CHAPTER VIII

ORGANIC EVOLUTION.

Formerly it was thought that God created everything as it is, but later on scientific observations led to the **Theory of Evolution.**

The creation of animals and plants independently without a gradual development is known as the **Theory of special creation.** It is in fact the literal interpretation of the story of creation as set forth in the first chapter of **Genesis.** The theory of special creation was supported by the **Christian fathers,** though an honourable exception must be given to St. Augustine, who would have taught otherwise. The theory was fated to suffer a severe shock from the discoveries of fossils in the rocks. These fossils were evidently the remains of an older population and the puzzle was how to account for them.

An explanation was suggested for these fossils by the great naturalist **Cuvier** who formulated the theory of catastrophism.

Theory of catastrophism—

Cuvier (1769-1832) suggested that the world had been the scene of a series of vast local cataclysms by which the plants and animals were exterminated but in certain cases preserved in the rocks. After each catastrophe the region was repopulated, not by a new act of creation, but by the migration of animals and plants from surrounding areas which had not suffered.

Evolution means the gradual development of complex highly organised animals or plants from simple pre-existing animals or plants. There are various evidences in support of the theory of evolution.

1. Structural and Anatomical—

The simplest animal Protozoa as Amœba gives place to Hydra with two body layers only. Then comes the next group of Annelida of which Leech has three body layers and gradually the highest complexity is reached in the mammals. The organs also show gradual evolution from simple to complex type. The paired organs like the forelimbs of birds, toad and guineapig are built on the same plan and hence they are the modifications undergone by the forefathers of those animals in course of time according to circumstances of life. The wing of pigeons is used in flight but is not functional in the Newzealand kiwi bird where only a remnant of the wings is found. The evidence is that the same muscles that are active in pigeon and the same type of bones are found in both the animals. The teeth of guineapig are necessary for the very existence of the animal but in the Whalebone Whale the teeth are only present in the foetus and are lost after birth. The conclusion is that the whale had ancestors with functional teeth but which are lost in the course of evolution.

By the study of comparative anatomy, it was realised that certain structures of the bodies of different organisms showed a great similarity one to another and were indeed homologous; that is, resembled each other in their architecture and corresponded to each other in their development. As an example, let us take a series of forelimbs of some backboned animals. The arm of a toad, the paddle of a turtle, the wing of a bird, the flapper of a whale, the wing of a bat or the arm of a man, though serving very different functions, are all built in the same pattern.

It is true that all are adapted in particular ways to their various uses, but in essentials these forelimbs are arranged on identical lines. Any interpretation of these facts is difficult other than the one that they are due to relationship. Again, it is found that the number of vertebræ in the necks of mammals, is with two exceptions always seven; the long neck of the giraffe and practically the non-existent neck of the whale have exactly the same number of bones. Evolution explains this fact but on no other theory is it explicable.

Vestigial structures—In the bodies of animals there are remains of structures which are now functionless which give a proof of the animals' ancestries. The remains of the second and fourth digits in the limbs of the horse are examples of such vestigial structures; the tiny bones in the body of the whale, representing the hindlimbs; in the baleen whales the teeth which never cut the gums.

2. Embryological—

The study of embryology affords good evidence towards evolution. The development of an individual organism repeats in a very brief form, from the early stage of fertilisation right up to the fully formed animal, a series of changes which had occurred during the development of the particular kind of animal through thousands of years. This development of race had many changes and modifications in life which is represented in a miniature form in the development of the embryo. This is known as the "Theory of Recapitulation," or "Biogenetic Law." The embryos of higher animals generally repeat the characters of lower animals in the foetal life. The development of a mammal shows Visceral arches and clefts comparable to the Branchial arches and clefts of the fish.

Next, the characters of an Amphibian are seen and further development shows the nature of Reptilian characters. Finally the Mammalian characters appear.

The development and metamorphosis of the Toad show the gills in the tadpole stage resembling the fish and strictly speaking the tadpole is more like a fish than a toad. It proves clearly that in evolution fish-like forms have given rise to the Amphibian stock.

From embyological study, let us take the example of the heart. In the fish, this organ consists of an auricle and a ventricle. The auricle receives impure blood and the ventricle drives it to the gills for purification. In the amphibia, the auricles become divided into two while in the reptiles the ventricle is divided partially—except in the crocodile where the division is complete and the heart is four-chambered. In birds and mammals, the four-chambered heart with two auricles and ventricles is the rule. During development, the hearts of mammals and birds pass through the stages outlined above; there are the fish and amphibian heart stages in every developing mammal. In the same way other organs of the body, such as the kidneys and the brain, demonstrate by their development their evolutionary history.

3. **Geographical—**

Animals and plants often are separated by wide oceans and mountains but nevertheless they originated from common ancestors so their similarities are often noticed although occurring in widely separated areas. The reason is that the surface of the earth had undergone changes and oceans have arisen where mountains stood thousands of years ago or mountains and plains have arisen where once oceans stood in ages long gone by. The flora and fauna of south Africa have similarities with that of India. Japan has similar flora and fauna with that of Europe. Besides the similarities another question has to be met. There are some forms that are peculiar to a land and generally do not occur anywhere else. These are known as endemic forms. The Australian Anteater or the Kangaroo is an example of endemic fauna. In China there occur a Gymnospermic plant which is endemic to that country. The explanation is perhaps that the land is very primitive in its history of the world and has been cut off from other parts of the world for a very long time so that its distribution is restricted to that particular area of land.

Let us discuss the geographical evidence which impressed Darwin so much. During Darwin's voyage in the Beagle (1831-1836) the Galapagos, a chain of islands some 600 miles west of South America, were visited. He collected as many animals and plants as could be collected and on classification found that each of the islands had its peculiar animal population. The species of one island though distinctive were similar to those of another and the general fauna of all the islands resembled that of the adjoining mainland. The explanation was that the species on the islands and on the mainland were blood relations claiming their descent from a common ancestor. Thus Darwin's attention was drawn to the question of the origin of species.

It is probable that at an earlier period in the earth's history these islands were joined together to form one large land mass which was itself once connected with the West Indies and Central America.

There was then presumably a much smaller number of species than to-day and they were distributed over the entire region. After separation from the American continent the species became isolated through the breaking up of this landmass into smaller islands. Subsequently these solitary groups of animals became differentiated into the several forms now characteristic of the various islands, showing descent from a common ancestor with eventual specialization. Australia affords another example. There was one time in the earth's history when only the marsupials or pouched mammals were found. Later on Australia was separated by oceanic waters from the continent of Asia. No aggressive mammal could come to Australia due to the barrier of water and thus the marsupials flourished and are living upto this day.

4. Palaeontological—

Plants and animals are preserved in the layers of the earth either as impressions or as calcified lumps. These are known as fossils. The Earth has different layers called strata. These strata have been formed by deposition through thousands of years. The age of the Earth is broadly divided into three periods, *viz.*, Paleozoic, Mesozoic and Tertiary corresponding to very early, middle and modern ages. Any fossil found in these strata can be approximately identified to that particular age. From the study of the fossils variations are seen which are co-related with the present forms and related types are known to be ancestors of the present forms. The present horse had various types of ancestors and gradually the present form has appeared. The mammals and other vertebrates are preserved as fossils more easily as they have bony skeleton but the invertebrates are less available as fossils except some which had hard external coverings on account of their soft bodily structures which are unsuitable for preservation.

5. Experimental—

New forms of animals arise from original simple types. The rock pigeon or the wild pigeon has given rise to the thousand and one types now available as fantail pigeons, pouters, Jacobins etc.

6. Serological test—

Freudenthal and Nuttal carried out blood tests to show the kinship of the various species of back-boned animals. They found out that the blood of a rabbit when introduced into the blood stream of a near relative such as a hare, the two kinds of blood mixed freely together. If the rabbit's blood was introduced into an animal not so closely related as for example a dog, a definite antagonism was produced, causing the destruction of the red blood corpuscles (haemolysis). Such tests can bring out the relationship between two animals specially their nearness.

THEORIES OF ORGANIC EVOLUTION

History of the theories of evolution—

The conception of organic evolution really began in the nineteenth century through the work of Charles Darwin. But the theory was foreshadowed long before the publication of the "origin of species."

Early Greek theories—It is interesting to note the views of ancient Greeks regarding evolution. Five centuries before the Christian era we find Anaximander dealing with the problem. Empedocles (495-435 B.C.) taught not only the relationship between the different species of animals or plants but said that nature was continually trying new types, some better fitted to environment whereas less fitted types were ultimately dead thus foreshadowing the theory of the survival of the fittest.

Heraclitus and Democritus believed that all things were in a state of continual change. Aristotle was the founder of the genuine scientific method and father of natural history. He believed in a gradation from the lowest organisms to the highest and that man was the highest point of one long and continuous ascent.

The fact remains, however, that not until the coming of such men as Linnæus, Buffon, Erasmus Darwin, Lamarck and Charles Darwin was real progress once more made and from then onwards the advance never ceased.

Linnaeus—This great swedish naturalist was born in 1707. Linnæus was sent to a good school, but his progress was unsatisfactory and he spent all his time in collecting natural history specimens. Linnæus is best known for his classification of animals and plants; he was a firm believer in the origin of species by "special creation," though he admitted the production of "post creation" forms by hybridization.

Buffon—He was also born in 1707. As an investigator, Buffon does not rank high for he left few original contributions to science; his mind was philosophically rather than scientifically inclined. He was a firm believer in the process of evolution.

To Buffon environment was all important as modifying the structure of animals and plants and he believed the modifications so produced were inherited.

Erasmus Darwin (1731-1802)—This country physician and naturalist, the grandfather of Charles Darwin was the greatest of Lamarck's predecessors. In 1794, he published a book, "Zoonomia" in which he stated ten principles regarding the course of evolution. E. Darwin's views are similar to Lamarck.

Lamarck (1744-1829)—His influence on the theory of evolution is second only to that of Charles Darwin, indeed by some modern biologists his theories are accepted, while those of Darwin are discredited. Lamarck was intended for the church but he disliked it and finally joined the army. Later on, being unfit for military life he took up medicine but changed to botany, to which study he remained attached until 1794, when he was fifty years of age. He changed from botany and took charge of the department of invertebrates. This change had a profound influence in shaping his ideas.

Lamarck's Theory—

Lamarck published his theory in 1809. His views are :—

(1) Use and disuse of parts.

He says that organs or parts of the body that are mostly used are preserved and develop while those parts that are in disuse undergo decay and finally are lost. Secondly, the changes on account of use and disuse are transmitted to the offspring as a character. In the plants environment plays a very important part for the fixing of a new character.

The giraffe has a long neck and the forelimbs are much longer than the hindlimbs. The giraffe lives in a part of Africa which has less vegetation and consequently the animal has to live upon the leaves of trees which it cannot reach unless the neck is long and the forelimbs are suitably so. The constant care for such endeavour has resulted in the long neck. The forefather of the snake had stout body and two pairs of long limbs. The subsequent life in this world necessitated longer body and disuse of limbs which have been gradually lost in the modern snake. The new characters which have appeared pass from generation to generation according to this theory. But this theory is not accepted by many Biologists.

His theory was that modifications, that is variations, in the structure of plants and animals were due to some force exercised during their life. In the case of plants, environment was the chief agent; thus soil conditions, altitude, moisture, heat and light were important factors inducing variations which were inherited. The shape of irregular flowers was supposed to have been caused by the strains induced by the visits of bees and other insects during their search for honey.

In the case of animals Lamarck regarded the environment as undoubtedly playing a part but considered that the most fruitful cause of variation arose from the effect of use and disuse.

During the last fifty years, the theory of Lamarck that useful characters when developed are transmitted by inheritance is controverted and denied.

Darwin's Theory—

In 1858, Charles Darwin simultaneously with Wallace gave an explanation of evolution as well as of Natural selection. Darwin is regarded as the father of evolution. He brought experimental data as proof of evolution. Previously people believed that God created everything all at once as stated before. Darwin's theory had many setbacks as there was a time when people burnt down places where Darwin's Theory was advocated, but truth conquers all difficulties, and modern scientist appreciates and believes in the theory of evolution. Darwin's theory had undergone many changes but still the basis remains and the science of Biology has a permanent debt to this genius of evolutionary theory. Two main points of Darwin's theory are:—

(1) **Struggle for existence** and (2) **Variation.** Darwin's theory of natural selection advocated that animals increase in great numbers in this world but there is not sufficient space for all of them; so those who are more fit will survive and those unfit will die away from the face of the earth. This is known as struggle for existence.

If a plot of garden land is allowed to run to waste i.e., if weeds are allowed to appear, then gradually the weeds will cover the whole surface and the garden plants will die out. The explanation is that the weeds are more fit to fight for their existence in the world than the garden plants.

Another factor of Darwin's Theory is that Variations or slight changes gradually appear in the organism but it does not admit that the variations are passed from generation to generation.

Among animals a severe struggle for existence is always going on. Large numbers of ova are produced in the lower animals. Some are eaten up by other animals, others do not get a favourable place and only a few can develop into maturity. Among higher animals the fight is seen between carnivorous animals and their prey in which the latter develop their power of flight, alertness etc., to protect themselves.

As an example of variation Darwin took much interest in the pigeons. The various types of pigeons are descended from a common stalk the wild blue rock pigeon. Man tends animals which attract his fancies.

The variation which appeals to him becomes more numerous by his care. The various domesticated animals like dogs, goats, sheep etc. have all originated by such variations.

Life of Darwin—

He was born at Shrewsbury on February 12, 1809. The Darwin family is an example of inheritance of mental capabilities. Charles Darwin was the grandson of Erasmus Darwin, the author of the famous book "Zoonomia;" his father was a physician. Sir Francis

Galton, the founder of the Science of Eugenics, was Darwin's cousin. Darwin's sons have attained eminence in the scientific world.

Darwin's early years gave no indication of his extreme intellectual ability. He went to study medicine but left the course to study theology prior to entering the church. He took a degree but he devoted the major part of his time in natural history pursuits. The turning point of his life came when he was appointed naturalist on the "Beagle" which was going on a surveying expedition under the command of Captain Fitz-Roy. The voyage lasted from 1831-1836 and Darwin collected much valuable material. He was greatly hampered for nearly forty years with a constant illness. For nearly twenty years Darwin collected evidence regarding the Origin of Species. In 1858, he published his first paper under unusual circumstances. In that year Darwin received from Alfred Russell Wallace, a letter asking him to read and criticize the theory Wallace had come to concerning the origin of species. To Darwin's surprise he found that the theory was entirely identical with his own and he was practically fixed in his mind to withdraw all claim and to publish Wallace's essay. Happily however due to Hooker and Lyell, a joint paper in the names of Darwin and Wallace was read before the Linnæan Society in London in 1858. In the following year, "The origin of species" was published. It is curious that the same book, Malthus's essay "On Population" gave to both of them the idea of Natural Selection.

There are three fundamental principles underlying Darwin's theory, variation, heredity and natural selection, the last being the central point of the whole idea.

Variation—

The members of a family are not all alike at birth. While collecting animals and plants one notices the variation between members of the same species. The variations are always found and Darwin frankly admitted his inability to explain how they arose.

Heredity—

It is found that variations found in animals and plants pass from one generation to the next. Darwin himself believed such characters might be inherited: a view not widely held to-day; but the ultimate solution of the problem will not materially alter the Darwinian theory.

Natural selection—

In the case of gardeners or poultry farmers, the breeder keeps the forms which he desires and destroys the rest. This is artificial selection. The selection of species by nature is natural selection.

The numbers of individuals composing any species of animal or plant are constant but the rate of increase is often very great. Prof. Punnett calculated that in the case of a Rotifer which is barely visible to the unaided eye, if after sixty-seven generations produced in a year all the Rotifers could be saved, then they would have formed a sphere greater than the earth. Darwin calculated and assumed that the elephant first breeds at 30 years and lives upto 100 years and has six young in the interval period then after 740-750 years, if all the animals survived there would be about 19,000,000 elephants descended from the original pair.

It is evident therefore that in Nature there must be some factor keeping down numbers. Since the space and food-supply available for all animals and plants are limited, it follows that there must be a proportion of them, that are killed before reaching maturity. There is, in fact, a struggle for existence. "It occurs between organisms of the same species; between friends and foes, and between living creatures and their environments with the inevitable result that the numbers are reduced and increase in population is checked. Natural selection is a passive agent, it cannot create, it can only destroy or preserve. It is the inevitable outcome of the interaction of variation and the struggle for existence by which the fittest survive.

The effect of Natural Selection as an evolutionary process, as Lull summarizes it, is:

(*a*) Under new conditions harmful characters will be eliminated by selection,

(*b*) Beneficial characters are intensified and modified.

(*c*) The great body of characters neither harmful nor beneficial will not be modified, but will persist through heredity.

Examples of Natural Selection:—

(1) The sharp eyes of the hawk have arisen by Natural Selection eliminating hawks born with weak or defective vision.

(2) In August 1909, a heavy snowstorm destroyed some trees in Johannesburg but the Deodars from the Himalayas survived.

De Vries' theory—

This theory advocates that new species arise by "mutation" or "saltation." Mutation means the appearance of a new type at once without accumulation of small distinctive changes. It is a jump and says that beneficial characters are transmitted to future generations while harmful characters are eliminated. The author of this theory carried out various experiments with plants. Although natural selection has a very prominent part in the fixing of the mutation but that is not openly admitted. The loss of limbs of snake can be explained by this theory as a loss at once and the character is transmitted to modern types of snakes.

CHAPTER IX

BIOLOGY FOR BEGINNERS

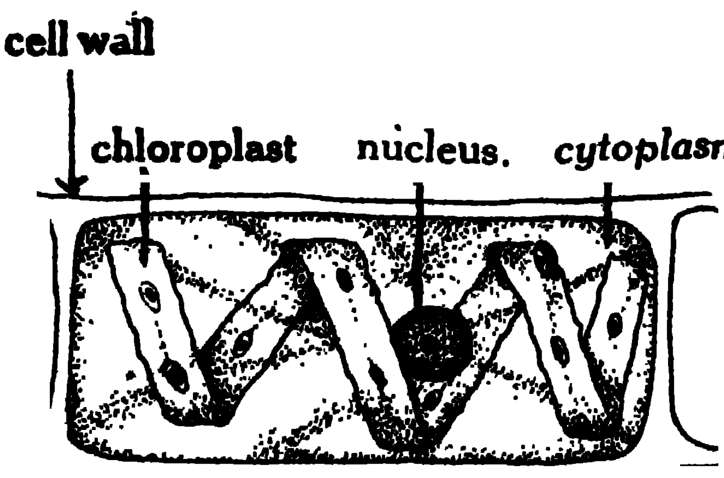
BOTANY

Divisions of the plant kingdom—

Plants are found everywhere on the face of the earth. The mountain peak or the depth of the ocean has its peculiar flora. The variety of plants may not be known to the general reader but once the pages of botany are turned, the richness of variety comes to one's mind.

The plant kingdom has been grouped into the following main divisions :

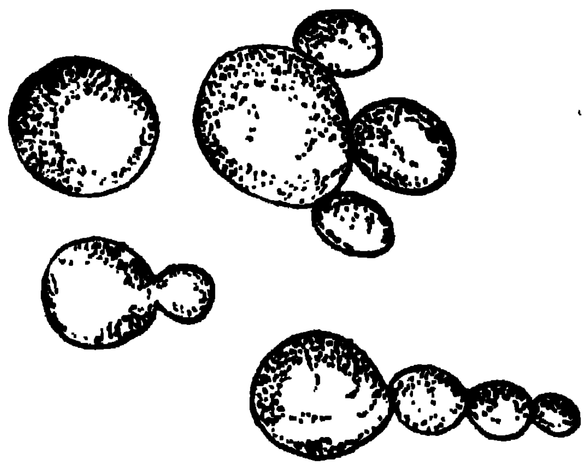
The first and lowest division is **Thallophyta** or **Thallophytes.** It includes simplest forms of plant life having a body which either consists of a single cell or



Spirogyra

many-celled in structure. Such a body is not differentiated into organs such as root, stem and leaves. This type of plant-body is called a **Thallus.** Some of the thallophytes possess chlorophyll and therefore green in colour while others lack this pigment. The former forms a definite group called the **algae** and the latter **fungi.** Examples of algae are pond scum such as **Spirogyra** and many seaweeds found in oceans and seas.

Toadstools, Yeast, Breadmould are familiar examples of fungi. In many seaweeds, the thalloid body is often differentiated into root-like, stem-like and leaf-like organs.



Yeast

In the second division of the plant kingdom, the **Bryophyta** or **bryophytes,** one notices a progressive differentiation of the vegetative body from **thallose to foliose** form with forms having distinct development of the shoot system, true roots being entirely absent from this group. Common examples of bryophytes are **Liverworts** and **Mosses** which are found plentifully on rocks in temperate regions and on walls, grounds, on roofs and on barks of trees, specially in the rainy season.

The **pteridophyta** or **pteridophytes** comprise the third great division of the plant kingdom. They differ from the other two divisions in that they have their vegetative bodies differentiated into roots, stems, leaves and a well developed conducting system. They also differ from the next higher group, the **spermatophytes**

Moss

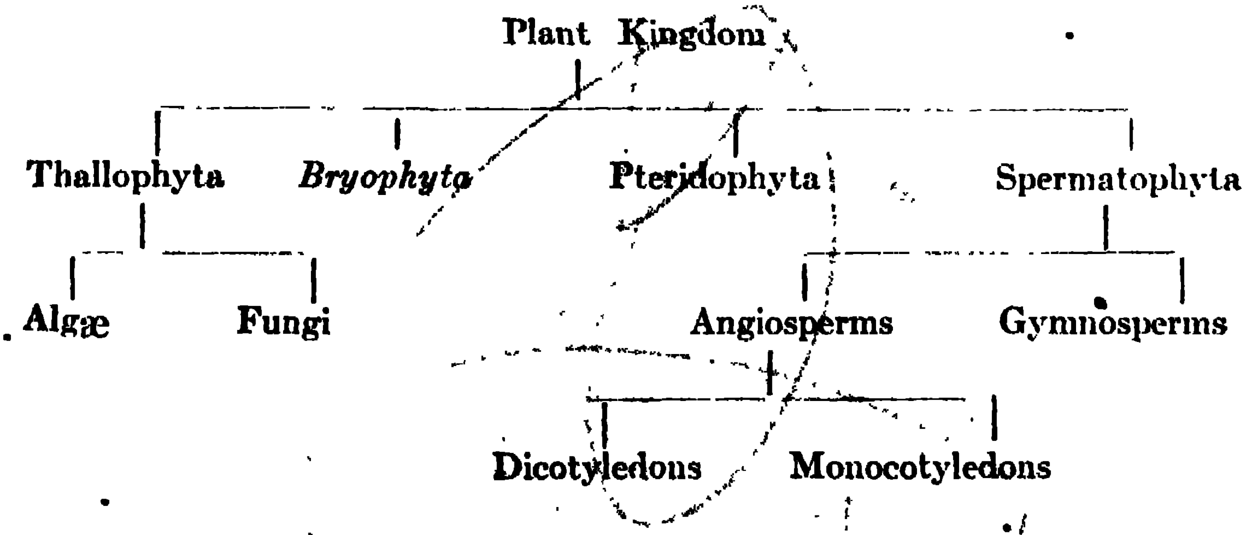
or **spermatophyta** by the fact that they do not produce seeds. Ferns, Horsetails, Clubmosses which are so abundant on hills and in the tropical forests are familiar examples.

Other important distinguishing features of Thallophyta are:—

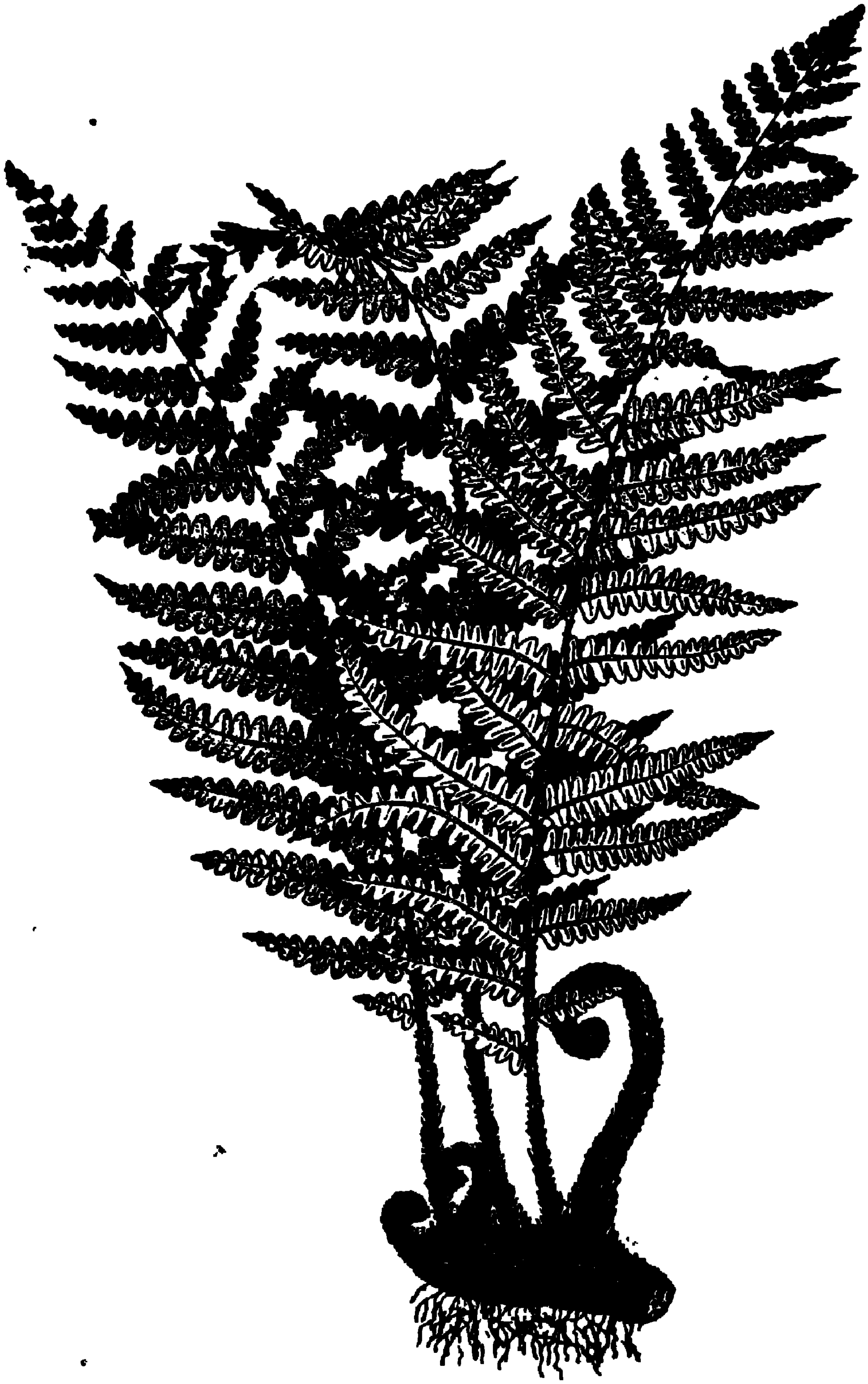
(1) Sex-organs mostly one-celled,
(2) Sporangia always one-celled,
(3) The zygote nerve develops into a multicellular embryo while still within the female sex-organs.

In the fourth and the highest division of the plant kingdom, the **spermatophyta** or **spermatophytes** one notices complete differentiation of the plantbody into the

vegetative organs such as *roots, stems* and *leaves* like the pteridophytes and they also possess a well developed conducting system. But the most important feature which distinguishes it from other groups is the production of seeds. The term spermatophytes means seed-bearing plants. The two sub-divisions of the spermatophytes are **Gymnosperms** and **Angiosperms.** In the former the seeds are naked *i.e.,* not enclosed in a fruit but in the latter the seeds are enclosed within the fruits hence these are close-seeded plants. Familiar examples of gymnosperms are Pines, Cycads, Cedars etc. The angiosperms are further sub-divided into two groups, the **Monocotyledons** and the **Dicotyledons.** The monocotyledons are represented by plants like Bamboo, Rice, Maize and other cereals, Orchids, Bananas, Grasses etc. The Dicotyledons include plants like Gram, Pea Bean etc. The essential differences between the last two groups will be discussed in subsequent chapters. Table of the divisions of the plant kingdom.



The Thallophyta, Bryophyta and Pteridophyta form the great group of **Cryptogams.** The cryptogams do



Fern.

not produce seeds but produce unicellular structures called the spores. The spermatophyta produce seeds. The old definition and divisions of the plant kingdom into Phanerogams and Cryptogams have been partly modified. The phanerogams were defined to be flowering and the cryptogams non-flowering plants but recently it has been discarded.

CHAPTER X

SEEDS

General structure—

Every seed contains within it, a rudimentary plant called the **Embryo** with an abundant supply of reserve food; the babyplant of the embryo is in a state of dormancy. Dormancy means the cessation of vital activities but alive. We have already seen that in a rudimentary plant, all the vegetative organs are represented. The leaves of the embryo are called the **cotyledons** or **seed-leaves.** According to the number of cotyledons, seeds are broadly divided into two main types *e.g.* Monocotyledons and Dicotyledons. Pea, Gram, Bean, Gourd, Castor oil seed, Mango, Tamarind and Pulses in general are examples of Dicotyledonous seeds while Maize, Paddy, Oat, Barley and other cereals, Bamboo, Grasses, Cocoanut etc. are monocotyledonous seeds. For the sake of convenience, the two main types are discussed separately.

Dicotyledonous Seeds—

For the purpose of examination of seeds, these should be thoroughly soaked in water for proper study. In describing a seed, the shape, colour of the testa, markings on the seedcoat or any other peculiarity may be noted down.

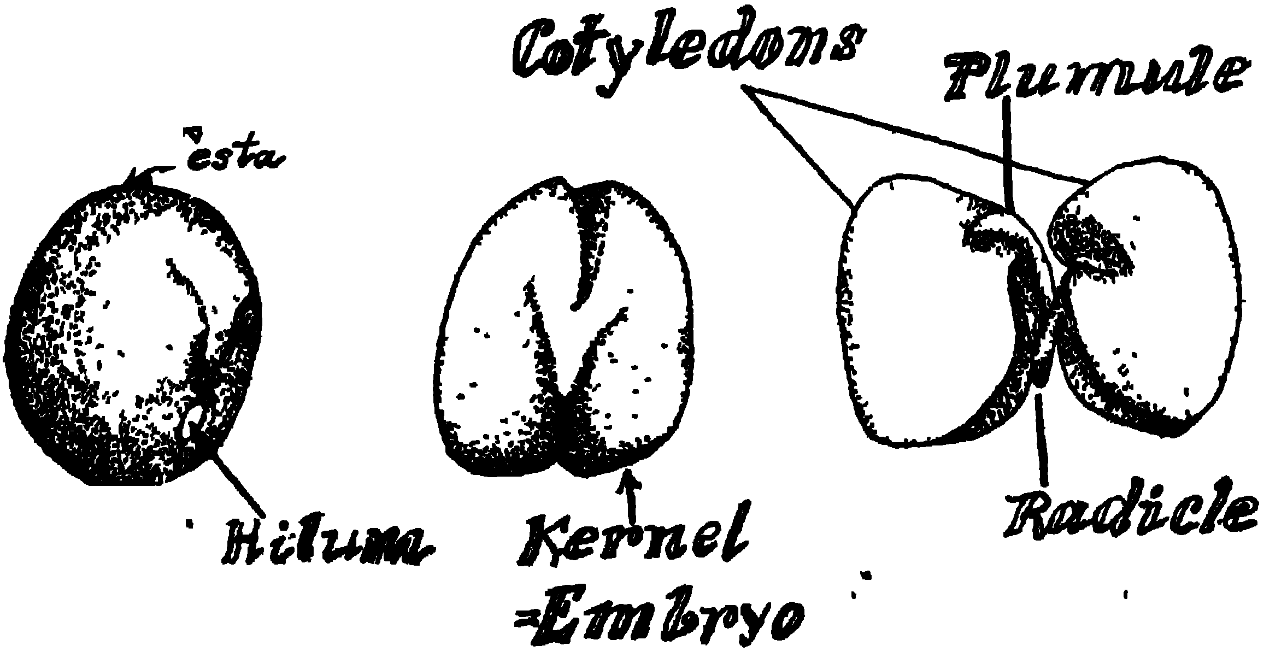
Every seed consists of a covering called the **Seedcoat** which encloses inside a fleshy substance called **Kernel.** The seedcoat is often differentiated into an outer covering called **Testa** which is thick, hard and resistive and an inner one called **Tegmen.** This Tegmen when present is thin and delicate and is either adpressed to the inner side of the testa or to the kernel. Somewhere on the testa, there is more or less, a prominent scar called the **Hilum,** which represents the place where the seed broke from the stalk (**funiculus**) by which it was attached to the wall of the fruit. Near about the hilum, there is a minute opening called the **Micropyle** through which in many cases water oozes out when a soaked seed is gently pressed. On removal of the seedcoats, the entire structure thus exposed is the **Kernel.** In case of Pea, Gram, Bean, Tamarind, Gourd and similar other seeds, when this kernel is gently pressed, it separates into two thick bodies called the **cotyledons** or seedleaves, which are attached laterally to a very short axis like a hinge. The region of attachment is called the **Nodal zone.** That end of the axis which is directed outward is known as the **Radicle** or future root while the opposite end which is placed in between the two cotyledons is the **Plumule** or future shoot. Thus all the organs of vegetation such as root, shoot and leaves are represented in the embryonic condition inside the seed to form the **embryo** or rudimentary plant. The cotyledons are fleshy owing to the deposition of food in them. When there is such a storage of food inside the cotyledons so that the kernel is equal to embryo, the seed is said to be **Exalbuminous** or **Non-endospermic** as there is no separate existence of food, (albumin or endosperm) outside the body of the embryo.

But in the case of castor oil seed, it will be noticed that food in the form of a separate foodbody (endosperm) is present outside the body of the embryo so that the kernel is equal to embryo plus endosperm. This type of seed is called **Albuminous or Endospermic.**

In Dicotyledonous seeds, the plumule is always the terminal member and the cotyledons are lateral members. The axis of the embryo has two more differentiated parts namely **hypocotyl** and **epicotyl.** The region which lies between the radicle and the nodal zone is the **hypocotyl** while that between the plumule and the nodal zone is **epicotyl.**

Brief description of a few seeds—

1. **Pea** (*Dicotyledonous, exalbuminous*)—Externally it is more or less rounded. Testa is present, and is



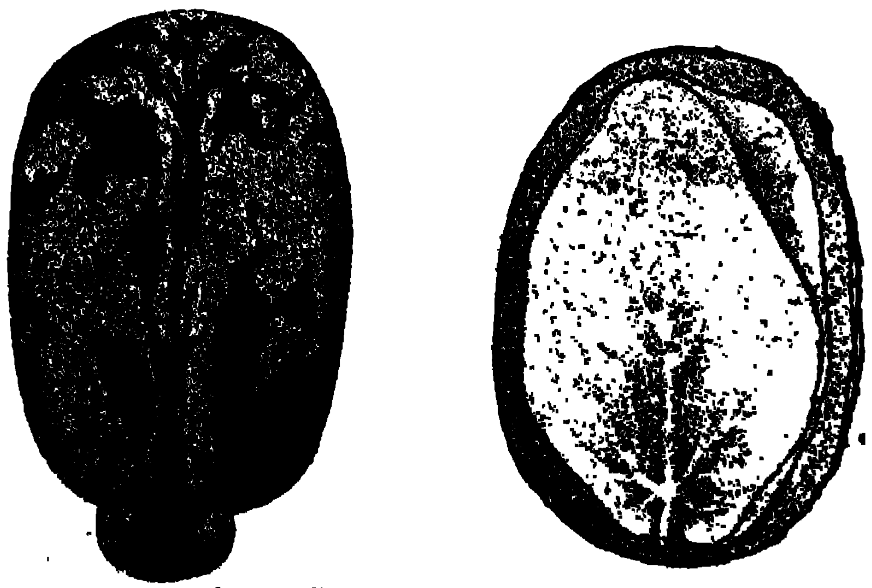
semitransparent and resistive; testa showing micropyle and hilum which lie side by side; kernel is equal to embryo having two thick, fleshy cotyledons hinged laterally to a short axis showing plumule and radicle at the extremities.

Structure of Pea seed:

Pea seed (Dicotyledonous, ex-albuminous)
- Seedcoat=*Testa* showing
  - Micropyle
  - Hilum
- *Kernel=Embryo*
  - Axis
    - Plumule
    - Radicle
  - Cotyledons (two, fleshy, lateral)

Castor oil seed—

Externally the seed is oblong in shape and consists of two seed-coats surrounding a massive **kernel.** The outer coat, testa is thick, hard, brittle and resistive with peculiar sculpturings on its dark, polished surface. At



Castor oil seed
C = Cotyledon

one end of the testa, micropyle and hilum are present no doubt but are usually hidden by a spongy swelling called the **caruncle** which is an outgrowth of the seed-coat near the hilum. On removal of the testa, the thin white papery tegmen is found to be closely enveloping the kernel. This kernel when carefully divided lengthwise (may be best done in boiled seeds) separates into two fleshy symmetrical halves which enclose an embryo. These two bodies together constitute the **Endosperm.** which completely surround the **embryo.** The embryo as usual consists of two lateral cotyledons and an axis showing plumule and radicle at the extrimities. The cotyledons, in this case, are thin and leaf-like and show venation because food has not been incorporated into them. The surface of the endosperm which lies in contact with the cotyledons, receives an impression of the veins of the cotyledons which is evident on removing the embryo.

Structure of Castoroil Seed:

- *Castoroil seed* (Dicotyledonous, albuminous)
  - —Seedcoats—
    - Outer=Testa showing hilum and micropyle covered by the caruncle.
    - Inner=Tegmen (adpressed to the Kernel)
  - —Kernel=
    - Foodbody =Endosperm containing the embryo inside.
    - Embryo
      - Axis—
        - Plumule,
        - Radicle.
      - Cotyledons (Two, thin, leafy, lateral showing veins)

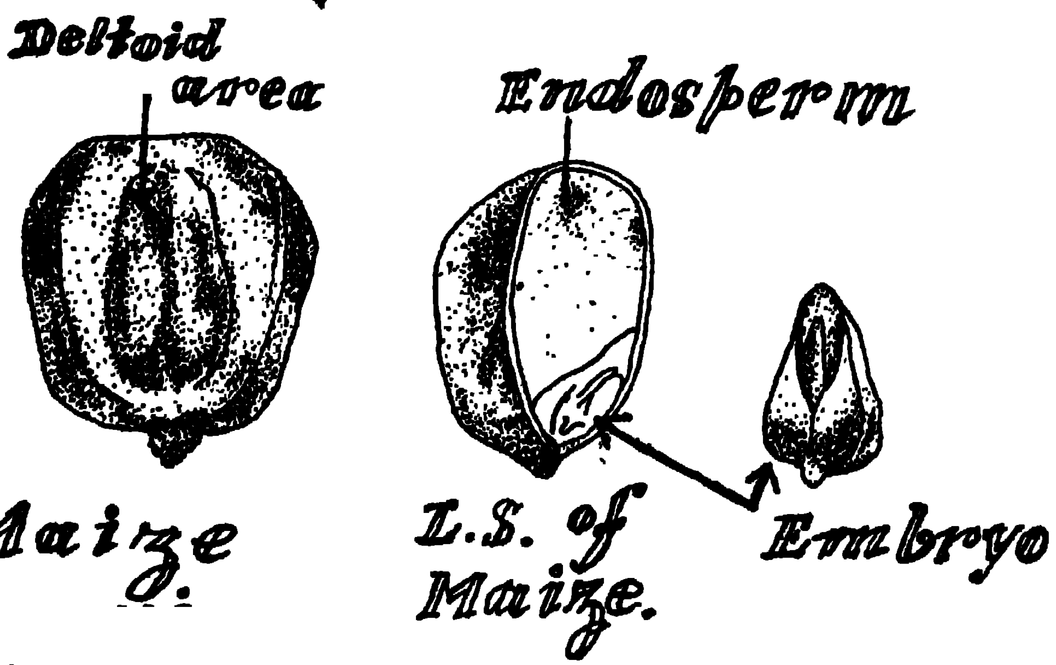
Monocotyledonous seeds—

Like the dicotyledons, the monocotyledonous seeds may be albuminous and exalbuminous but the former are more numerous and common than the latter. Examples of albuminous monocotyledonous seeds are Maize, Paddy, Barley, Wheat, Oat and other cereals, cocoanut, datepalm, grasses etc. While seeds of onion, Vallisneria etc. are exalbuminous in nature. Only the structure of the albuminous type will be discussed below.

The so-called albuminous seeds of cereals and grasses are really fruits, each containing within it a tightly fitting seed inside. The wall of the seed (seedcoat) and the wall of the fruit (pericarp) are inseparably fused together to form a common covering which when removed exposes the kernel directly. Therefore the seed has got no separate existence from the fruit. The main bulk of the kernel in most cases, constitutes the endosperm commonly known as cereal grain in case of all cereals. Either at one side or at one corner of this endosperm, lies a minute embryo, the structure of which will be discussed in detail in the type described below. The cotyledon of grasses is very peculiar. It is known as the **scutellum.** It is shield-shaped and partially encloses the axis of the embryo and separating it from the adjoining endosperm. The back portion of the cotyledon which directly lies in contact with the endosperm is modified in such a way that it absorbs food from the endosperm with the help of enzymes secreted by it for the developing embryo when the necessity arises.

Description of an albuminous Monocotyledonous seed, Maize—

Each grain which is actually a fruit is more or less oblong in shape and flattened at both sides containing a tightly fitting seed inside at maturity. During development of the seed within the fruit, the seed consists of two coats but the outer one soon disappears and the inner one becomes firmly fused with the fruit wall or pericarp apparently forming a common wall. There is a deltoid area on one of the flattened sides of the grain which indicates the position of the embryo which may be seen through the semitransparent common wall. A longitudinal section of the fruit through the embryo



shows the embryo embedded in a mass of endosperm together forming the **kernel.** The outermost part of the endosperm consists of a single layer of cells, the **aleurone layer** containing abundant aleurone grains, the remaining portion of it is well-differentiated into two distinct regions, an outer horny endosperm and inner starchy endosperm, the former containing more proteins than starch.

(Between the common wall and the endosperm, another tissue, the **perisperm** may sometimes be present in some seeds which is the remnant of the nucellar tissue). The embryo consists of a single cotyledon, the scutellum which surrounds a very short axis. The cotyledon is a broad and flat absorbing organ lying in contact with the endosperm. The axis consists of plumule and very short hypocotyl and a radicle. The plumule has a growing stem-tip with a few rudimentary foliage leaves and is completely covered by a leaf-sheath called **coleoptile.** Similarly the radicle is also surrounded by a sheath called the root-sheath or **coleorhiza.**

In general, it may be stated that the maize grain is a typical monocotyledonous type containing endosperm.

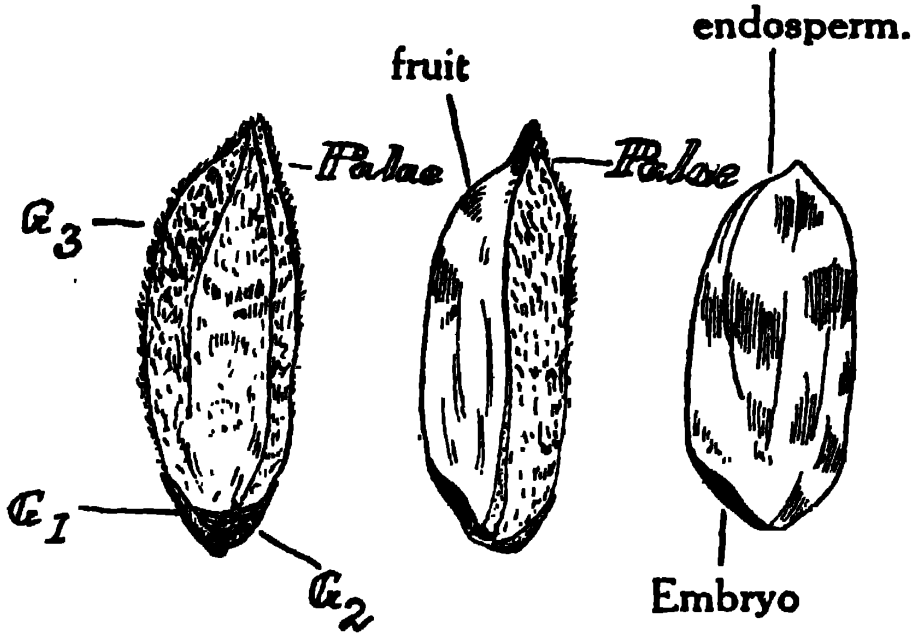
Structure of Maize grain :

Maize grain (Really a fruit containing a tightly fitting monocotyledonous albuminous seed inside, which has no separate existence from the fruit).

- Common wall (Pericarp and seed-coat inseparably fused together).
- Kernel
  - Food body = Endosperm (main bulk) and Perisperm (rudiments)
  - Embryo
    - Cotyledon (one, terminal) or Scutellum
    - Axis
      - Plumule, covered by the coleoptile.
      - Radicle, covered by the coleorhiza.

Structure of Unhusked rice grain—

It is similar to Maize grain but the wall of the fruit is formed by three glumes and one palea. Its structure is shown in the following diagrams. G=Glume.



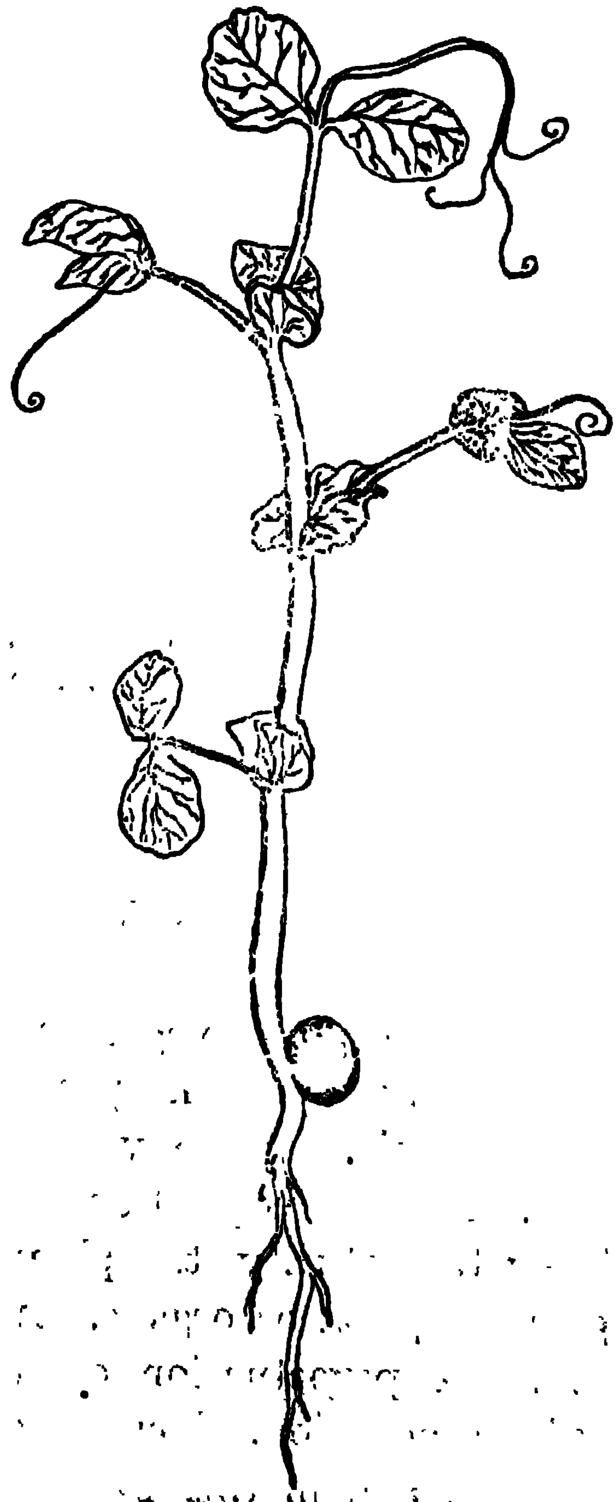
Parts of an angiospermic plant—

Normally the *vegetative body* of angiospermic plant consists of two main parts :—

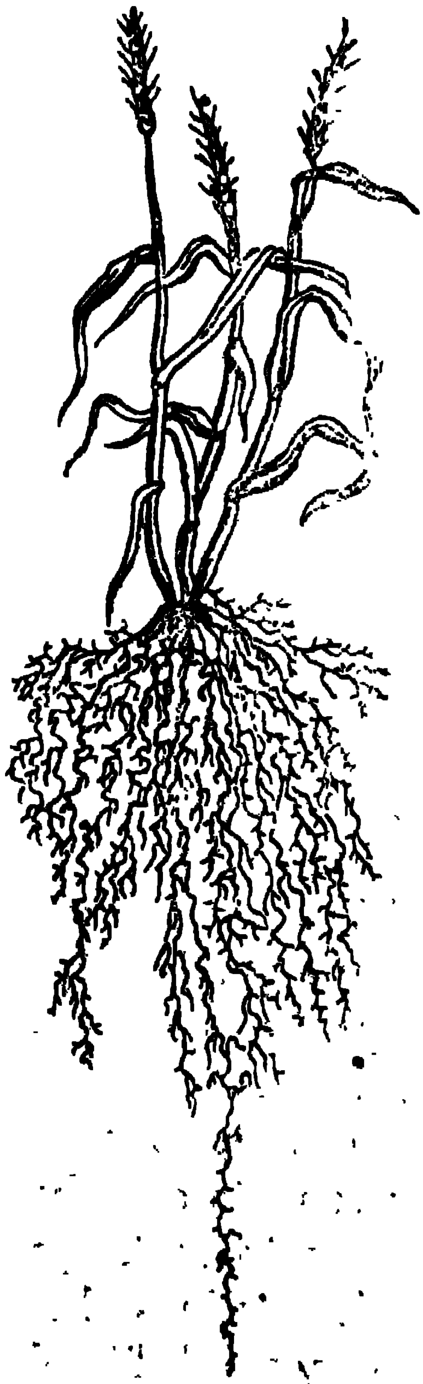
(1) An underground part—the **root-system** and

(2) A subaerial part—the shoot-system.

The root-system in dicotyledons consists of a main axis (**taproot**) from which secondary and tertiary branches (**rootlets**) originate in *acropetal order i.e.* the youngest branch is found towards the growing point, while the oldest branch is found farthest away from it while in monocotyledons there is no such taproot but a cluster of thread-like roots (**fibrous roots**) developed from the base of the stem. This rootsystem not only anchors the plants to the soil but also absorbs raw food-materials in solution from it for the plant. The shootsystem consists of a main axis called the **stem** which bears similar and dissimilar lateral members. The similar lateral members are the **branches** which often develop acropetally. The dissimilar lateral members are the



Seedling of pea showing taproot



Grass showing fibrous root

leaves which develop from *definite regions* (**nodes**) of the axis or of its branches. The region between two successive nodes is called the **Internode.** Each leaf usually bears a bud in its **axil** (*i.e.* the angle made by the upper surface of the leaf with the stem) called **Axillary bud.**

The apex of each axis (stem or branch) is normally terminated by a bud called the **Apical** or **Terminal** bud. By the activity of the terminal bud, the stem elongates while by the activity of the axillary bud, the branch system is produced. The stem in case of trees, remains unbranched upto a certain height forming a **Trunk.** When the plant attains maturity, at proper seasons, it produces flowers and fruits in succession and within the latter seeds are produced. All these parts of plant have definite functions to perform and are spoken of as **organs.** The organs like roots, stems and leaves are concerned with the **vegetation** (*i.e.* growth from infancy to maturity) of the plant and are hence called **organs of vegetation.** Flowers, fruits and seeds are only produced at the time of its reproduction. Hence these are known as **organs of reproduction.**

Thus the plantbody consists of organs, vegetative and reproductive, because every living organism passes through two main phases in its life-cycle. One is vegetation, the other is reproduction. During vegetation *i.e.* growth of the plant from infancy to maturity, the plantbody consists of only the vegetative parts or organs. At maturity to make provision for the perpetuation of its race, it develops the organs of reproduction. Reproduction is again followed by vegetation and in this way the cycle of life is continued.

In seed—bearing plants, one notices that plants develop from seeds which when placed under favourable conditions develop into fully developed plants. Each seed contains within it a plant in a rudimentary state called Embryo where all the organs of vegetation such as roots, stems and leaves are represented in miniature forms. For this reason we begin our study from the study of **seeds.**

Seed germination—

It has already been pointed out that embryo lies within the seeds in a state of dormancy. When such a seed is placed under favourable conditions, the embryo wakes up and begins to grow until it establishes itself to the soil. The term seed germination includes all the stages from the time the dry seed is placed under those favourable conditions until it establishes itself to the soil forming a **Seedling.** This awakening of the embryo from inactive to active life and growth including a succession of changes is called seed germination.

Provided the seeds are viable and are placed on suitable substrata, the following essential conditions are necessary for successful germination. These are suitable **supply of water, supply of oxygen** and a **favourable temperature.** With a few exceptions *e.g.* Mistletoe and certain varieties of tobacco, light has got a retarding influence on germination at the primary stage. If any of the above conditions be absent, the seeds will not germinate.

Viablity or Vitality of seeds means its capacity to renew growth or germinate. This vitality also depends on longevity of the seed meaning the length of time a seed can remain dormant (which is very variable) and still be viable. The maximum longevity of seeds on record is that of Indian Lotus which can remain dormant but able to germinate even after 200 years.

1. **Water**—Water plays a most significant part during germination. It softens the seedcoats and thus helps the embryo to break through them easily. It swells the seeds, as a result the seedcoat bursts. It also facilitates the entrance of oxygen into the seed through the wet cell-walls. Water dilutes the protoplasm and helps it to perform its various functions actively. Finally the transfer of various foods is only made possible by the presence of water from the endosperm or the cotyledons to the growing regions of the germinating embryo for the building up of protoplasm. Too much or too little water prevents germination.

2. **Oxygen**—Every living organism requires suitable supply of oxygen for respiration in order to live. During germination, the growing embryos respire vigorously owing to the vigorous activities of the cells for which the supply of oxygen is necessary for normal germination.

3. **Temperature**—Favourable temperature is necessary for successful germination. For every type of seed, there are always maximum and minimum temperatures, above or below which germination will fail. There is also an optimum temperature when germination is at its best.

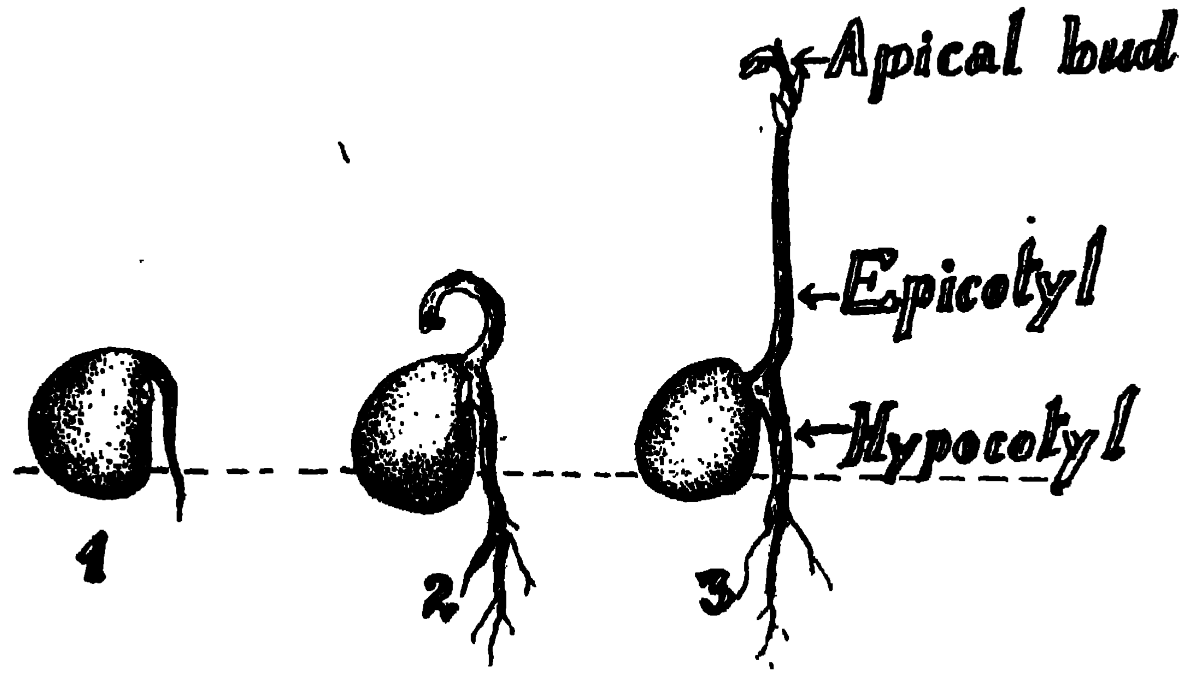
The essential nature of these conditions may be proved by the following experiments:

Seedlings—

There are two main types of germination—**Hypogeal or Hypogeous** and **Epigeal** or **Epigeous.** Both the above types are found in Dicotyledonous and Monocotyledonous seeds. Among the dicotyledons the seeds of Pea, Gram, Mango etc. have **hypogeal** whereas those of Castor oil, Gourd, Tamarind etc. have **Epigeal** types of germination. Among Monocotyledons, the germination is mostly hypogeal as in Maize, Rice, Wheat and other cereals though epigeal germination is not uncommon as in Onion. The germination of dicotyledonous and Monocotyledonous seeds will be discussed separately.

In Dicotyledonous Seeds—

Hypogeal germination.—This type of germination is typically exemplified by pea seed. After having been



Germination of Pea

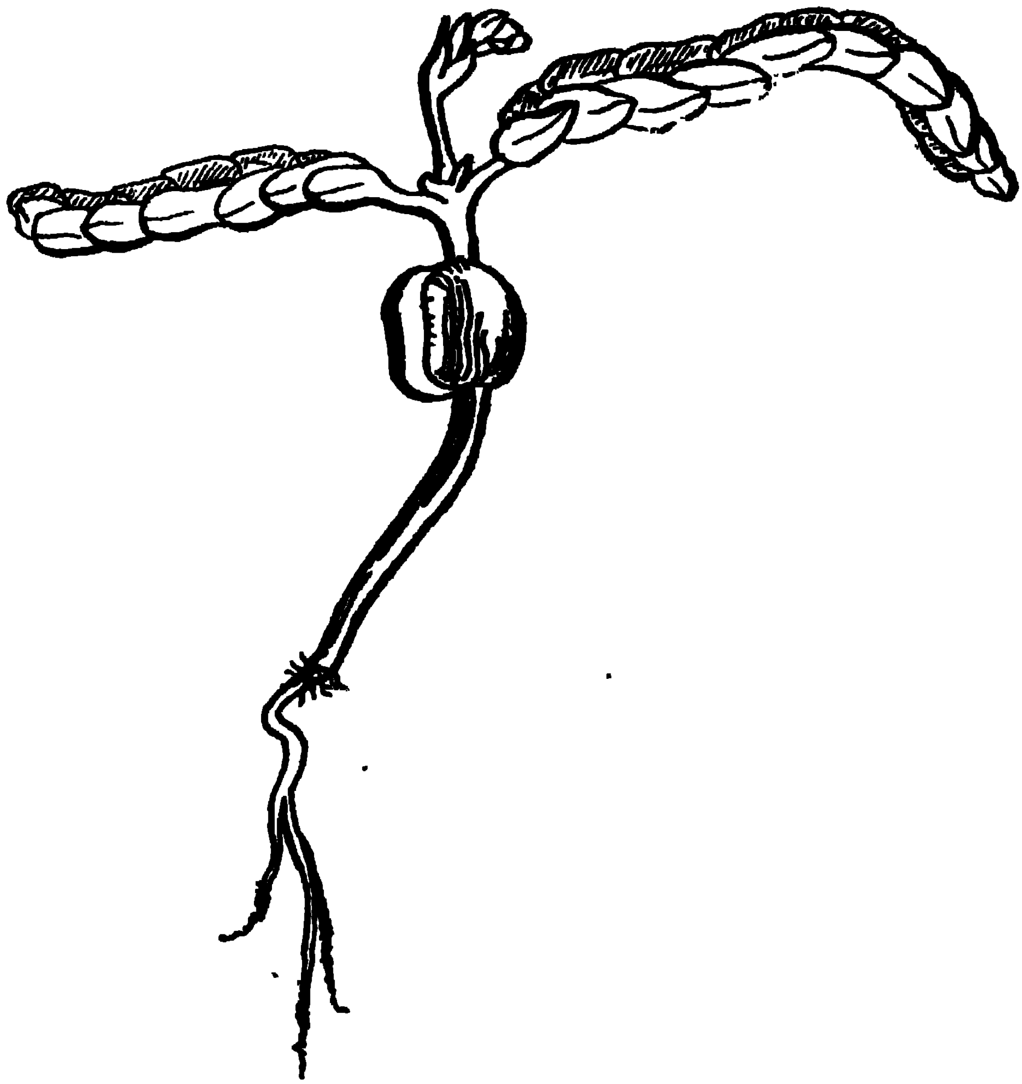
N.B.—For conditions of germination (Experiment), see Practical Biology.

placed under all the favourable conditions necessary for germination, the seed may start to germinate. There occur a series of changes preliminary to germination.

The seed imbibes sufficient quantity of water, resulting in the swelling of the seed and softening of the seed-coats. This initiates greatly increased physiological activities in the seed. By means of enzymes the stored foods inside the cotyledons are digested to some soluble and diffusible forms which can be easily assimilated directly by the active awakened embryo. Respiration is very marked at this stage and due to the presence of imbibed water, the protoplasm becomes more dilute to carry on renewed vital functions due to the transfer of digested foods to the growing regions of radicle and plumule, these organs now begin to grow. It is the radicle that usually starts its growth first and it is the first structure of the embryo that emerges out of the seed usually through the micropyle. This radicle then grows downwards into the soil forming an axis called the **Taproot** which in its turn produces secondary and tertiary branches in acropetal order, eventually producing the **root system.** In this way, the root system anchors the developing seedling to the soil. In such cases, the hypocotyl does not elongate. But during the development of the radicle due to the elongation of the epicotyl, the plumule is dragged out of the cotyledons in the form of a loop. The stalks of cotyledons also lengthen and help the plumule to emerge out of them. The plumule which is at first strongly hooked then straightens, out into the air and eventually forms the **Shootsystem.** The cotyledons being all along confined within the seedcoat, gradually shrivel up and ultimately die down when the seedling is completely established in the soil. *This type of germination is called hypogeal or hypogeous because the original position of the cotyledons is not disturbed at all, no matter whether the seed lies on the surface of the soil or inside the soil being all along confined within the seedcoat. In some cases, pea—seeds show epigeal type of germination (Priestley and Scott).*

Epigeal germination—

This type of germination is seen in Tamarind, Castor oil-seed etc. In this case also after the usual

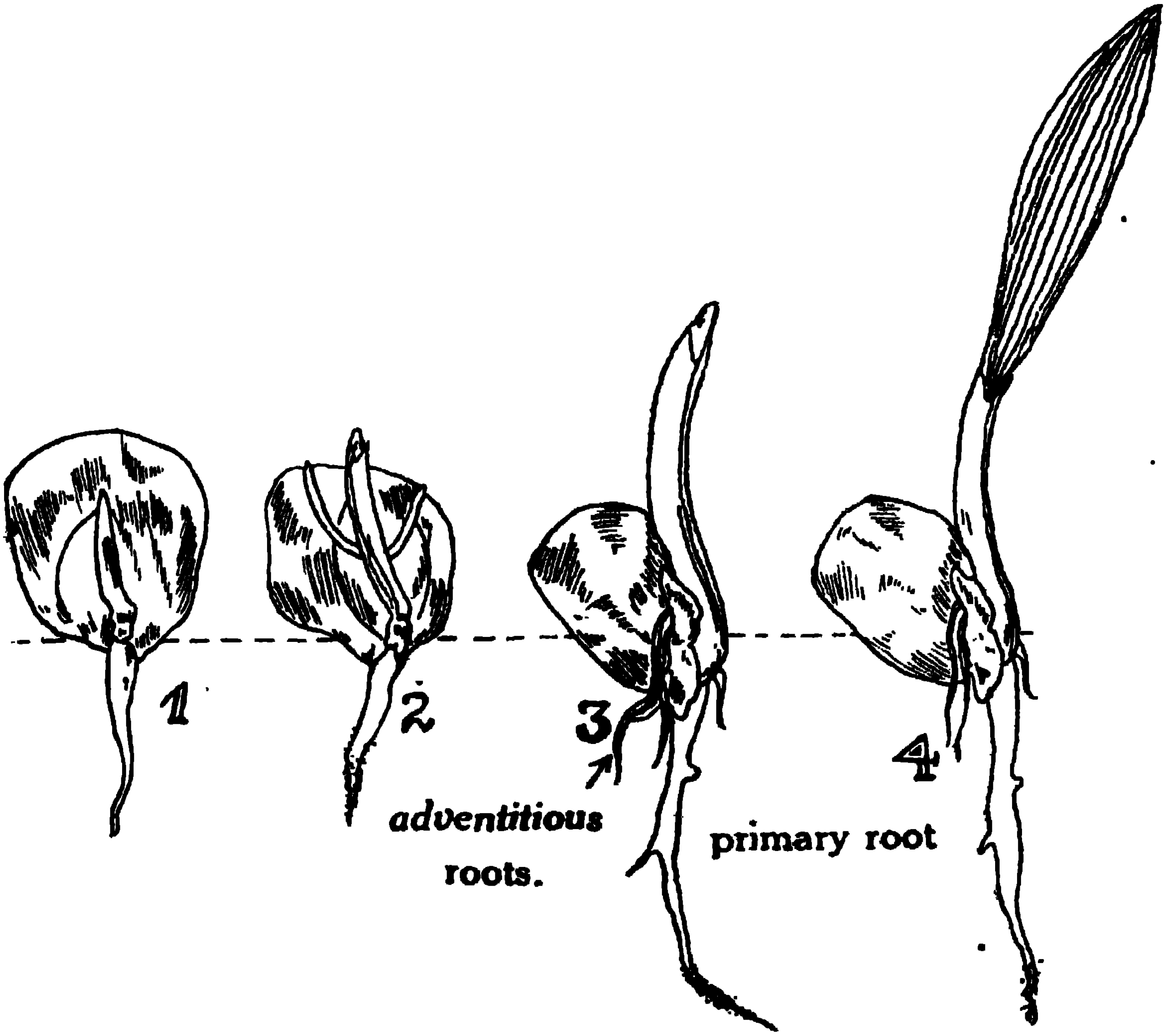


Tamarind Seedling

preliminaries, it is the radicle that comes out first and forms the rootsystem. During the development of the rootsystem, the hypocotyl begins to elongate vigorously as a result of which, the endosperm is carried up with the cotyledons from its original position. It has been pointed out that in this case, the cotyledons are relatively thin and at first act as absorbing organs Castor. The cotyledons, at first do not spread until the endosperm is almost entirely consumed. Finally, they separate and the remaining endosperm either dries up and falls off or their remnants adhere to the spreading cotyledons. The cotyledons now become green and function as first foliage leaves. The growth of the plumule is very slow in this case but ultimately it produces the shootsystem. The two cotyledons then dry up and fall away. *This type of germination is called epigeal because the original position of the cotyledons is disturbed, no matter whether the seed lies on the surface of the soil or inside the soil.*

In Monocotyledonous Seeds—

The germination of maize may be taken as typical of albuminous monocotyledonous seeds particularly the cereals and grasses. In such cases, the cotyledon or the scutellum which acts as an absorbing organ transfers food in digestible forms from the endosperm to the growing regions. As a result the plumule and the radicle begin to grow. As in pea, the hypocotyl does not elongate and the radicle is the first structure to come out but is followed almost immediately by the plumule. The radicle breaks through the coleorhiza and the common wall (fused pericarp and seedcoat) and forms a tiny primary root. Almost simultaneously with its development, adventitious roots begin to develop vigorously from



Germination of Maize

the point of origin of the radicle on the hypocotyl eventually producing an elaborate fibrous rootsystem. The primary root does not grow further and lives only for a short duration. In some cases, the primary root may last for several months. Later on, adventitious roots may also develop from the lower nodes of the axis of the shootsystem. The plumule surrounded by the coleoptyle, similarly emerges through the common wall and may often attain a length of ¾″ to 1 inch, when the apex of the coleoptyle bursts (scott) and the first foliage leaf emerges. In this way, gradually the shootsystem is produced. After the establishment of the seedling in the soil, what is left of the seed gradually decays on the soil. *The germination is no doubt hypogeal, the cotyledon (scutellum) being all along enclosed within the common wall.*

Seeds and germination—

Dicotyledonous

- Exalbuminous
  - Epigeal *e.g.* Tamarind, Gourd
  - Hypogeal *e.g.* Pea, Gram
- Albuminous
  - Epigeal *e.g.* Castor oil
  - Hypogeal *e.g.* Jack

Monocotyledonous

- Exalbuminous
  - Epigeal *e.g.* Water plantain
  - Hypogeal *e.g.* N. O. Naiadaceae
- Albuminous
  - Epigeal *e.g. Onion*
  - Hypogeal *e.g. Maize*

CHAPTER XI

ROOTS

Distinguishing features—

Normal roots are derived from the direct downward prolongation of the radicle as in all dicotyledons at the time of germination of seeds but in some cases roots also arise from other parts of plants such as stems, leaves etc. and these are distinguished from the former as **adventitious roots.** Adventitious roots are characteristics of all monocotyledons though in dicotyledons they are not uncommon. Roots whether normal or adventitious in origin are typically underground structures and are distinguished from certain types of underground stems by certain characteristics. Roots usually grow downwards into the soil forming the descending axis of the plant avoiding light in search of water and food-materials from the substratum. Usually they are radially symmetrical and non-green. The body is not differentiated into nodes and internodes and do not bear leaves, leaf-buds and true reproductive structures, the flowers. In dicotyledons, the branches develop acropetally and these are endogenous in origin (*i.e.* structures originating deep in the tissue of the root). The tip of the root is protected by a cap-like structure called the **Root-cap,** a distinctive structure found on no other part of a plant.

Parts of a root—

Typically, the free ends (usually varying from 4 to 6 cm.) of the main axis (taproot) and of its main branches are called **root-tips.** Behind the root-tip in the older part of the root, growth in length never takes place and in this region that the secondary roots make their appearance. This region may be called the **Permanent region.** The root-tips when critically examined shows that it consists of four distinct regions beginning from the very end which are as follows :-

The root-cap region—

The apex of the root is protected by a tissue often of considerable thickness and is called **Root-cap.** In some cases as in Screwpine, it is **Multiple** or many layered being distinguished from the former which is **Simple** as in Banyan. The main function of the root-cap is **protection** of the delicate growing tip. The outermost part of the root-cap is slimy and mucilaginous for this reason, the passage of the root-tip is greatly facilitated through the soil. During growth of the root, the cap withers away no doubt but is replaced continuously by an active formative tissue within.

The region of cell-division—

The growing point which is completely protected by the root-cap is the region where active cell-division takes place forming new tissues.

The region of elongation—

Just behind the growing point, the newly formed cells which were in a state of division now begin to elongate and form the elongating region of the root. It is in this region that growth in length mainly takes place and the growing point with the root-cap is pushed through the soil.

The region of root-hairs—

Just behind the region of elongation, there is a region of the root varying in length where practically the growth in length has ceased and is densely covered by minute elongated unicellular hairs called the **root-hairs** by means of which the root absorbs raw food materials in watery solution from the soil. It is in this region only that the actual absorption of nutritive material is confined. These hairs also firmly adhere to the soil particles thus giving additional anchorage of the root to the soil. The root-hairs develop superficially *i.e.* are **exogenous** in origin. As the root elongates, new root-hairs develop towards the elongating region and the old ones gradually die down.

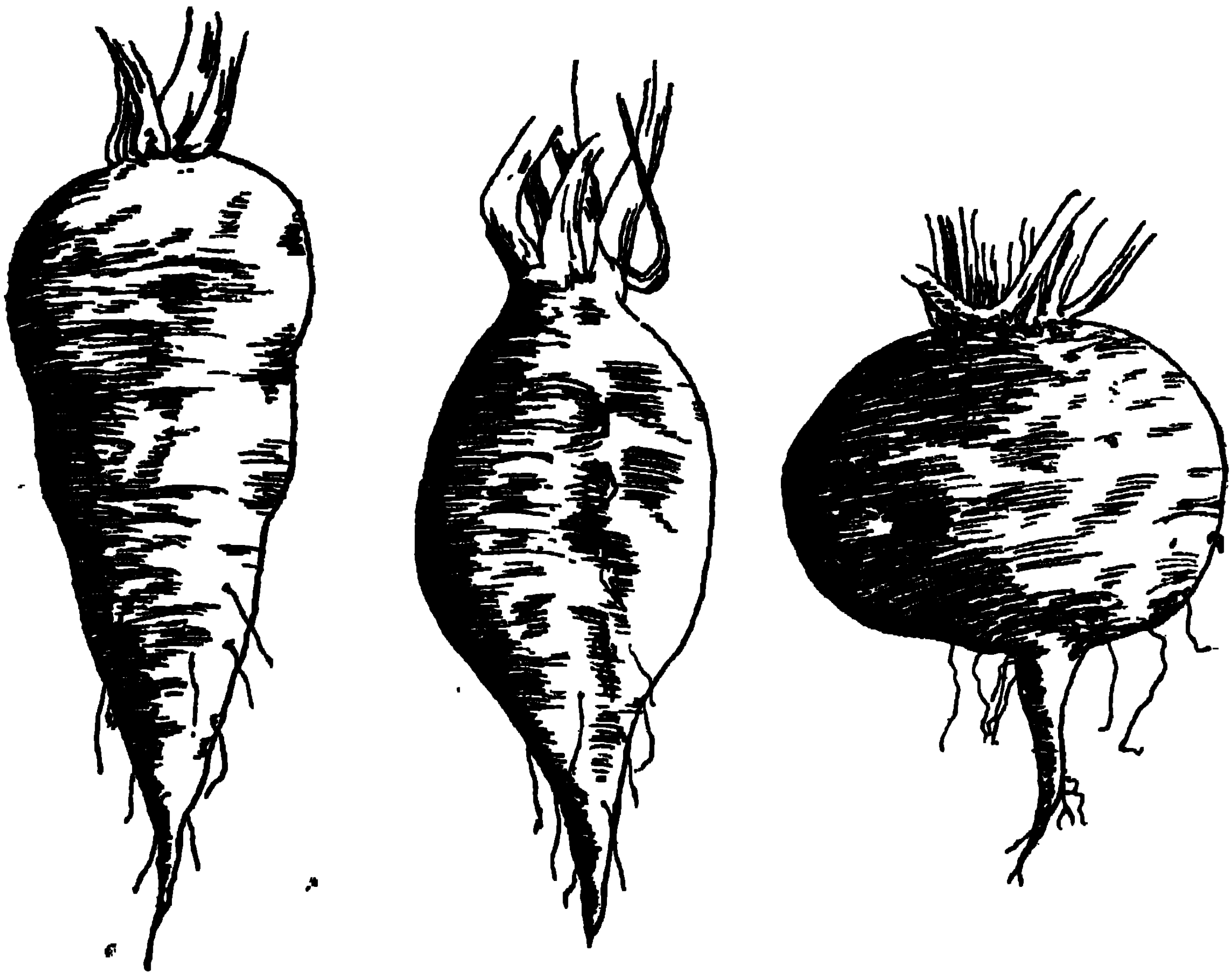
The above four regions together constitute the **root-tip.** The root-hair region is also called the *region of maturation* because various internal tissues and conducting channels are gradually differentiated.

The permanent region—

Behind the root-tip the main bulk of the root bearing the secondary branches is called the permanent region which is mainly concerned with the conduction of raw-food materials in watery solution already absorbed by the root-hairs from the roots, up the stem to the leaves for elaboration.

Kinds of roots—

Roots according to their origin are of two types namely **Normal** and **Adventitious** which have already been dealt with. The taproot of all dicotyledons is normal root and is called **Primary.** It produces **secondary** and **tertiary** branches in acropetal succession. The taproot with its branches forms the normal or taproot system. All other roots are **adventitious.** The *fibrous rootsystem* of monocotyledons is the typical example of such roots.



Conical Fusiform Napiform

Sometimes roots whether normal or adventitious undergo **modifications** in response to varied requirements. Thus for the purpose of storage, taproots become very much swollen and assume various forms. It may be

fusiform *i.e.* broadest in the middle with the two ends tapering like a spindle as in Radish; **Napiform** *i.e.* very much swollen in the middle but abruptly tapers towards the apex as in Beet, Turnip etc. and **Conical** when it is broadest towards the base and gradually tapers like a cone towards the lower end *i.e.* apex as in carrot. (Excepting the carrot, the various examples which are cited are in reality in case of turnip—swollen hypocotyl, in Beet—swollen root and hypocotyl and in case of radish—sowllen hypocotyl and base of leafy stem—Priestley and Scott.

Rarely however as in Ruellia tuberosa, the secondary branches of the primary rootsystem become swollen and **tuberous.** All these roots are collectively called **storage roots.** Similarly **adventitious roots** also undergo modifications to meet various requirements of plants. These modifications are due either *to meet special mechanical or special physiological functions* and the important types are described below :

Chief types of *modified adventitious roots performing special mechanical functions are*: **Prop roots, Stilt roots and Climbing roots.**

Proproots—In order to give additional support to large horizontal branches as in Banyan, adventitious roots originate from these branches which are at first aerial but subsequently grow vertically downwards and on reaching the ground fix themselves to the soil. These ultimately become thick and woody and thus act as *pillars* supporting the horizontal branches. These supporting roots when young are non-green.

Stilt roots—In many plants growing usually in swampy situations as in Screwpine, stout adventitious roots develop from the trunk and these grow obliquely downwards and finally by fixing themselves to the soil give additional anchorage to the plant.

Climbing roots—The climbing roots of such plants as Scindapsus officinalis (Gajpipul), Piper (Gachpan) are also a form of adventitious roots. Large number of these roots are usually produced on the sides of the stem from nodes and internodes growing along the surface of another plant or other suitable objects where they radiate and flatten out and hold the stem firmly to the surface. In Scindapsus (Gajpipul), these often become very long and often grow around the support forming an intricate network.

The various *modified adventitious roots performing special physiological functions* are as follows:

Storage roots—The storage is a normal function but sometimes it has carried it to such a degree as to completely modify the ordinary forms. Like the modifications of taproot for storage, several types of adventitious storage roots are recognised such as **Tuberous, Fasciculated, Nodulose etc.** When tuberous, some of the adventitious roots become swollen and fleshy like tubers as in sweetpotato (Rungaloo) where these roots usually develop from the nodes along with other fibrous roots. When all the fibrous roots become swollen and fleshy so that they seem to arise from a common point from the base of the stem giving rise to a cluster of fleshy roots, the roots become *fasciculated* as are exemplified in Asparagus (Satamooli).

Examples of *nodulose* roots are rare but are found in costus species and sometimes in Curcuma (Amada). In such roots only the apical portion of adventitious roots suddenly becomes swollen.

Tuberous roots of sweetpotato

Pneumatophores—Plants inhabiting swampy situation where the soil is waterlogged and poor in oxygen-content, develop special roots from underground parts which grow vertically upwards into the air for maintaining the gaseous interchange between the plant and the atmosphere. There are minute openings usually on the surface of these roots, through which the plant respires. Such *breathing roots or pneumatophores* are commonly found in Heritiera (Sundri). Rhizophora, Jussiaea (Keshardam).

Epiphytic roots—These are hanging aerial roots which are characteristic of *epiphytes* such as orchids. These are not positively geotropic *i.e.* do not grow vertically downwards like the aerial roots of banyan and

Fasciculated roots of Asparagus

are usually green towards the tip. Such roots develop special structures called *Velamen* on their surface for absorption of atmospheric water.

Haustoria—These are highly modified types of adventitious roots for absorbing prepared foods from other plants and are found in some parasitic seed-plants such as the common Dodder, Mistletoe, Loranthus, Orobanche etc. The common dodder is a parasitic twiner devoid of foliage leaves which twines round suitable plants called hosts and sends out short roots into the stem of the host plant wherever the parasite comes in contact with it. Such roots are called *Haustoria* or *parasitic roots* which on penetrating the host plants establish connection with their food-conducting channels robbing them of the prepared food and often killing them by this method.

Assimilatory roots—In Tinospora (Goloncho) long, hanging aerial adventitious roots develop which are green in colour. Due to the presence of the green pigment, the chlorophyll, these roots can prepare organic foods in the presence of sunlight from formative materials. Such roots are called *Assimilatory roots* which are concerned with the process of assimilation.

Functions of roots—

Normal functions of roots whether normal or adventitious are :—

1. **Anchorage**—*i.e.* fixation of the plant to the soil (environment) which is a *mechanical function.*

2. **Absorption and conduction**—Raw food materials which are absorbed in watery solution by the root-hairs are conducted through the root to the stem.

3. **Storage**—Roots also store up sufficient quantity of food and water in them for future use of the plant.

Functions of absorption, conduction and storage together constitute the *physiological functions of the root.* Besides these normal functions roots also carry on special mechanical and special physiological functions which are as follows :—

Special mechanical functions

1. Additional support as in the case of prop roots of banyan.
2. Additional anchorage as in the stilt roots of screwpine.
3. Climbing roots of Scindapsus (Gajpipul).

Special physiological functions

1. Storage as in the fleshy roots of sweetpotato.
2. Breathing as in the pneumatophores of Heritiera (Sundri).
3. Absorption of moisture from the atmosphere as in the epiphytic roots of orchid.
4. Absorption of prepared food from other plants as in the haustoria of dodder.
5. Assimilation as in the assimilatory roots of Tinospora cordifolia.
6. Vegetative propagation—This function is performed by the roots of Trichosanthes (Patal). Many roses, Black-berries and similar other plants are often propagated by root-cuttings.

- **Roots**
  - **Normal**
    - **Ordinary forms**
      - **Taproot system** *e.g.* In dicotyledons.
    - **Modified forms** Storage roots
      - Fusiform *e.g.* Radish
      - Napiform *e.g.* Beet.
      - Conical *e.g.* Carrot
      - Tuberous (Branches) *e.g.* Ruellia
  - **Adventitious**
    - **Ordinary form**
      - Fibrous root system *e.g.* In monocotyledons
    - **Modified forms**
      - Performing Special mechanical function
        - Prop-roots *e.g.* Banyan
        - Stilt-roots *e.g.* Screwpine
        - Climbing-roots *e.g.* Gajpipul
      - Performing Special physio-logical function
        - Storage-roots
          - (*a*) Tuberous *e.g.* Sweet-potato
          - (*b*) Fasciculated *e.g.* Asparagus
          - (*c*) Nodulose *e.g.* Amada
        - Pneumatophores *e.g.* Sundri.
        - Aerial roots *e.g.* Orchid.
        - Haustoria *e.g.* Dodder
        - Assimilatory *e.g.*. Tinospora

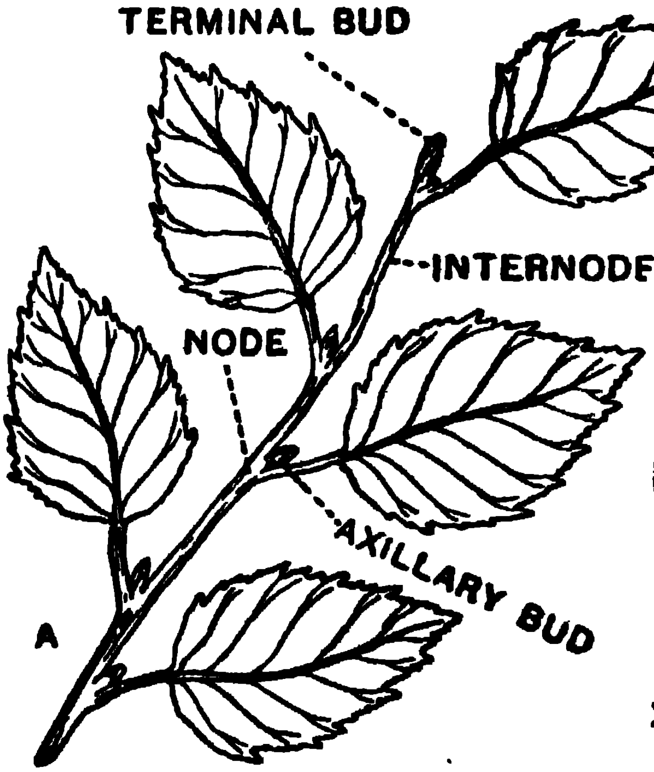
Function of Roots

- **Normal**
  - **Mechanical function** *i.e.* **fixation**
  - **Physiological**
    (*a*) Absorption,
    (*b*) Storage
- **Special**
  - **Special mechanical functions**
    - Additional support *e.g.* Prop roots of banyan
    - Additional anchorage *e.g.* Stilt roots of screwpine
    - Climbing *e.g.* climbing roots of Gachpan, Gajpipul
  - **Special physiological functions**
    - Storage *e.g.* swollen tap-roots and fleshy adven. roots.
    - Breathing *e.g.* Pneumatophores of Sundri.
    - Absorption of moisture from air *e.g.* aerial roots of orchid.
    - Absorption of prepared food of other plants *e.g.* Haustoria of dodder.
    - Assimilation *e.g.* Green aerial roots of Tinospora
    - Propagation *e.g.* Waterhyacinth, roots of Patal,

CHAPTER XII

THE SHOOT

The structure developing from the plumule with axis, branches, leaves and flowers goes by the name of **shoot.** The main axis is the stem which gradually branches in acropetal succession. The stem has the tendency to grow upwards and to bear dissimilar organs like the leaves. The development and healthy growth of the leaves are dependent on sunlight therefore the stem seeks light.



Shoot

Longitudinal section of bud

The stem bears at its ultimate apex, a much compressed leafy structure which is called a **Bud.** The similar members developing on the stem *i.e.* the branches arise from the superficial tissue of the main stem. The position from which the leaves arise is called the **Node.** The branches arise from an angular position made by the leaves with the main stem. The upper angle made by the leaf with the stem is the **AXIL.** The axil is the most important position because buds arise from it and develop into branches. The space which is free from any leafy structure on the stem between two successive nodes is called the **Internode.** Sometimes the *internodes* are suppressed and the leaves seem to arise from the same position as in **Pineapple** (Anaras). This is the *Rosette* type.

Distinction between a root and a shoot.

Root.	Shoot.
1. The root arises from the radicle.	1. The shoot arises from the plumule
2. The root avoids light.	2. The shoot seeks light.
3. The root is the descending axis.	3. The shot is the ascending axis.
4. Root bears organs like itself *e.g.* branches.	4. The shoot bears both similar and dissimilar organs *e.g.* branches and leaves.
5. The apex of the root has a rootcap.	5. The apex generally terminates in a bud.
6. There is no node or internode.	6. There are nodes and internodes.
7. There is absence of green colour.	7. Green colour is invariably present.
8. Branches are endogenous in origin.	8. Branches and leaves are exogenous in origin.

Functions of the stem :—

(1) The food material in solution goes up from the root to the leaves through the stem.

(2) The manufactured food from the leaves is transferred to different parts through the stem.

(3) It sometimes acts as a reservoir of reserve material for future use.

(4) It bears leaves, branches and flowers to their advantage.

Forms of Stems—

Stems are generally *round* as in the majority of plants. Sometimes they are *triangular* as Cyperus rotundus (Mootha) or square as in Ocimum sanctum (Toolsy) or *flattened* as in Opuntia (Phanimonsa).

A classification of plants is often made according to the nature of the stem *e.g.* **Herbs, Shrubs** and **Trees.**

Herbs—These are soft and delicate plants and are characterised by the absence of the thickening and hardening of tissues. They are again subdivided into three kinds *e.g.* *Annual, Biennial* and *Perennial.*

Annual—These plants complete their lives in one season only *e.g.* wheat, rice etc.

Biennial—These plants complete their life-cycles in two seasons. In the first season, they grow and store up reserve food matter for the next season which is primarily meant for flowering and fruiting. The Biennials are often cut short in the duration of their life-cycles and become annuals *e.g.* Radish (Moola), Cabbage, Beet.

Perennial—These plants live for more than two seasons *e.g.* Plantain, Ginger, Canna.

Shrubs—The plants are not very large but they are characterised by hard and woody stems and a number of equally developing stems arise from the level of the soil as Rose, Chinese Rose (Jaba), Croton, Cotton.

Trees—These plants have main axes next to the soil which are known as Trunks and are considerable in bulk and are hard and woody, *e.g.* Mango (Am), Teak, Rose-apple (Golap-jam).

Modifications of the Stem—

I. Underground stems or subterranean forms.

Stems are generally found above the ground but are often underground or subterranean, the usual green colour is absent, the leaves are replaced by scale leaves and often they become reservoirs of reserve materials. They are commonly mistaken for roots but are characterised by having structures similar to stems, bear scale leaves and are often divided into nodes and inter-nodes. The underground stems perform the following functions:—

(1) They store up reserve food,

(2) They help in perennation *i.e.* allow the plant to tide over a period of bad weather conditions,

(3) They help in propagation of plants.

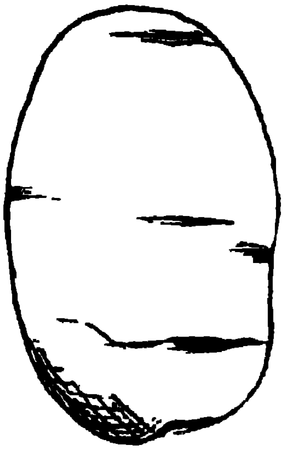
The common forms of underground stems are:—

(1) *Rhizome,* a fleshy stem occurring under the soil. It is divided into nodes and inter-nodes. It bears scale leaves from the axils of which annually leafy shoots arise. It grows at one end and dies at another *e.g.* Turmeric,

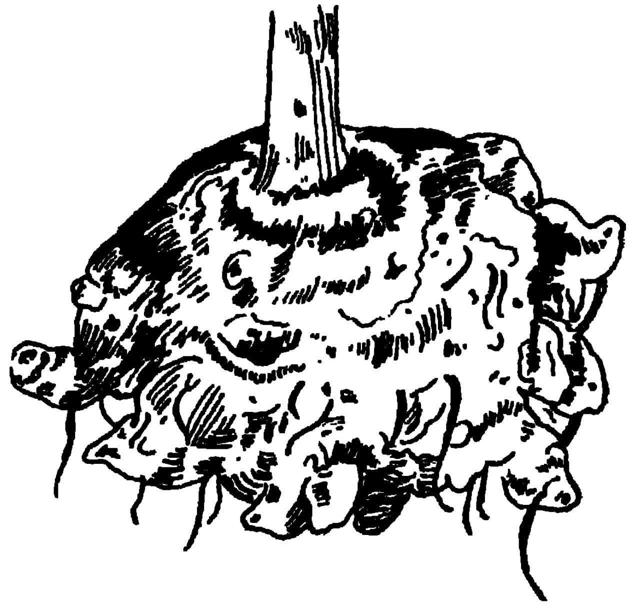
Ginger etc. Sometimes the rhizome is vertical and is called Rootstock as Alocasia (Mankachu).

Rhizome of ginger

(2) *Tuber,* this is the form of underground stem which becomes swollen with the accumulation of starchy food material. There are scales on a tuber with buds which are known as eyes *e.g.* Potato.



Tuber of Potato

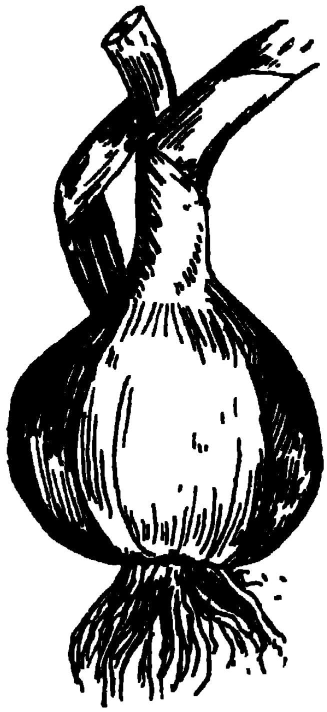


Corm of 'Ol'

(3) *Corm,* this form of underground stem is much swollen and bears a number of thick leaves on the top.

The corm bears a large number of roots and a number of buds on its sides *e.g.* Amorphophallus (Ol), Kohl-rabi or Ol-kapi, Saffron (Jafran).

(4) *Bulb,* this form has a small disc bearing a number of closely packed leaves. The leaves are fleshy and store up reserve food materials *e.g.* Onion (Pianj), Garlic, Lily.



Bulb of onion

Bulbs are of two types *e.g.* Tunicated and Naked. Tunicated bulbs have fleshy scales enclosing one another in concentric manner and covered externally by dry scales as in Onion, Garlic while the naked bulb has fleshy scales but not covered externally by dry scales as in Lily.

The underground stems have the following special features :—

(*a*) They often bear scale leaves.

(*b*) They store up reserve food.

(*c*) They are often divided into nodes and internodes.

(*d*) They bear buds.

II. Stems found aboveground—

The stems that are found on the ground are either erect or they trail along the ground. The former is known as Erect and the latter Prostrate or Weak.

Thorn

Erect stems are generally found all round the earth. When the growing point elongates almost straight and the main stem bears lateral branches in acropetal succession so that the whole plant looks like a conical structure, it is called **excurrent** as in pine, deodar. When the stem by repeated branching assumes a bushy structure and the main axis is difficult to find out, it is called **deliquescent** as in Banyan, Jack-fruit tree. Sometimes the erect stems are very jointed as in Bamboo. These are known as **Culms.** The stems of palms are unbranched bearing a tuft of leaves. These are known as **Caudex.**

Tendril

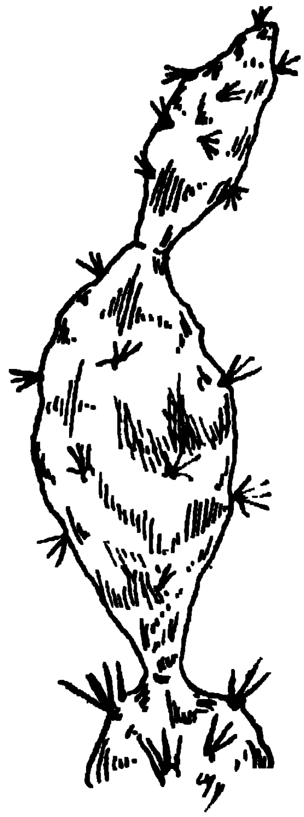
The aerial stems are sometimes modified as follows: —

(1) **Tendril**—the stem is modified into a thread-like structure as in Cucurbita family (Kumra, Lau etc.). They help the plant to climb.

(2) **Thorn**—Sometimes stems are changed into spinous processes which protect the plant *e.g.* Bael, Lemon.

(3) **Cladode** and **Phylloclade**—these are flat leaf-like structures which are modified stems. They arise in the axil of leaves and often bear flowers. When the flat structure has but one internode, it is called cladode *e.g.*

Asparagus (Satamooli). When there are several inter-nodes it is known as Phylloclade *e.g.* Opuntia (Phani-monsa).



Phylloclade

Weak Stems—

When the plants are not erect, they may trail along the ground and are known as the trailing plants while others climb up on some support and are known as climbing plants.

Weak plants may be :—

(*a*) **Procumbent,** when they travel along the ground but do not root at the nodes *e.g.*, Basella (Puin).

(*b*) **Decumbent,** when the growing point rises while the other part remains flat on the ground as in Portulaca.

(c) **Creeping,** when they root at the nodes *e.g.*, Cynodon (Durba grass).

There are several modified forms of subaerial stems:—

(1) **Stolon,** when the plant arises as a branch and travels over the ground and forms an arch rooting at the place where it meets the soil *e.g.* Hydrocotyl (Thulkuri), Gooseberry.

(2) **Sucker,** travels along the ground and the separated plant is capable like the stolon to lead an independent life *e.g.*, Mint (Pudina), Chrysanthemum.

(3) **Runner,** it is a thin prostrate branch. It is produced from axillary bud, goes to some distance and produces roots and becomes an independent plant when separated as in Oxalis.

(4) **Offset,** it is a short, thick and prostrate branch. When separated it becomes an independent plant as in Pistia (Pana).

Climbing plants may be :—

(1) **Tendril climbers,** which climb by means of tendrils *e.g.*, Cucumber.

(2) **Root climbers,** give rise to additional roots from the stem to climb up as a support *e.g.*, Piper betle (Pan).

(3) **Hook climbers,** when the plants rise up by hooks on their supports *e.g.*, Artabotrys (Kantali Champa).

(4) **Stem climbers,** when plants twine up their support by means of stems *e.g.*, Dolichos.

Stems

- **Normal**
  - **Erect**
    - Excurrent *e.g. Deodar*
    - Deliquescent *e.g.* Banyan
    - Caudex *e.g.* Palm
    - Culm or Haulm *e.g.* Grass, Bamboo, Sugarcane.
  - **Weak**
    - Prostrate
      - Not rooting at the nodes
        - Prcumbent *e.g.* Puin, Evolvulus Sp.
        - Decumbent *e.g.* Portulaca.
      - Rooting at the nodes
        - Creeping stem *e.g.* Durba.
    - Climbing
      - Twiners
        - *a.* Dextrose
        - *b.* Sinistrose
        - *c. Lianas.*
      - Rootclimber *e.g.* Pan.
      - Tendril *e.g.* Gourd, Passiflora
      - Petiole-climber *e.g.* clematis (chagalbati).
      - Hookclimber *e.g.* Kantali-champa.
      - Ramblers e.g. Rose, Cane.
- **Modified and metamorphosed forms.**

Modifications of Stem

Subaerial

1. For propagation
   a. *Runner* eg. Oxalis Sp.
   b. *Stolon* e.g. Hydrocotyl Sp.
   c. *Offset* e.g. Chrysanthemum Sp.
2. For climbing
   e. *Tendril* e.g. Passiflora
3. For self-defence
   f. Thorn e.g. Lemon
4. For assimilation
   g. *Phylloclade* e.g. Phanimansa.
   h. *Cladode* e.g. Asparagus Sp.

Subterranean

For propagation, perennation and storage
   a. *Rhizome* and *Rootstalk* e.g. Ginger, Alocasia
   b. *Tuber* e.g. Potato
   c. *Bulb* e.g. Onion
   d. *Corm* e.g. Ol.

Bud—

Bud is really a condensed shoot having a delicate growing point with a rudimentary axis and having compressed nodes and inter-nodes surrounded by minute rudimentary leaves.

Plants generally show their development by the growth of the terminal bud where leafy structures are at first found to be in a compressed condition. The compressed structure shows small leaves in various stages of growth. This rudimentary structure consisting of a number of leaves, nodes and inter-nodes in a miniature form is called a **Bud.** The Buds are generally found at the apex of the main stem or branches. Another conspicuous position is the axil of a leaf. The buds found at the apex are called **Terminal** while those at the axil are called **Axillary.** Usually one bud is found at the axil but if there be more than one bud, the **additional** buds are known as **Accessory** buds.

Normal and **adventitious** buds—

Buds when they arise from their normal positions are said to be normal but sometimes they are found to arise.

Bryophyllum

from abnormal position when they are known as **adventitious** buds *e.g.*, Leaf of Bryophyllum (Pathorkucha).

Dormant and deciduous buds—

Sometimes the buds without unfurling the foliage remain in an inactive state only to renew their growth when there is any necessity. In cold regions of the world, the buds protect the plant by remaining dormant in the unfavourable period and grow when the rigours of climate disappear.

Buds may appear but fall away before showing the foliage. Such buds are called *deciduous* buds.

Sometimes buds might appear but on falling to the ground do a distinct service since by developing into an independent plant, such a condition gives an example of vegetative propagation. These buds are called *Bulbils* *e.g.* Dioscorea (Chuprialoo).

Buds can be classified broadly into two types :—

(1) *Vegetative* or Leaf-buds.

(2) *Reproductive* or flowerbuds.

The bud developing ordinary foliage is called a Vegetative bud while the bud which develops into a flower is called a Reproductive bud.

Buds are often without any protective covering or contrivance; such buds are called Naked buds. These buds are found in tropical countries.

Buds are often protected by means of scale like structures. Such Buds are known as scaly buds. Sometimes leafy structures overlap or the outer leaves become thick and fleshy and still another mechanism is found namely a resinous secretion or the presence of hairs on the buds to protect them from drying.

BUDS

- **Buds**
  - **According to the nature**
    - **Leaf buds**
    - **Flower buds**
  - According to origin
    - Normal
      According to position
      - Terminal or Apical
      - Axillary or Lateral
    - Adventitious
      - Epiphyllous
        e.g. Bryophyllum
      - Cauline
        e.g. Rose
      - Radical
        e.g. Trichosanthes.