on account of excess of CO_2 and absence of atmospheric oxygen. Thus animals produce their poisons which must be eliminated from their bodies.

Chemical substances in the form of waste products might go out through the skin in the form of perspiration. The hibernating animals like the snake or toad can exchange oxygen for carbon dioxide through the skin. Respiration is the process which takes place in animals throughout their lives. Even in the foetus or in the embryonic condition while animals are still placed inside the mother, the exchange of gases takes place through the blood-vessels of the placenta. A very illuminating

example is found inside the eggs of birds where the embryo develops. The eggs have spaces within the shells filled with oxygen meant for the developing embryo.

While the animals have constructive chemical secretions inside the various parts of the alimentary tube which make the food fit for the nourishment of the tissues. This is known as Anabolism. Side by side, there is destructive process mainly in the form of respiration by which CO_2 is produced. The balance is kept up by the supply of food. The extra amount of food is stored up in animals in the form of fat or glycogen in the Liver. Besides the above chemical processes, there are other chemical reactions in the body namely the formation of urine by which water and dissolved waste products in the form of urea and uric acid and salts go away from the body.

There are certain important chemical substances in the body which keep up the chemical balance. These are called Vitamins. The vitamins are necessary for the welfare of the body and are found in foodstuffs. Adulterated or decomposed food lose the vitamins and consumption of such substances is prejudicial to the body. The prevalence of Beri-beri is due to the absence of vitamins in our food. Fresh fruits, fresh vegetables, fresh fish and fresh meat, all abound in vitamins. Besides the vitamins, there are certain chemical agents in the blood of animals called Hormones, which regulate the various chemical actions of the body. These hormones also regulate the development and growth of animals.

The food of animals, consists of starch, sugar, fat, protein etc. There are chemical agents known as

Enzymes which help to split the above mentioned types of food and make them fit for digestion. These enzymes are very peculiar in that they do not take part in the chemical reactions but only help in the process. These are found both in animals and plants. Plants have a further complicated type of chemical action. They take in raw food materials from the soil which come up to the leaf through the xylem vessels and then the chemical reactions take place by which the CO_2, combines with water, in the presence of sunlight and chlorophyll. This chemical reaction liberates free oxygen and takes in CO_2. In water-plants too, this process of photo-synthesis is not wanting and we find the following chemical reaction taking place in the body of the plant :—

$$CO_2 + H_2O = CH_2O + O_2$$
(Formaladehyde)

$$6(CH_2O) = C_6H_{12}O_6$$
(Sugar)

$$C_6H_{12}O_6 - H_2O = C_6H_{10}O_5$$
(Starch)

As a result of photosynthesis, firstly formadehyde is produced which afterwards forms a compound called sugar. This sugar loses one molecule of water and forms starch.

There is another process namely respiration which takes place in plants both day and night. This consumes a considerable amount of plant protoplasm, supplying it with energy and liberating CO_2. In water-plants, the CO_2 is passed into the water. Plants also liberate various forms of etherial oils and odourous substances through their leaves, stems and flowers. They have no definite

system for the passage of excretory products which are generally stored up in the outer parts and with their fall namely the fall of the Bark, the waste products are got rid of. Thus the living cells carry out the various chemical reactions of the body and their absorption, secretion and elimination depend upon the activity of the protoplasm. These changes are in harmony so that all the reactions are carried on in definite order and contribute to the due discharge of the different functions of both the plant and the animal economy.

CHAPTER VI.

REPRODUCTION.

Reproduction is a process by which new individuals are produced from already existing ones. The plants and animals reproduce in order to leave representatives in the world as all plants and animals after a period of growth must die. There are various processes of reproduction. A dog gives rise to a pup or pups, the method of producing a new pup is called reproduction. A plant flowers, the flowers develop into fruits and the fruits contain within them the seeds. The seeds on falling to the ground can give rise to a new plant. This is called reproduction. Principal methods of reproduction are asexual and sexual. The former takes place without the intervention of sex and the latter through sex.

The plants have all the principal methods of reproduction :—

Asexual method of reproduction is again sub-divided into, (*a*) Vegetative, (*b*) Asexual reproduction by spores. It occurs mostly in lower plants.

Reproduction—

Vegetative reproduction takes place by a separation of some vegetative part as by cutting, grafting, underground and creeping stems, adventitious buds etc. Vegetative structure means either root, stem or leaf. This method of reproduction is artificially used by agriculturists in the propagation of plants. The commonest example of vegetative reproduction is by cutting, grafting

or layering of plants. The stem of rose is cut and added to a plant from which the upper portion has been removed. The rose plant develops into another plant. In the case of "Jaba," "Sajina" or Croton another plant is developed from a cutting of the parent plant. The rose also furnishes an example of layering, when a branch is bent and made to touch the soil, after a number of days, the point so fixed produces roots and is cut off from the main plant to lead an independent life. The roots of Patal (Trichosanthes) can produce other plants. Mango is generally cutivated by cuttings and graftings. The lower plants like the yeast reproduce by budding. The plant spirogyra vegetatively reproduces by separating a part of the filament. Mucor vegetatively reproduces in sugar solution by the production of oidium cells.

Asexual reproduction mostly takes place by the production of unicellular structures called spores without any sexual fusion. The Moss plant produces spores inside the capsule, each spore is capable of producing protonema on which the moss plant arises as a bud. The Fern plant produces spores on the under surface of its leaves. Each spore on germination can produce a Prothallus.

In some Algæ naked cells called Zoospores are produced which are meant for asexual reproduction.

In Mucor, asexual spores are produced within Gonidangium.

Sexual Reproduction—

This essentially consists in the production and union of two cells called Gametes. These Gametes are some-

times differentiated into male Gamete or Antherozoid and female Gamete or Osphere or Ovum.

When the gametes are similar the process of fusion is called conjugation and the cell produced after fusion is called Zygospore. When the gametes are dissimilar the result of union of Antherozoid with Oosphere is called Oospore. The process is called Fertilisation. There is a common term by which both the fusions can be denoted and that is Zygote. Zygote is the common name both for oospore and Zygospore. Fertilisation occurs in all higher plants, *e.g.*, in the flowering plants like Mango, Rose, Banyan, Pea, Maize &c., and in Fern, Moss. In the plants like Rose, Mango, etc., the male elements are inside the stamen in the form of pollen grains which germinate and produce gametes while the female element is contained within the ovule of the ovary.

The process of conjugation is found in the Mucor and Spirogyra.

Animals show the higher forms of reproduction and unlike plants sexual method is the universal method with the exception of cerain lower form of animals.

The essence of every act of reproduction is the origin, by the fission from the body of an organism of a reproductive body which will develop a young, the likeness of the parent. Sexual reproduction entails the union of the gametes whereas asexual reproduction is the production of a new individual without the union of the gametes.

In Hydra asexual reproduction takes place by the development of a multicellular bud which separates and forms a new Hydra. Thus reproduction by budding takes

place in Hydra. Sexual reproduction also takes place in Hydra which essentially consists in the separation of two germs, *viz.*, ova and spermatozoa. The former is the female element while the latter is the male element. By their combination a new individual is produced.

In the Amœba, the asexual reproduction is the general rule and takes place by binary fission or division into two new individuals without any sexual congress. The Monocystis shows sexual conjugation and asexual formation of sporozoites in its life-history.

The Leech is an animal where male and female organs known as Testes and Ovary are found in the same individual. Consequently the animal is called a Hermaphrodite animal. The Prawn is a specialised animal having the sexes separate *i.e.*, unisexual but the peculiarity is that the openings of the sexual organs lie at the base of the third and fifth legs.

The vertebrates including Fish, Toad, and Guineapig have male and female animals separate. They have sexual Gonads which develop into Testes and Ovaries ultimately producing at maturity sperms and ova. These suitably unite and gradually form the young animal. As regards asexual reproduction, a solitary example can be cited in the Lower Chordata called Ascidians. The Ascidians might reproduce asexually by buds.

The Higher Invertebrates have asexual reproduction as in the insects where majority of animals are produced asexually in the form of workers. Sexual reproduction occurs but rarely.

In conclusion, the merits of sexual reproduction are far higher than those of asexual reproduction. In sexual

reproduction the newly formed individual is more strong and better adapted for the world whereas asexual reproduction generally impairs the strength of the successive generations and makes them unfit for the world. Asexual Reproduction is a simple process and there is no specialised tissue for it. Sexual Reproduction has many failures and it is rather a complicated process. Sexual Reproduction completely replaces Asexual Reproduction in the higher animals because the tissues become specialised and are not able to produce new individuals from any and every part of the body. The puzzle of asexual reproduction lies in the case of ants, wasps and bees. The eggs of these social insects are unique in the animal kingdom, for they will develop equally well whether fertilised or not; they can be parthenogenetic but don't need to be so

Unfertilised eggs always turn into males, and fertilised eggs into females. Whether an egg is to be fertilised or not, is controlled by the Queen as she lays it. The Queen in the Bees, Wasps and Ants mates only once in her life-time during her "nuptial flight." The Queen stores up the sperms and controls its flow by a sphincter muscle. If she desires, the muscle is relaxed and while passing down the oviduct, the egg receives some sperms and one of them fertilises it and the individual becomes a female while the majority are males as they are unfertilised and no fertilisation takes place in their case but they develop into males.

Parthenogenesis—

Some animals and plants develop gametes but the fusion does not take place. Generally the female gamete develops and behaves like the structure produced after

conjugation. Parthenogenesis is a degenerate process and occurs in lower organisms. In the Spirogyra the gamete may develop parthenogenetically and behaves like a Zygospore. In the higher plants Parthenogenesis is rare and it is said that the jack-fruit is sometimes produced parthenogenetically under the soil and by the odour the fruit is detected under the soil.

The animals show Parthenogenesis in such types as the Ants. The individuals, namely the workers, are produced parthenogenetically. The nature of the gamete from which the parthenogenetic individual develops is an ovum. This occurs in various crustaceans (Prawn group) insects and worms. The female in the Green fly or in the Liver fluke reproduces for several generations without the assistance of the male. In certain Rotifers and Waterfleas fertilisation has never been observed. Parthenogenesis is a double process since the gamete is sexual but there is no fertilisation or conjugation; therefore it is asexual.

Alternation of Generations—

Some animals and plants show two distinct stages in their life-history. The asexual form is generally alternated with the sexual form. This alternation of asexual and sexual form is known as the phenomenon of "Alternation of Generations." The lower plants generally do not show any alteration of generations. In the Moss plant the plant itself is the gametophyte and the sporophyte develops as a sporogonium upon it. Here the sporophyte is dependent upon the gametophyte but nevertheless there is alternation of the two generations *i.e.*, between two gametophytes the sporophyte is introduced. The Fern

shows alternation of two generations, the plant itself is the sporophyte and the gametophyte is in the form of Prothallus. Thus the two generations are independent of each other. The asexual generation is the sporophyte producing spores whereas the sexual generation is the prothallus producing the gametes. In the higher plants like Rose, Pea, and Maize, the plants represent the sporophyte stage while the gametophyte is much reduced and is found after the germination of the pollen grain or in the formation of embryo-sac within the ovule. The higher plants have a prominent sporophyte and an inconspicuous gametophyte.

Thus alternation of generations is a constant feature of the higher plants i.e., the sporophyte alternates with the gametophyte.

The animals do not generally show such alternation as almost all the higher animals are sexual individuals. The exception is found in the Hydra and a related animal of the same group called Obelia. In Obelia the animal has an asexual form called the Polyp which produces two kinds of buds one gives rise to another polyp while the other form of bud is called the Medusa-bud which gives rise to free-living sexual individuals called Medusæ. This Medusa produces sexes in the form of male and female gonads in separate individuals. Thus in obelia there is distinct alternation of asexual or polyp form with the sexual or medusa form.

In Monocystis there are some authors who state that there is some sort of alternation of generations. The gametocyte represents the sexual and the sporozoite represents the asexual form. In the Malarial Parasite,

the asexual and sexual forms have been correlated to be of the nature of alternation of generations.

Thus both in animals and plants there is the occurrence of the phenomena of alternation of generations although it is more pronounced in the case of plants than in animals.

CHAPTER VII

THE FORMATION OF THE EMBRYO IN THE FOWL

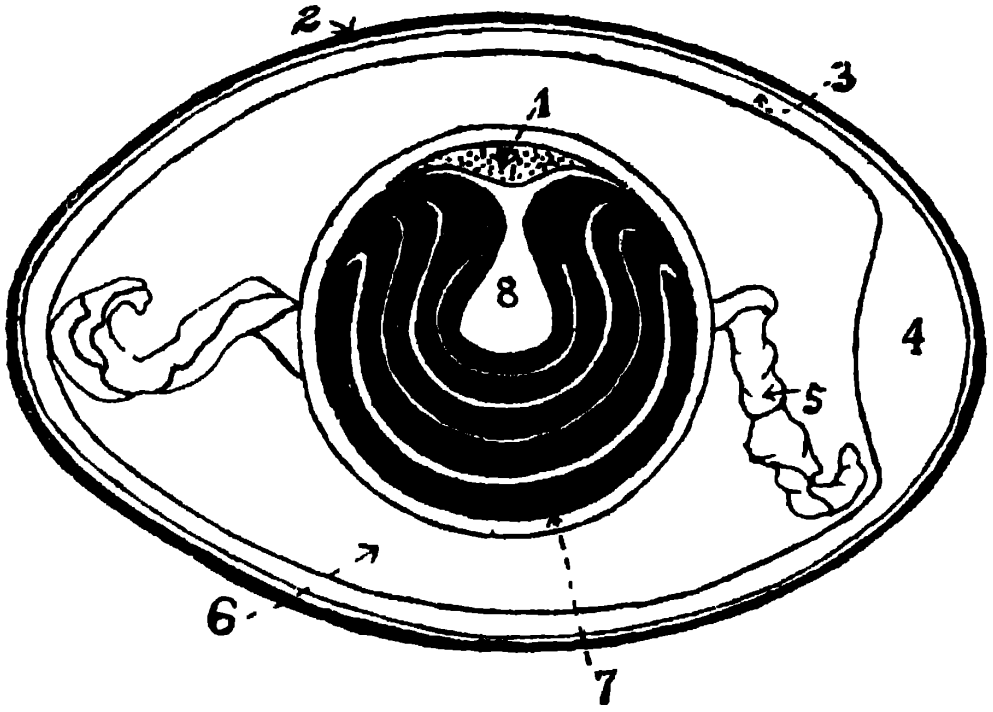
It is known that the hen lays eggs from time to time. There are two types of eggs and generally those of the market are unfertilised and some are fertilised. The ovum is discharged from the ovary and while the female gamete comes through the oviduct, it receives the coating of yolk and albumin. The fertilised hen's egg is developed by the union of the "mature" egg (the egg-cell after attaining its full size and forming its polar cells by unequal division) and the "mature" spermatozoon—*i.e.*, one of the male gametes formed by the final equal division and differentiation of a sperm-mother-cell. These sexual cells are called gametes and when the two opposite (male and female) gametes unite, they form a zygote.

All the ova of the hen are produced from the left ovary. The right ovary and oviduct disappear early in life. "Good layers" produce 100 eggs or more in a season.

1. Cleavage or segmentation of the Egg—

Cleavage is the process by which the zygote becomes divided into cells. The first few generations of cells are called **blastomeres.** The egg of a bird consists of cytoplasm distended very greatly by concentric layers of white and yellow yolk, except for a small area where the nucleus lies. This is seen as a white disc when seen from above and is known as the "germinal disc." The "germinal disc" gives rise to the greater part of the bird. The early cleavage begins in this area when the egg moves down the oviduct and is completed by the time the egg is laid. Firstly, two furrows appear at right angles to each other. Four radial fissures then appear about midway between the former furrows. In this way, the surface of the disc is converted into a mosaic of small polygonal areas, bounded peripherally by larger irregular divisions which form the **germ-wall.** The cleavage of the hen's egg is partial or **meroblastic** owing to the great mass of egg-yolk. The layer of the surface becomes double and the disc is then known as the **blastoderm.** At or about this time the egg is laid.

The egg of a fowl is more or less oval, the yolk is of immense size due to the deposit of a larger quantity of nutritive material and the germinal disc is pushed to one side. The ovum is covered by the Vitelline membrane. Then the white of egg or allumen surrounds the



1. Germinaldisc,
2. Shell,
3. Double membranes,
4. Air space,
5. Chalaza,
6. Albumen,
7. Yolk,
8. White Yolk.

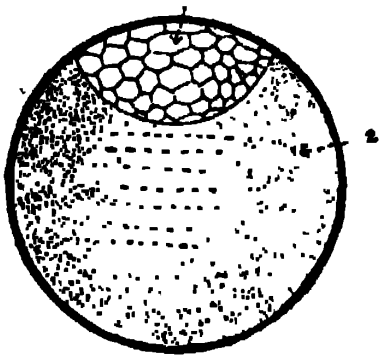
large ovum. The white portion consists of a solution of proteins and salts. Then the whole is covered by a double membrane. The two membranes enclose a space called the air-space for the respiration of the young embryo. Finally a shell encloses the whole structure. At the two ends of the egg twisted structures are found called Chalazae.

Therefore the egg of the fowl consists from the outside of the following structures :—

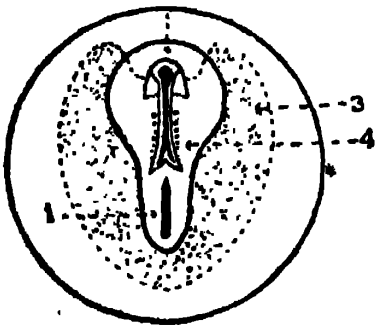
(1) Shell.
(2) Double membranes.
(3) Chalazae.
(4) Air-space.
(5) White of egg or Albumen.
(6) Yolk.
(7) Germinal disc.

2. The first day : Formation of the Germinal layers—

When the egg is laid on the ground, further development ceases until it gets the necessary temperature either from the hen or it may



Surface view.
1. Blastoderm,
2. Yolk.



1. Primitive Streak,
2. Head process,
3. Area opaca,
4. Area pellucida.

be hatched artificially with the help of an instrument called the **Incubator.** The blastoderm at the time of laying is a circular patch about 3·5 m.m. in diameter, on the surface of the yolk. Owing to its lower specific gravity the blastoderm remains uppermost however the egg be rolled over. It has a marginal white rim called the **area opaca** and a central circular translucent portion called the **area pellucida.** The blastoderm is not uniform in structure and in section appears to be of several layers. Among the blastodermic layers, there is formed a cavity containing a fluid called the **blastocoel.** As the disc expands, the upper cells are thinned out to form an outer germinal layer called the **ectoderm** or **epiblast** and a lower germinal layer called the **endoderm** or **hypoblast.** The cavity below the hypoblast is the **sub-germinal cavity** and corresponds to the archenteron of the frog. After the beginning of incubation, the blastoderm spreads rapidly. On the close of the 1st day, it is 20 m.m. in diameter and on the close of second day it has spread half-way round the egg. Complete enclosure of the yolk does not take place before the 17th day.

The Primitive Streak and origin of the Mesoblast.

An opaque band appears just after incubation in the posterior part of the pellucid area which becomed elongated and is known as the primitive streak. It grows backwards and the pellucid area also elongates simultaneously. The primi-

tive streak while elongating shows a fine transparent line running down its centre. This is caused by a groove called the **primitive groove.** The primitive groove has a small pit in front. The primitive streak is a keel-like band of proliferating epiblast and the hypoblast does not take part in its formation. The cells that the primitive streak buds off between epiblast and hypoblast is a paired sheet of loose tissue. This tissue is the **mesoderm** or **mesoblast** and this germinal layer is formed by the primitive streak by budding of the epiblast.

Fate of the Germinal layers—

The epiblast gives rise to the following organs and tissues of the chick :—

(*a*) The epidermis and its appendages (feathers etc.) ; the nervous system ; the sensory epithelium of the sense-organs ; the lining of the month and of the cloaca.

(*b*) The hypoblast gives rise to the epithelium of the alimentary canal and of the glands that spring from it.

(*c*) The mesoblast gives rise to all the connective tissue, vascular, muscular and Skeletal Structures as well as to the urinary and reproductive organs.

The Notochord and medullary folds—

An area develops in front of the primitive streak towards the end of the 1st day which is a forward continuation of the primitive streak. This is called the head—process and ultimately forms the **notochord** or forerunner of the vertebral column. Blastoderm in front of the primitive streak at the 16th hr. of incubation shows that the epiblast is several cells thick and is called the neural or medullary plate. The neural plate folds to form the first trace of the nervous system called the **neural** or **medullary folds** ; the centre or axis of the head-process possesses for the hinder part of its length a rod of cells called the notochord. The mesoblast spreads out as a pair of wings. At the end of the first day, the embryo is all head having only the nervous system of the head and the notochord.

3. The Second day—

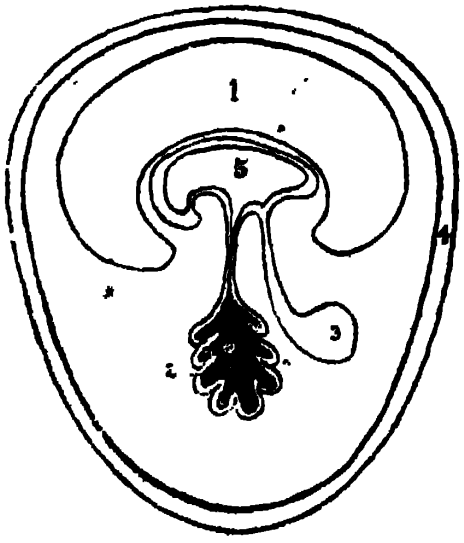
On the second day, the head fold has the effect of folding off the anterior region of the embryo from the underlying yolk. The blood-

vessels develop on the surface of the yolk and a circulation of blood within and without the embryo is established. Somites increase in number on either side of the nervous system and notochord. These somites give rise to voluntary muscles (except those of the head), the axial skeleton of the body and the dermis. By a horizontal slit in the lateral wings of the primitive streak, the mesoblast from which they are cut off becomes hollow. This cavity forms the coelome or body—carity of the future chick. The outer wall of the cavity forms the body wall of the chick and is called the *somatopleure*, while the inner wall forms the gut or **Splanchnopleure.**

4. The Third day—

By the union of the head-fold, lateral-folds and tail-fold, a structure is formed called the amnion. This is one of the foetal membranes. On this day, the rudiments of the internal organs of the adult are established. From the hind-gut, there develops on the 3rd day, a pouch like outgrowth called the allantois. The allantois is also a foetal membrane and is cast off at the time of hatching. It is highly vascular and the allantois acts as a respiratory organ of the embryo by absorbing oxygen from the air-chamber.

The heart on the 3rd day of incubation is like a S-shaped loop which ultimately forms the auricles and ventricles.



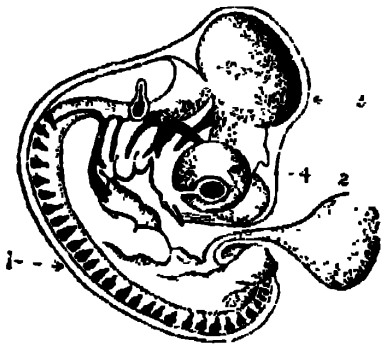
1. Amnion,
2. Yolk-sac,
3. Allantois,
4. Chorion,
5. Embryo.

5. The Fourth day—

The egg albumen is restricted in area. The wings and legs appear. The kidney and ureter are developed.

6. The Fifth day—

The embryo is strongly bent. The cartilaginous portions of the skeleton appear.



1. Embryo,
2. Allantois,
3. Headfold,
4. Eye.

7. The Sixth day—

The characters of a bird appear in the wings, feet, skull and alimentary canal.

8. The Seventh day—

The amnion and allantois show contractile movements. The head now grows less rapidly than the body.

9. The Ninth day—

Feathers appear through the skin.

10. The Twentieth day—

The beak perforates the inner shell-membrane and the chick breathes air. The lungs breathe air.

11. The Twenty-first day—

The chick is hatched.