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General Botany

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SUBJECT

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The study of plants is an adventure into a world whose inhabitants are strangely different from those of the animal world. Members of the plant world feed without mouths, move without limbs, 'see' without eyes, and find their way about without the aid of brain or nervous system.

The plant world is a world of pioneers. In the exploration of the earth and settlement of the land, its members prepare the way, and only after the occupation of the land by plant may animal possess it. Not only do plants colonize tracts of new land, but they also render them fertile. Simple plants, such as the familiar yellow and green lichens, are able to gain a hold and penetrate the barren surface of rocks and help the forces of nature, such as rain, frost, and wind, to break it up and form from the rock the mineral debris which is the beginning of soil. Many generations of some of the simpler plants must colonize and live and die upon the soil before it becomes fertile enough to support the higher kinds of vegetation. The fertility of the earth, created by plants, is also

maintained by them. If a soil were deprived of all vegetation, it would in time pass back into its original barren state.

Plant Nutrition. — Green plants, by virtue of their green pigment Chlorophyll, possess the power of manufacturing the food materials on which their own nourishment and that of the animal world depend. The food materials which the green plant manufactures are chiefly of two kinds, sugars, and proteins; the former composed of the three elements Carbon, hydrogen, and oxygen, and the latter composed of these, together with nitrogen and other elements.

The raw materials which the green plant uses in making sugar are water and carbon dioxide — simple substances abounding on the earth. The energy used in the process of manufacture is the radiant energy of the Sun. The actual elements of which the raw materials are composed, together with the energy supplied are temporarily stored in the manufactured food substance. In course of time the food substance, by uniting with oxygen, undergoes combustion, when the raw materials

are reproduced and the energy liberated. In this way the manufactured food materials provide the energy used by living things.

The study of plant nutrition discloses the facts that materials used by plants in the construction of their bodies are of the same as those used by animals, and that the forces employed by both animal and plant worlds in the work of living is derived from the same ultimate source — the Sun.

The green plant is an accumulator of energy. Each molecule of food material which it makes may be compared with an efficient storage battery, and when that molecule is decomposed, the store of energy is freed. Green plants in sunlight continue this process of manufacture on so lavish a scale that the products suffice not only to form the fabric of their own bodies and those of animals, but also to supply energy for living for both vegetable and animal worlds.

Source of fuel: — Plants by their past activities, have made the world's fuels, peat and, more important, coal.

The source of the latter's energy is this: long ago the sun shone on the leaves of prehistoric green plants growing on swampy ground. Some of the radiant energy was absorbed by the green leaf and was used in the manufacture of sugars. The plant consumed much of this sugar in the course of its life, but some, undergoing slight chemical changes, became part of the woody framework of the plant. The tree died and fell into the mud. Before decay of the wood was complete, the plant was embalmed and carbon, hydrogen and oxygen, originally united by the sun's energy and the plant's activity, remained united, and the plant remains became still further carbonized. The energy derived from the sun remained thus dormant until, in the furnace of the steam-engine, the coal unites with oxygen, re-forms carbon dioxide and water and liberates the long-stored energy.

Thus the plant-world supplies the power employed alike in the animal body and in industrial enterprise. Even though Man resorts to water-power for electrical energy, he must still apply to plants for rubber and

gutta-percha to insulate the cables and for oils to lubricate the machinery.

Natural Medicines:- Discoveries have shown that, beside the food materials supplied by plants for body-building and sources of energy, there are others of more obscure nature which play the part of natural ~~malnutrition and~~ preventive medicines. Without these malnutrition and disordered growth of the animal body result. These accessory foods, known as vitamins, are, in the main, plant-products. The progress of chemical discovery has already begun to work a change in the relation between animal and plant worlds. Already the chemist has succeeded in building up sugars from simpler materials, and has gone far towards synthesizing the complex proteins which are essential constituents of living matter. The ~~chief~~ chief inorganic (mineral) nitrogen compounds used by plants in building up proteins are nitrates, soluble salts which owe their presence in fertile soil to the activities of certain kinds of bacteria at work on the dead remains of animals and plants. Slow

production of nitrates by the soil bacteria and leaching out of the soluble salts by rain frequently result in an insufficient nitrate contents in the soil. To make good this loss, it has long been the custom to apply artificial manures containing nitrogen. Even so the growth of the World's crops is limited by insufficiency of cheap supplies of such manures.

The plant world sustains the life of land & sea. The members of its highest and lowest groups make the greatest contribution. The seed-bearing plants supply food-stuffs, fibres, such as cotton, flax, Jute, timbers, resin, rubber, Gutta-percha, Camphor, Waxes, oils, Varnishes, spices, Condiments, perfumes, dyes, ~~an~~ and drugs. They sustain the life of the earth. The algae, the lowest division of plants, consisting of seaweeds and innumerable microscopic forms, support the teeming life of the sea.

Algae and Fungi:— The lowest division of plants comprises not only the algae but also the fungi (e.g. mushrooms etc) The fungi lack the green pigments, chlorophyll, and are therefore, unable to feed themselves, but live animals

must obtain their food from outside sources. A fungus therefore, lives either as a 'parasite', preying on other plants, or as a 'saprophyte' on the dead remains of once living things. In this respect fungi resembles other members of the plant kingdom - the bacteria, which are of minute & extremely simple structure. Fungi and bacteria - the underworld of plants - play a great part in the world's work. Bacteria are largely responsible for the fertility of the soil. These simple plants are the world's sanitary authority. By their ordered activities dead remains of once living things are decomposed, step by step, until they are resolved into the simple inorganic substances from which green plants constructed in the first place.

In spite of wonderful performances in applied chemistry, the plant world still remains, and will remain, the great source of supply of materials and energy for the sustenance of animals and men and for the development of social and industrial life.

We will be to give an outline of the classification of the

Vegitable kingdom and the outstanding characteristics of the main groups. The four principal sub-kingdoms (Phyla) are: (1) flowering plants. (2) fern like plants (3) Mosses & liverworts (4) algae, fungi, bacteria and lichens.

Phylum 1 Comprises all flowering plants, trees, shrubs, or herbs. They are technically known as phanerogams. All the members have ~~roo~~ root-, stem, and leaves, which are traversed by tough strands or 'veins' and all produce seeds. There are two sub-divisions to this phylum: (1) angiosperms, in which the seeds are protected by being enclosed in a special seed-case, and (2) gymnosperms, in which the seeds are not specially protected. The large majority of seed plants belong to the former sub-phylum; Conifers, such as fir, pine, and larch belong to the latter.

The remaining phyla comprise the great groups of flowerless plants, called cryptogams. Neither flowers ~~nor~~ nor seeds are produced. The propagation method is by means of spores. Phylum 2 Comprises the Vascular cryptogams that- include all ferns, the club mosses, and the horsetails.

Phylum 3- Consists of mosses and liverworts, known as

'Bryophyta' which possess neither roots nor vascular strands. Phylum 4. The last includes the lowest plant forms, called the 'thallophyta'. The plant body is not differentiated into root, stem, and leaves, but is of very simple form and known as a 'thallus'. Many of them are of microscopic size. The 'thallophyta' include the following four groups. 1. algae, which contain Chlorophyll e.g. the green slime of ponds and all seaweeds 2. fungi, which lack Chlorophyll e.g. toadstools, and moulds. and moulds, 3. bacteria minute fungi of great importance 4. lichens, which are compound plants consisting of an alga living in association with a fungus.

Lesson TWO:— External Features of a Plant.

The great variation in plant forms has been brought about by the keen struggle for existence which everywhere takes place. It is a struggle for bare foothold, a competition with other plants for food and light, a perpetual endeavour to resist the unfavourable influences of weather and the attacks of animal foes. It is not merely a struggle for the maintenance of the life of the individual but from a continued existence of the species, for the production of

healthy seeds which may have some chance of carrying on the never-ceasing warfare.

Hence have gradually been evolved all sorts of shapes and forms, differences in size and habit, diversities in colour and odour, and endless modifications in structural detail, all concerned with maintaining the life of the individual or of the species.

In beginning the study of plants we will fix our attention on the wall flower, with which everyone is familiar, and consider what are the most striking points in its construction. The wall flower, like all flowering plants, has two distinct parts which clearly live under very different conditions. These parts are easily distinguished. There is a branched, colourless root which is fixed firmly in the ground and consequently lives in perpetual darkness; from this rises the upright shoot, consisting of the stem bearing leaves, ~~with~~ which is surrounded on all sides by the air and exposed during daytime to the sunlight.

Root and stem:—on examining the root more closely, we find that there is a main portion which grows straight downwards in the same

line with the direct axis of the stem. A main root of this kind is called a tap root. This main axis of the root bears side branches which grow obliquely downwards, forming an acute angle with the tap root. From these lateral roots further branches may be born which penetrate the soil in all directions. If the plant is very carefully removed from the soil for examination, it will be seen that particles of earth stick firmly to the youngest branches of the root a little behind their extreme tips. This is because these regions of the root are covered with very fine root-hairs which have withered away from the older parts. These root-hairs are not easily visible to the naked eye, but may be discerned with a magnifying glass. They are clearly visible on the young roots of seedlings which are grown on moist blotting-paper. Examination of such seedling roots with a hand-lens will also reveal a thimble-shaped cap over the extreme root-tip. Growth takes place at the root-tip, and the root-cap thus serves as a protection for the growing plant. The stem is also branched, each branch arising from the angle between a leaf and the erect main stem. This angle between a leaf and the stem upon which it is

does some definite work for the good of the whole. The highest plants are those in which division of labour is most complete that is, a distinct organ is set apart for each distinct kind of work. The wallflower is an example for a very highly organized plant, and we will now consider the main functions of its organs.

The root in the wallflower, as in the higher plants generally, has two chief functions: it has to fix the plant firmly in the ground and also to take up food from the soil. The chief office of the leaves is the absorption of food from the air in the form of the gas, Carbon dioxide. The stem has to conduct the food, absorbed by the root and the leaves, to other parts of the plant, and also to support the leaves in such a position that they may best be able to do their work; moreover, it has to bear the flowers. The duty of the flowers is to produce seeds and, so to provide a supply of new wallflowers for the future. The organs which have been mentioned are of two kinds. The root, stem and leaves do work for the benefit of the particular plant to which they belong; these are called the vegetative organs. On the

other hand, the flowers are concerned with the production of fresh plants; they are called the productive organs.

DURATION OF PLANT LIFE.

Many common plants, such as the sweet pea and the poppy, appear above ground in the early spring, arising from seeds which have lain dormant in the soil during the winter. These plants grow rapidly and form flowers. Towards the end of the season they produce fruits from which more seeds are eventually shed. Later on the rest of the plant dies away, and the same sequence is repeated in the following season. Plants like these, which pass through their whole life-history in the course of a single year, are called 'annuals'.

Some plants, particularly weeds such as the groundsel and shepherd's purse, pass through their whole life-cycle in a much shorter interval of time, so that several successive generations may be produced in the same year. ~~Such~~ Such plants are termed "ephemerals" and on account of their rapid growth are readily able to establish themselves on new ground.

Biennials:— A large number of plants require more than a single

year to form seeds. One season is not enough for them to accumulate a sufficiency of food materials. Some of these, which are termed biennials, flower only in the second year of their life and then die away; for example the carrot, beetroot, turnip, mullein etc. During the first season's growth these plants produce only rosette of leaves at the surface of the ground. The food substances formed by the leaves pass into the underground portion of the plant, which becomes swollen and serves as a storage-organ. Through the winter the plant remains in a dormant condition; and the following year rapid growth takes place, largely at the expense of the stored-up food, resulting in a stem bearing a mass of flowers. Seeds are thus produced, and when the seed is ripe the plant dies.

PERENNIALS:— The vitality of many plants is not completely exhausted by the production of flowers & fruits; sufficient food material remains to support renewed growth in the following spring. If this goes on from year to year, the plants are called 'perennials', and in nature a large number of plants persist in this way. We may give as examples the stinging

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perennials it is usual for some part to die back at the approach of Winter: this is well seen in the falling of the leaves of such as ~~Teak~~ Teal, Toon, which are therefore described as deciduous trees. Some other such as the ~~holly~~ Sal & ~~laurel~~ Mango are evergreen, bearing leaves at all times of the year. These Woody perennials lay down their store of food throughout the woody portion of the plant, and this food is here again responsible for the rapid sprouting which takes place in the spring.

Reaction to Winter:— Why so many plants die back to varying extents on the approach of Winter? The answer concerns the intake of water by the plant. One of the chief functions of the root is to absorb food from the soil. This food is a very weak solution in water of the various mineral substances present in the soil, many of which are necessary for the nourishment of the plant. Much of the moisture that reaches the leaves is given off from their surface in the form of water vapour, while some is retained and built up into the substance of the plant.

During the Winter the temperature of the soil is often so low that absorption of water by the roots practically ceases. Of therefore,

the plant were to lose water vapour at the same rate as in the warmer periods of the year, it would soon wither and die. To avoid this, the surfaces which give off water vapour are reduced as much as possible; the leaves are shed or the whole aerial shoot-system withers away. The evergreens are an exception to this rule, but all evergreen leaves have an unusually thick surface skin, which gives them their familiar leathery texture. Evaporation of water from such leaves goes on slowly at all times of the year, and the slight absorption which occurs in the winter is sufficient to replace this loss.

Reproduction by seeds: Most flowering plants, sooner or later in the course of their life, produce fruits and ~~seed~~ seeds which represent the culmination of each season's growth. The seed is a detachable part of the parent plant, which contains the germ of a new individual, that is, the embryo. When ripe, this usually hard and dry, but drying up does not cause it to lose its vitality. In the dry state it may remain dormant for a long time, often for years, and is able to withstand conditions of extreme heat and cold which are unfavourable for active life. When conditions are suitable, the active life of the germ is resumed.

the test of vitality of the seed is whether or not it will sprout, or germinate, when exposed to favourable conditions. In the winter nothing of the annual is to be found except its seeds, which are buried in the soil awaiting the return of spring.

Now consider the conditions which are necessary for germination to occur. Seeds can only germinate when provided with sufficient warmth, moisture, and an adequate supply of oxygen for breathing, which process is as necessary for plants as animals. In nature, the supply of water and oxygen in the soil are as a rule sufficient for the germination of seeds, and it is the low temperature which delays this process till the spring. It is easily shown that warmth and moisture are essential by sowing seeds of, for example, peas, in different pots in sawdust or soil and keeping some well watered others dry, some in a warm room others in the cold; only those with warmth and water will germinate. The necessity for oxygen ~~has been~~ can be shown by placing peas seeds in cool, boild water from which all the oxygen has been driven off by boiling, and others ordinary unboild water. Those which have no oxygen for breathing will not germinate

at all. Practical Work:— Place several seeds pea or bean in four pots of soil or sawdust. Keep two pots well watered and two without water, placing one pots of each set in the warm, one in the cold. After a few days note the number of seeds germinated in each pot. Mustard seeds placed on blotting paper in saucers are easily obtainable and can be tested and observed in a ~~same~~ similar way.

Structure and Germination of Seeds:—

The broad bean seed is excellent material to study on account of its large size. It is a flattened, somewhat oval body, covered by a tough pale-brown skin. Along one edge is an elongated black scar called the hilum, which marks where the seed was attached to the parent plant, that is to the pod or fruit of the bean. Near to the hilum on the slightly concave edge of the seed, is a small triangular swelling caused by the tip of the first-root lying under the seed coat, and between this and the hilum is a very small hole known as the micropyle. The micropyle is an important channel for the absorption of water by the dry seeds before they are able to germinate.

Inner structure of the seed:— For the examination of the seed

contents, it is best to use seeds which have been soaked in water, as this process causes considerable swelling of the seed coat and contents. On removal of the tough seed coat, the embryo will be disclosed, filling the whole space within. Its most conspicuous features are two large fleshy cream-coloured lobes, the seed leaves or cotyledons, and the small first-root lying as a projection against their edges. If the two cotyledons are carefully separated, a small bud bearing minute yellowish leaves will be seen lying between them near to the edge. This bud is the first shoot or plumule. Each cotyledon is attached to the base of the plumule by a very short stalk and below this point its axis is continuous with the radicle.

Bean type of germination:- When the conditions are suitable for germination, the radicle first bursts through the seed coat and grows rapidly downwards. Very soon branch roots arise from it, so that the young plant becomes firmly anchored in the soil. In the meantime the plumule starts to grow upward. The tip of this young shoot is sharply curved so that the most delicate leaves at the apex are not injured by pushing up through the soil. On emerging

at the surface of the soil the plumule straightens out, the leaves expand and become green.

Food storage:- The food material required for the growth of shoot- and root- is supplied from the fleshy seed-leaves. If seedlings are examined at successive stages of germination it will be seen that as growth proceeds, these cotyledons shrivel up more and more, until finally a shrunken remnant is left. By the time the food store in the cotyledons is exhausted the young plant is able to obtain its own food from the soil, by means of the roots, and from the air by means of the green leaves. Thus we see that in the broad bean the cotyledons are merely storehouses for nourishment and never come above the soil. The other examples will show that they don't always behave in the same way.

Sunflower type of germination:- The so called 'seed' of the sunflower is in reality a fruit, that is the organ in which the true seed is enclosed. The fruit is traingular in shape, and the fruit coat is hard, dark and brittle. When this is removed, the seed coat, a thin white skin, will be seen enclosing the embryo, which as in the bean, consists of two cotyledons a radicle and a

plumule. When the radicle emerges at germination, the fruit coat splits into two halves along the edge and the stalk region below the Cotyledons grows up in the form of a crook and, Containing Continuing to elongate, carries the cotyledons and the split-fruit coat above the ground. The portion of the stalk which elongates, carrying the Cotyledons and the plumule into the air, is known as the "hypocotyl" The Cotyledons then turn green and act as the first-green leaves, obtaining food from the air.

We have thus two types of germination: (1) that in which the Cotyledons stay below ground and serve only for food storage, and (2) that in which the hypocotyl carries the Cotyledons up into the air, and in which the Cotyledons serve first- for food storage and latter on carry nutrition. These two types are known as "hypogeal" and "epigeal" germination respectively. Common examples of hypogeal germination are the sweet and edible pea and the Corn; of epigeal, sycamore mustard and cress.

Endosperm:— In the bean and Sem flower seeds, it is apparent that the food reserve which is drawn upon by the young

Shoot- and ~~food~~ root- is contained in the Cotyledons, that is in part of the embryo itself. In some seeds the food store of the seed is not in the embryo, but in a special part called the 'endosperm', which lies with the embryo inside the seed coat. An example of this type is the seed of the Castor oil plant. The seed coat of the castor oil plant is hard and brittle, and dark or mottled in colour. If this is ~~re~~ removed, the white food store which is oily to the fingers, is seen. On splitting open this endosperm, the embryo may be seen, consisting of plumule, radicle and two thin papery Cotyledons. On germination the embryo, lying in close contact with the food store, extracts nutriment from it, and the food store gradually shrivels away. The germination is of the Sunflower type, and the Cotyledons, endosperm and seed coat are carried out of the ground by the hypocotyl. As the ~~endos~~ endosperm shrivels, the seed coat is thrown off and the Cotyledons finally become green and expand. Here the Cotyledons first act as nutrimental organs and later expand into nourishing leaves.

We see therefore, that seeds may have the food substances stored up in the embryo itself, as in the bean, or in a

a special food tissue outside the embryo as in the castor oil plant. Since the endosperm is sometimes spoken of as albumen, seeds which possess this tissue are said to be albuminous, while those lacking it are described as exalbuminous.

Hitherto we have considered seeds with two cotyledons but many plants e.g. grasses and lilies, possess embryos with but one cotyledon. For this and other reasons such plants are grouped together as "monocotyledons", and with the dicotyledons form the two great sub-divisions of the angiosperms. The majority of monocotyledonous seeds possess endosperm.

Maize type of germination :— The maize grain is really a fruit, the fruit coat and seed coat being united. If a soaked maize grain be cut down at right-angles to its broader surface, the yellowish endosperm and white embryo, consisting of one cotyledon, plumule and radicle, can be readily distinguished. The cotyledon lies in close contact with the food store and extracts the necessary nourishment from it for the growth of radicle and plumule. The plumule grows straight-up through the soil

the tender growing point being protected by the outer sheath of leaves which is hard & pointed. The radicle bursts through the root-sheath and grows downwards. It does not grow to become a large main root, but is rapidly followed by other roots, which arise from the base of the plumule. Such secondary roots from a stem are called "adventitious.

Practical Work:— With a drop of iodine, test-cut seeds of bean, pea wheat and maize for the presence of starch. This is a common form of food reserve in seeds. A blue-black colour results.

Obtain any common seeds mentioned in the text- and observe their germination in damp sawdust. Small seeds, such as mustard grow well on damp blotting-paper. Large seeds such as bean, may be suspended in the neck of a glass bottle filled with water.

From peas or beans which have failed to germinate, cut off the cotyledons. Note the subsequent starvation of the seedling.

Vegetative Propagation

A broad distinction is drawn between sexual reproduction which in the higher plants is effected in the flower & results in the formation of seed, and vegetative reproduction, in which some of the parts helping in the maintenance of the life of the individual become detached and produce in plants.

Runners. The strawberry is a good example of vegetative propagation by runners, which are long, ~~and~~ thin branches that grow along the ground away from the parent plant. From every node can be produced roots and shoots, which grow downwards and upwards respectively. By decay of the inter nodes, the connexion with the parent is lost - and young distinct - plants result.

Suckers:— Some trees, such as damson, apple and poplar reproduce from underground shoots known as suckers. These shoots come above the surface of the soil near to the parent plant, with which they remain connected till new plants are established from the tip of the sucker. This connexion with the parent ensures nourishment of the young plants till they are sufficiently developed to fend for themselves.

Rhizomes:- Many plants have stems which creep horizontally under the surface of the soil; these are called "rhizomes" and can be distinguished from roots by the fact that they bear small, scaly leaves and buds in the axils of these leaves. Roots are produced from each node, and the end bud of the rhizomes grows upward to form a new aerial shoot, while growth of the underground portion is continued by an axillary bud. These new plants are established some little distance from the parent, as in the strawberry. Some common plants which propagate by means of rhizomes are grasses, sedges and lilies, irises and many of the decorative plants used in herbaceous borders, e.g phlox, golden-rod etc. The rhizomes of the marram grass grow to many yards in length, and this habit makes them useful in reclaiming sandy shores or binding together the banks of canals and railways. Long and slender roots are formed which grow deeply in search of water, and these, together with the long rhizomes, produce a tangle serving to bind the sand. In the case of iris the rhizome serves not only for vegetative reproduction but also for food storage.

Tubers:- The swollen underground stems producing new plants are found in the potato. The large quantity of food materials stored in these organs renders them valuable as vegetables. These organs are termed "tubers", and differ from the swollen rhizomes in the fact that the food store is accumulated at the tip of the underground stem. The so called eyes of the potato represent the scale leaves and their axillary buds. If left in the ground, the eyes grow out into new shoots and roots. In practice the potato is cut up into a number of pieces, each including an eye, which thus serves as the starting point for a new plant.

Corms:- The storage organ of the Crocus is also an underground stem, technically known as a "Corm". It is formed by the swelling up of the base of the flowering stem, as can be seen if one examines a plant in April. If the lower part of the specimen is cut in half lengthwise, the new Corm (C. 3. Fig 4) is seen as a swollen structure enclosed within the sheathing bases of the lower leaves of the flowering shoot, while below it is the Corm (C. 2 Fig 4) from which the latter has arisen.

the aerial shoot- draws upon the food stores in the corm which bears it, causing this, later in the season to appear as a shrivelled remnant. Meanwhile food which is manufactured by the green foliage leaves passes back into the new corm, which becomes greatly swollen and will produce new overground shoots- the following spring from the axillary buds on its surface. In addition to ordinary adventitious roots-, the crocus also produces thick 'contractile' roots-, which pull the corms of successive seasons deeper into the soil.

Bulbs:- The remaining important organ of vegetative reproduction is the bulb. Bulbs are produced by many familiar flowering plants, such as the tulip, hyacinth, snow drop and narcissus. If a tulip bulb is cut in half lengthwise, it will be seen to consist of a short-, thickened stem which bears roots- on its under surface, and a number of large, fleshy leaves encircling one another. It is in these modified leaves that the food reserves are stored. The bulb is enveloped externally by thin, paper, scaly leaves and in the centre of the fleshy leaves is a large bud, in which parts of the future flower and young foliage leaves can be recognized

growth of this bud takes place in spring at the expense of the food materials in the fleshy leaves. Food substances manufactured by the green foliage leaves pass back into the small axillary buds of the bulb, which increase greatly in size. The original bulb is thus replaced by one or more daughter bulbs, which repeat the sequence of events in the following year.

We see that vegetative reproduction is of wide spread occurrence among flowering plants. As contrasted with seed production, its advantage lies in its simplicity, a complex union of different structures being unnecessary, such as we shall see is involved in the formation of a seed which results from a sexual process. Seeds or the fruits which bear them, are on the other hand, usually well adapted for wide dispersal from the parent plant by wind or other agencies, where as vegetative reproduction in most cases fails to bring about wide separation of the off spring.

Food Materials:— Let us consider the principal food materials in the storage organs and seeds of plants. The chief reserve substances are (1) Carbohydrates (2) fats & oils (3) proteins.

In a large majority of cases the food reserve consists in the main of the carbohydrate starch, eg. potato, bean, pea; in other cases of sugars — cane sugar in beetroot, grape sugar in carrot and onion.

Less familiar carbohydrates are inulin, stored in dahlia and artichoke tubers, and cellulose, which causes the well known hard character of the date stone. Fats & oils are present in a large number of seeds many of which are of economic important e.g. those giving castor oil, olive oil, linseed oil and mustard oil. Nearly all nuts also contain some amount of oil. Carbohydrates and fats are usually accompanied in storage organs by the more complex proteins which contain nitrogen. Large quantities of proteins are present in castor oil seeds. With the exception of grape sugar, none of these stored foods is directly utilizable by the plant, either the substance is insoluble or because if soluble, it will not readily pass through the plant body. The stored foods are converted into utilizable form by ferment actions, caused by a class of chemical substances known as enzymes.

Branching and Buds

In order to live and grow, a plant must feed and breathe. Its food consists of liquid taken from the soil and carbonic acid gas from the air; to absorb which a large external surface is necessary. Breathing on the other hand, involves the absorption of oxygen gas, which at the same time carbonic acid gas passes out to the exterior, so that here, again, surface area is of importance. It is obvious that an increase in surface is conveniently brought about by branching of the stem and root.

Branching:— Woody plants will afford the easiest means of studing the mode of branching, because the succession of events is more clearly seen in them than in herbs, which frequently do not branch much until the time of flowering. If we examine a woody shoot, as for instance, of the beech in winter time, we find that it is terminated by a long, slender and pointed structure of a brown colour, the 'terminal' bud; this contains next year's continuation of the shoot, both stem and leaves, in miniature. Along the sides of the woody shoots are a number of perfectly similar buds, the lateral buds. Each capable in the next season of growing out into

a rich branch. Beneath each lateral bud, the bark shows a somewhat kidney-shaped smooth scar, which bears a curved band and dots. Each scar marks the former point of attachment of a leaf, and the dots on its surface are the broken ends of the veins which ran from the leaf into the stem. We see, therefore that the lateral buds are all axillary to leaves of past season, the terminal bud alone having no leaf scars.

The colour and shape of buds and leaf scars vary so much in different trees and shrubs that it is not difficult to recognise them in winter by such characters. Other interesting external features are the 'lenticels' — small, generally lighter coloured projections of varying shape, which are distributed inegularly on the bark of woody twigs and serve the purpose of gaseous interchange between the interior of the branch and the atmosphere, an aim prevented, except at these points by the impermeable bark.

Terminal buds:— The most fundamental point of distinction in the mode of branching lies in the behaviour of the terminal bud. In a considerable number of trees, of which

the Conifers e.g. Cypress etc are excellent examples, the original plumule of the seedling steadily continues its growth year by year, lengthening out in the spring and forming a new terminal bud in the autumn, so that a tall, straight main axis is produced. A certain number of lateral buds develop into side branches, but these are all subsidiary to the central shaft - and again branch in the same manner This method of growth is called "monopodial" branching; it is the oldest - and largest - side branches are farthest from the growing point, whilst - the youngest - and smallest - are close to it. This very regular branching of the results in a symmetrical conical shape, well seen in a good specimen of a Christmas tree.

The characteristic of the last type just - considered is the persistence of the growing point of the main axis, and herein lies the distinction from the so called 'sympodial' branching seen in its simplest - form in the elm or lime. If the twig of these trees is examined in summer, it will be seen to have a well - marked terminal bud, which later in the season withers, while the axillary bud situated

just beneath it increases in size. In the Winter this latter bud occupies a position at the extreme end, while the true terminal bud lies as a shrivelled remnant or scar at one side. The bud at the end of the branch can always be recognized as a lateral bud because of the leaf scar beneath it. Thus in the lime it is the lateral buds which continue the growth of the branches in successive season, the branches being so adjusted as to form an apparently continuous whole. In many cases, however, 'sympodial' branching does not take place with such regularity as is observed in the lime.

Inactive Buds:—In all woody plants the materials available for growth suffice for the development of only a small number of the buds, many being doomed to inactivity, either permanent or temporary. These inactive, or dormant, buds retain their vitality thro'out the life of the tree or shrub, and are ready to grow out into branches should occasion demand. That it is lack of nourishment which prevents their development is easily seen if the terminal part of any branch is removed: lateral buds borne lower down on it, which would otherwise remain dormant, are caused to sprout. In hedge making

by cutting off the tops of the upper branches, numerous laterals are enabled to develop, causing a dense growth.

Structure of Buds:— In Winter the leaves in the bud are so tightly packed, and the parts so small, that they are difficult to dissect. The essential structure is, however, always the same, and may for the sake of Convenience be examined in a brussels sprout, a bud in which, owing to its large size, all the parts are easily recognized. Each sprout arises in the axil of a leaf like any typical bud. outwardly we see merely a series of overlapping leaves, but a more Complicated structure is revealed when the bud is halved lengthwise. The centre is occupied by the stem, which tapers to the growing point. The stem bears a series of developing leaves, the youngest- nearest- the growing point, the oldest- and largest- farthest- from it. Minute buds are present in the axils of the young leaves, and further from the apex each axillary bud can be seen to have the structure of the main bud in miniature. The young leaves are closely crowded together and the upper internodes scarcely developed. Consequently there is enough room for the enlarging leaf

blades, which become thrown into numerous folds, and thus we obtain the familiar compact structure of a bud.

The young buds in brussels sprout are protected by close packing and folding of the mature outer leaves. They are not protected outside by tough scales and hence are called naked buds. The ivy and mistletoe's buds have additional protection against the hardships of winter, this protection being provided by close-fitting leathery or membranous scales, brown or black.

Bud scales:— The bud scales are of different types. If the structure composing the bud of lilac or privet are removed in succession and laid out in order, it is impossible to draw the line exactly between bud scale and foliage leaf. The bud scales, are in fact, entire leaves much reduced in size and of leathery consistency.

The horse chestnut bud is an excellent example of the second type. The bud scales are large and brown, with an extra protective layer of sticky varnish on the outside. If the bud scales are removed in succession, a gradual transition is seen between them and the foliage leaves within. the outer

scales are oval; a little further in they show an enlarged tip which is an arrested leaf blade; this becomes more prominent in successive scales, till we come to the first-foliage leaves, in which a true leaf stalk appears and in which the scaly enlargements at the base are diminished. In the innermost-leaves of the bud this scale has contracted into a small horse-shoe shaped leaf base, such as is found at the base of the true leaf stalk (Petiole) of mature foliage leaves. The bud scales are thus much enlarged leaf bases with-most-completely arrested blades.

The opening buds of beech will show that-here the protecting scales are of yet-a different nature. Growing out from the base of each foliage leaf in the bud is a pair of light-brown scales. Outgrowths of the leaf base are called "stipules" and the careful observation will show that the scales of the beech bud are stipules, while the blade between them has been completely arrested. The scales fall off when the bud opens, and the mature leaves appear without stipules.

The study of bud scales affords a good example of that branch of Botany known as morphology. The function

of bud scales is always that of protection, but morphologically they may be reduced leaves, enlarged leaf bases or stipules, that is, different parts become changed to serve the same function. The girdles of scars plainly seen on winter twigs of beech are formed by the fall of bud-scales in spring. The distance between two successive girdles of scale scars thus shows the extent of growth in any one season.

Practical Work:—1) The common twigs and buds mentioned in this lesson should be obtained & examined to make out all the features referred to. 2) Place twigs of beech in water and carefully notice all the changes as the buds unfold.

Internal Structure of Plants.

If a thin slice of any plant is examined under the microscope — for example, a section cut straight across the stem of a Wall-flower — We see that its substance is not uniform but is divided up by a network of walls into numerous minute chambers of varying size and shape. If another section is cut at right angles to the first, that is lengthwise through the stem, We see the same structure, except that in this view the chambers appear to have somewhat different shapes.

Combining the two views together, we may then conclude that the whole substance of the plant is composed of a system of closed compartments. This is the reason why, if a juicy fruit like a melon is cut into pieces, all the juice does not run out but only a little is lost. The juice is held in these little closed chambers, and only those which are actually opened by the knife are emptied.

Plant Cells:— These chambers of which the whole substance of almost all plants consists, are called 'cells'. They are very small and cannot be distinguished at all except under the microscope. A few of the largest may reach a diameter of $\frac{1}{100}$ of an inch, while many measure only $\frac{1}{1000}$ of an inch or less. Cells were discovered in plants by Robert Hooke in 1667, and during the next fifteen years the internal structure of many plants was elucidated by Nehemiah Grew in England and Marcello Malpighi in Italy. These early students of anatomy were struck by the resemblance of many plant tissues to the honeycomb of a bee, and the word cell was applied to the chambers in both cases in the same sense.

Until well on the 19th century, those botanists who studied

internal structure at all attended chiefly to the walls of the cells. These are by far the most conspicuous features in a section of any fully formed organ seen under the microscope. The net work of walls around the cavities strikes the eye at once, while the contents are not specially conspicuous. It is however now known that it is the cell contents which are the most important part of the cell; it is the contents which form the wall, not vice versa, and in many plants the cell contents are able to grow and increase without any wall at all, while on the other hand, the cell wall without its contents is a dead shell, quite incapable of growth or of activity of any kind.

General structure of the cell:— Now consider the structure of a single cell. A young cell, such as those of which a growing point is composed, is surrounded by a delicate but firm and elastic membrane, the cell wall which separates the cell from its neighbours, this wall consists of a substance called 'cellulose' which is chemically very similar to starch. Cell walls are responsible for the strength and elasticity of all parts of a plant, and they serve as a firm, supporting frame work for the whole ~~plant~~ structure. In very young plants, such as we are now

Considering; however, the cell walls are still very thin, and for this reason growing points are very tender, and require external protection, afforded in the case of stems by the surrounding leaves and in the case of roots by the root-cap. The interior of the young cell is filled with a colourless, finely granular substance, the "protoplasm" which is the essential living matter of all plant and animal bodies. Protoplasm is mixture of proteins, composed of carbon, hydrogen, oxygen, nitrogen and sulphur, and in the active state it contains a large proportion of water. In consistency it resembles a thick fluid, but it has powers of spontaneous movement and continuous change of form such as no fluid possesses. Protoplasm is present in all cells in which growth is going on, or in which food is assimilated, or any new structure formed, or any kind of spontaneous movement carried out — is in fact, the seat of all those processes, whether in plants or animals, which serve to distinguish living organisms from lifeless matter.

Embedded in the protoplasm of the young cell is a roundish denser body, which appears more coarsely granular than

the protoplasm itself. This body is the "nucleus". A nucleus is certainly present in all living cells of the higher plants, & probably in all living cells whatsoever, though its presence as a definite body in the bacteria and some low algal forms is not yet proved. It has a complicated structure, which cannot be fully described here, but it may be mentioned that, under a microscope of high magnifying power, the granules are seen to represent extremely minute threads joined into a fine network. The nucleus also contains one or more comparatively large round bodies, the nucleoli, which are quite distinct from the fine threads of the network. The substance of the nucleus contains the same chemical elements as are found in protoplasm; in addition, phosphorus is a constant component of nuclear material. The protoplasm nucleus, and cell wall are the most constant constituents of a living vegetable cell.

Growth of Cells:— If older cells are examined, such as those found at a little distance behind the growing point we see that the whole cell is larger, and that its cavity is no longer filled by the protoplasm. Clear spaces are present

in the protoplasm; they are filled with water, which contains various substances, salts, sugars, acids, etc; in solution and is called the 'cell-sap.' The spaces filled with cell sap are known as the "vacuoles", because they look as if they were empty. The nucleus has hardly increased in size, and therefore, appears smaller in proportion to the whole cell than it did at first. An examination of the older parts of a plant reveals the structure of fully grown living cells. The protoplasm is reduced to a thin layer which lines the inside of the wall; that is, it is occupied by one large vacuole containing cell sap, the large vacuole having been formed by the small ones running together; the nucleus now lies close against the cell wall, embedded in the protoplasmic lining. The cell wall has become further thickened by new cellulose being added to it from the active protoplasm.

This is the structure of most of the mature living cells of plants. The protoplasm does not keep pace with the growth of the whole cell, and hence the vacuoles appear in it. Some cells lose their protoplasm altogether; they are then dead or incap-

able of any further growth, though they may still continue to be of use to the plant as passages for dissolved food substances.

Variations in structure:— Many other structures are found in cells besides protoplasm, nucleus, and cell wall. Embedded in the ordinary protoplasm there are often round bodies of denser protoplasm. Such protoplasmic granules are called "plastids"; the most important being those which contain the green pigment chlorophyll. Starch grains are frequently seen in cells. In all vegetable tissues the protoplasm of each cell is in communication with that of its neighbours by means of very fine protoplasmic threads which pass through the cell wall from one cell to another. The living matter in the plant is thus continuous. The plant in fact, is a living protoplasmic body, supported, but not interrupted, by the skeleton of cell walls.

Structure and Function of Roots.

We will consider now the kind of cell division which goes on in the vegetative organs of plants. A single nucleus is present in the cell which is about to divide, ~~into two~~

and in it the first obvious changes take place. The changes which occur in the nucleus are extremely complicated, but the result is that the nucleus becomes divided into two exactly equal and similar parts, the daughter nuclei, which for a time remain connected by delicate threads of protoplasm. A new cell wall is formed at right angles to their threads, midway between the daughter nuclei. The substance of the cell wall is formed from the protoplasm. The new cell wall does not at first stretch right across the mother cell, but ultimately it divides the latter into two parts, each of which contains an exactly similar daughter nucleus. The cells of which the mature parts of the higher plants are composed show many modifications of structure from that of the typical living cell considered in the last lesson. The different cells are not distributed uniformly throughout the body of a plant, but are definitely arranged with the various kinds of cells associated together in fairly well defined layers or strands. Such an association of similar cells is called a 'tissue'.

General structure of the Root:— The growing point or tip of a root- consists of a mass of young cells filled with protoplasm, and is protected from injury in the soil by the root- cap. A little behind the root- apex the young cells have become vacuolated, and still further from the apex show the modifications of shape, size, character of the cell wall and contents which are characteristic of the mature parts. The middle of the root- is traversed by a cylindrical strand of vascular tissue, which runs in a straight- course from apex to base, and is directly continuous with the vascular tissue of the stem. This central vascular core is largely composed of long woody cells, which are very tough and thus enable the root- to withstand the pull upon it in windy weather. The cells of the wood, technically known as xylem, owe their strength to the great thickness of their walls. They contain no protoplasm, therefore they are dead cells, but still of service to the plant in providing its mechanical strength and conducting its water and dissolved mineral salts up to the stem and leaves. The passage of solutions takes place along the wood vessels, which are like continuous tubes in the wood being formed from longitudinal rows of cells from which the transverse ~~of~~ separating walls have disappeared.

Another important tissue in the vascular core is the 'bast' or phloem, which always accompanies the wood, but except in very young organs, is not present in such great amount. The cells of the bast- are living, elongated and thin-walled. They provide no mechanical support but serve to conduct such foods as sugars, which are manufactured in the leaves, through the stem and roots to be used in growth or stored.

The vascular cylinder is surrounded by a layer of thin-walled cells, the "pericycle", which is of special importance in a root, for from it all the branches of the root- arise. The outer part of the young root-, the "cortex" is composed of many layers of living thin-walled cells rounded, square or oblong in shape, which as a rule do not fit closely together, but separate slightly from one another at the corners so as to leave little spaces between. These inter cellular spaces contain air and water vapour, but not-water. The outer most-layer of these cells is of great importance, for many of them grow out to form the long slender root-hairs which take up all the food that the plant obtains from the soil.

There are naturally very marked differences between the structure of a young root- such as has just been described and that of an old thick root-. Old roots are no longer capable of absorbing food from the soil, because they bear no root-hairs. The reason for this is that as a root- ages a layer of cork, or bark, is formed in the position of the 'pericycle' and all the organs original cortex dies away. The great increase in thickness in older roots is due to a large amount of wood being formed. A very important layer of cells, the "cambium" arises between the original groups of wood and bast-cells. The cells of the cambium are to filled with protoplasm and large nuclei and are capable of rapid cell division. Their daughter cells become modified to form large amount

of secondary wood and smaller quantities of secondary bast-, as long as the root- remains healthy.

Functions of Root:— The chief functions of a root have previously been mentioned: (a) fixation of the plant in the ground, (b) absorption and conduction of food, Bearing these in mind, it is easy to see the reason for the extensive growth of the root-system and increase in the amount of vascular tissue. New branches are continually being formed by the overground shoot; hence a large root system is necessary for anchoring the plant securely. Every new branch bears a number of leaves so the older a plant grows, the greater is its total leaf surface inspite of the loss of the old leaves. The plant loses water vapour through its leaves: hence the greater the leaf surface, the more must pass up from the roots; therefore the amount of conducting tissue, the wood must be increased. Leaves also manufacture foods from the carbon dioxide of the air, the more leaves the greater the amount of assimilated foods to be conveyed through the plant, hence the increase in bast- to deal with it.

While the activity of the Cambium is providing these necessary tissues, the absorptive surface of the root- is also increasing by the number of young branch roots being formed. If a young root- of a seedling bean is examined, it is seen that the root-hairs are not- borne immediately behind the growing tip, but a little distance from it.- this region which is devoid of the hairs is known as the region

of elongation, for it is here that the cells are becoming greatly lengthened and modified for their future work.

Practical Work.

(1) Cut across the main root of a bean seedling and examine the cut surface with a hand lens. Note the central vascular core.

(2) Take roots of vegetable marrow, cut them across the root, the cavities of the vessels appear to naked eye as little holes.

(3) Cut vertically down the root of a bean seedling and note the vascular strand running through the length of the root.

(4) Mark a bean seedling root with lines of Indian ink at equal distances apart. Suspend the seedling in a jar lined with damp blotting paper and note the change in the ink lines.

Plant stems and Tree Trunks

The stem of a plant is charged with the office of displaying the leaves to the best conditions of light and air, and of serving as a means of communication between them and the root. Typically, it assumes an erect position, with the branches are directed obliquely upwards. The vascular tissue of a plant is continuous throughout root, stem and leaves, and consists always, in the main, of the two types of cells, wood or xylem and bast or phloem.

Tissue of stems:— the distribution of tissues in the stems differs from that in a root, though the actual types of cells forming the tissues are, on

the whole, similar. Examination of a cross-section of the young stem of the typical plant will show that it is covered by a layer of rather flattened cells. the "epidermis" of which the outer cell-walls are thickened as a means of protection. A little distance within this we see a ring of small groups of vascular tissue.

Each group is called a vascular bundle and consists internally of wood and externally of bast-, while between the two is a narrow layer of cambium. The structure and function of these cells are the same as in the root-, with which they are continuous, and also with those of the vascular bundles of veins in the leaves. The rest of the stem is largely composed of typical living, thin-walled cells. Those in the centre make up the pith, or medulla, which is relatively large in a stem, and those external to the bundles compose the cortex, which is comparatively narrow. Similar cells run between the vascular bundles and form the medullary rays, which communicate between pith and cortex.

Structural support: It is clearly of advantage that the vascular bundles should be arranged so as to give the best support to the stem, specially in windy weather. Hence the ring-like disposition towards the exterior of the stem as seen in the cross-section. This construction with isolated bundles separated by soft tissue gives much greater resisting power than would be attained by massing together at the centre.

In many young stems of dicotyledons the relation

of the structure to girder construction is plainly seen. It is particularly clear in the stem of the dead nettle. The arrangement of the four chief vascular bundles at the corners of the square stem is equivalent to two crossed girders. Additional support is given by the development of a special thick-walled tissue (Collenchyma) immediately under the epidermis at the four corners of the stem. Greatly increased firmness is brought about by transverse and oblique bands, which unite the bundles girder-fashion at the nodes. This method of support by peripheral girders disposed in a ring is seen in the frames supporting large gasometers. This girder principle is apt to be lost sight of in older stems of dicotyledons owing to the formation of secondary tissues from the cambium and subsequent development of the vascular ring into a central column of wood.

It is at the ground level that the tissues in the plant become rearranged, thereby giving quite different appearances to cross-sections of root & stem. These changes are of a complicated nature, & involve not only a separation of the centrally massed bundles of the root to the peripheral ring in the stem, but also a rearrangement of the groups of wood and bast with respect to one another. The groups of wood and bast are always arranged alternately in a root. While

in a stem the groups lie radially, the bast always external to the wood.

As growth of the aerial shoot continues, it is necessary that the stem should increase in strength and thickness in order to support the weight of new branches. The conducting tissues, wood, vessels, and bast, must be increased also in amount in order to convey the more abundant food supplies up and down the plant. As in the root, the cambium forms these necessary secondary tissues, always producing secondary wood on its inner side and secondary bast on the outer.

Age of trees :- If the cut surface of a tree trunk is examined, it is seen to be marked with a number of concentric rings. Each ring shows the amount of secondary wood formed in any one growing season by the cambium and thus some idea of the age of the tree can be obtained by counting the number of rings, which are spoken of as annual rings. Trees may attain a great age; the few of the cases of are as follows; - Cypress and yew, 3,000 years; sweet Chestnut oak and cedar 2000; Spruce 1,200; lime 1,000.

Structure of the stem :- In the epidermis of a young stem there are numerous small holes, called stomata, through which air can pass to the inner tissues of the stem. In leaves they are more abundant and of utmost importance. When the epidermis is replaced by cork, the process of breathing is carried on through lenticels, which are small areas in the cork where the cell do not fit tightly together and thus allow air to pass between

them and thence into the intercellular spaces in the cortex.

Prior to the fall of leaves in autumn, a layer of cork cells is formed in the stem at the base of each leaf stalk (Petiole). When the leaf stalk falls the surface of the stem is thus provided with a protective covering, and not left as a raw surface of thin-walled living cells which might easily be damaged by insects or fungi. Cork is similarly formed very rapidly through the agency of the living cells of the cortex in response to any mechanical injury which is followed by wounding.

The type of stem which we have described is found in plants belonging to the group of dicotyledons, and is in the main similar to that found in the gymnosperms, e.g. pine. The stems of monocotyledons, e.g. maize, differ in several important respects: The vascular bundles are seen in cross-section to be scattered in the ground tissue of typical living cells and not arranged in a peripheral ring; the bundles have no cambium between the wood and bast-, so that when once these bundles are formed no further increase in thickness is possible in them. The growing tip of the stem, like that of the root-, is composed of cells filled with protoplasm and containing large nuclei. If a longitudinal section through the middle of the growing point is examined, it is seen that the end of the stem is slightly domed, while the young leaves arise as slight projections on the sides of the growing apex. Further from the apex the leaves are larger and the tissues in stem and leaves can be

distinguished. Branch roots are "endogenous"; that is, they arise from the central tissues of the main root; while in the stem branches are 'exogenous'; only the more external tissues contributing to their formation

Structure and Function of Leaves.

Leaves are flattened outgrowths from the nodes of the stem, with which their tissues are completely continuous. They are of various kinds.

A fully developed leaf consists of a flattened blade or lamina, born upon a stalk or petiole, at the base of which there is sometimes a pair of flattened outgrowths known as stipules, e.g. in the rose and the sweet pea. Stipules are, however, often absent, and many leaves are also destitute of a stalk, as in the Wallflower. In some cases, e.g. grasses, the attached part of the leaf is in the form of a sheath which wraps round the stem. Leaves present almost endless variations in shape, proportion, and arrangement on the stem.

The majority of plants exhibit only one leaf at each node, an arrangement which is described as alternate; but there are a large number of plants in which a pair of leaves arise together. When the leaf arrangement is said to be opposite. This is found in, for example, the horse chestnut, lilac & privet. Such pair of leaves almost invariably occur at right angles to one another at successive nodes. If more than two leaves occur at a node, the group is spoken of as a whorl, an example being the common goosegrass, in which again the leaves of one whorl usually alternate with those above and below. The object of such alternation

between the leaves of successive nodes is to prevent undue over-shadowing, and the same end is attained in the case of alternate leaves by their spiral arrangement.

In many herbaceous plants, such as the dandelion and the daisy, a large number of leaves arise close together from the base of the stem just above the surface of the soil; such leaves are usually collected in the form of a rosette and are described as radical leaves.

Leaf Mosaics:— In the case of erect shoots, or of rosettes, the leaves retain throughout life the position which they occupied at their first development. But in the case of horizontal branches of trees and shrubs the matter is different; the leaves develop in the same arrangement as on the upright-branches, but during development this becomes obscured and replaced by an arrangement which is more suited to receive direct illumination. The leaf stalks become twisted, so that the blades are placed more or less horizontally at right-angles to the light; this is well seen by comparing the erect with the horizontal branches of beech or hornbean.

The necessity of making the most of sunlight in a climate where it is not too abundant has caused the evolution of a great variety of leaf mosaics, in which a number of adjacent leaves, or parts of leaves, fit together to make up an almost continuous sheet of green without

much overshadowing. The leaf rosettes of daisy, dandelion, etc, and the foliage of many trees furnish excellent examples. Let us study ivy (Hedera helix) when this plant applies itself closely to the ground, a tree trunk, or a wall. its leaves are illuminated from one side only, and each of them is provided with five sharp lobes, which fit neatly into the corresponding indentations of their neighbours. But in such a place as the top of a wall we shall find shoots growing straight up into the air, and receiving light from all directions. The leaves are then of a continuous egg-shaped outline, retaining only the angle at the tip.

Simple and Compound leaves:— The leaf blade may consist of one continuous undivided surface, in which case it is described as "simple", or it may be cut up into a number of lobes connected with one another by an undivided portion, when the leaf is said to be ~~lobed~~ "lobed"; or again it may be completely segmented into a number of separate leaflets, when it is called "Compound". Compound leaves are readily distinguished from branches bearing small leaves by the presence of the bud in the axil of the main stalk and by the absence of axillary buds to the leaflets.

The manner in which the veins are arranged in a leaf blade is called the Venation. In the Wall-flower we noticed that each leaf showed a prominent main vein or midrib, giving off lateral

veins, which by continued branching formed a network throughout the lamina. Such 'reticulate venation" is characteristic of the leaves of most dicotyledons, though differences occur as regards the way in which the prominent veins are distributed. In most monocotyledons a different type of venation is found; the blade is traversed by several veins of equal size running side by side and connected by small cross-branches, this venation being described as parallel.

Internal Structure:— The leaf stalk closely resembles the stem in structure. The more important leaf blade is surrounded externally by a protective layer of epidermis, the cells of which in some cases, such as holly and laurel, have very thick outer walls. In the blade is horizontally expanded we can distinguish between upper and lower epidermis. It is characteristic of the latter that it should be perforated by a large number of minute holes, by means of which the interior of the leaf is placed in communication with the exterior. Each pore is known as a "stoma" and is bounded by two guard cells, which are capable of altering their shape so as to vary the size of the slit between them. Stomata are also found in the epidermis of young stems. In the floating leaf of a water-lily, for example they are only found in the upper epidermis, which is next the air; while in vertical

leaves, as those of the iris, they are fairly equally distributed on both sides.

Between the two layers of epidermis, there is a mass of green cellular tissue, divisible into an upper layer of cells elongated and right angles to the surface thus giving an appearance which has earned for it the name of "Palisade layer" and a lower "spongy layer", which exhibits no such regularity. Between the cells of the spongy layer are air spaces, which form part of a continuous system of narrow chinks and passages by which the plant is traversed. If the blade of a thick-stalked leaf is immersed in water, the existence of this continuous set of air passages may be demonstrated by placing the cut end of the stalk in the mouth and blowing into it as hard as possible. Minute bubbles of air will then be seen to come off from definite points on the leaf blade, having in fact passed through the stomata.

Function of stomata: — Each stoma opens directly into a large air space amongst the spongy tissue of the leaf, and it is through these pores that all gaseous exchange between the plant tissues and outer air takes place — that is, the loss of water vapour, the entry of carbon dioxide in the process of breathing. The action of the guard cells regulates the opening & closing of the stomatal pore. The factors which control this action are many, the most important is the water content of the cells. When cells contain much water they are rigid and firm and is known as turgid. When the guard cells are in this state, the stomatal pore is wide open; when they lose their turgidity, the

by pore closes. Hence if a plant starts to wilt, the stomata close, and by this expedient the plant guards against further loss of water vapour.

The veins of the leaf blade are its vascular bundles consisting of wood above and bast below. These bundles are so arranged as to prevent the leaf from tearing easily. While they guard against the collapse of the delicate green cellular tissue, by keeping the two layers of epidermis well apart.

The leaf is admirably suited to perform its chief function of manufacturing foods from the carbon dioxide of the air - this is done by the green chloroplasts in the presence of sunlight. The palisade cells filled with chloroplasts, lie just below the upper epidermis and therefore receive the best illumination, at the same time being adequately protected by the thick walled epidermis. Carbon dioxide enters through the air passages. Water is necessary for food manufacture & is brought up from roots in the wood vessels which contain continue into the finest veins of the leaf, and the elaborated foods are conveyed to other parts of the plant through the cells of the bast.

How plants adapt themselves to environment

A typical non-specialized flowering plant has a cylindrical upright stem, bearing leaves with petiole and lamina radiating out on all sides of it, and with axillary branches repeating the characters of the main shoot. The root-system consists of a fibrous tap-root bearing lateral roots. This scheme of construction may be worked out in detail in very different ways. This variations are due to the circumstances under which the plants grow and being suitable for life under particular conditions. Such modifications, are called adaptations.

Plants may show adaptations to the medium in which they grow – that is in water or air; to the direction of light; to the climate; or to the soil; or they may show special features which are advantageous, such as climbing habit or a parasitic mode of life.

Most plants are adapted to a climate which shows marked seasonal changes. Annuals pass the Winter as resistant seeds; the overground shoots of biennials and herbaceous perennials die down at the approach of Winter; Woody perennials lose their foliage at the autumnal leaf-fall. These habits may all be regarded as seasonal adaptations.

Modified Roots:— The functions of a typical root are to anchor the plant in the ground and to absorb absorb Water and dissolved salts from the soil. Roots may be modified to serve for other purposes. For example the swollen tap-root of the carrot is a ~~store~~ storage organ for food; the contractile roots of Crocus pull the plants lower in the soil; the adventitious roots of the ivy which arises in clusters on the aerial stems, act as holdfasts and climbing organs, and enable the plant to reach a great height and as expose its

leaves to good illumination, which the weak stem alone would not be able to do.

Many tropical orchids grow perched on the trunks of trees and have roots which hang down into the air. These aerial roots have a special sponge-like outer tissue which enables them to absorb moisture from the air. Plants such as these orchids which grow on others to obtain better support but not to obtain nourishment from them, are known as epiphytes. Occasionally the roots may even become green & perform the work of food manufacture, but such cases are exceptional.

Among the interesting examples of special development of roots are those furnished by the maize and by tropical mangroves, which grow in loose shifting mud subject to tidal inundation. Some way above the surface of the soil adventitious roots grow out from the stem and grow down obliquely into the soil. These are known as prop-roots, and help the somewhat insufficient normal root system to keep the plants erect.

Stem adaptations:— The ordinary functions of a stem are to bear the leaves in the best possible position for them to carry on their work and to give passage to the various nutritive solutions passing between roots and leaves. These functions may, however, be carried on in many different ways, according to the mode of life of a plant in its environment. Stems in different plants must have a structure adapted to the conditions in which they live, and in addition, they may take on special functions.

thus they may serve as organs of vegetative propagation, as do the rhizome of Couch grass, or as perennating store-places of nourishment, as do swollen rhizomes, Corms & and tubers already mentioned. They may be specialized to act as protective organs or to perform functions usually carried on by other members. stem-structures, therefore, assume an immense variety of forms, according to their special adaptations.

Climbing plants:— The typical form of stem is erect and self-supporting. others are weak stems, which may merely creep along the surface of the ground, as in ground ivy and creeping jenny, or climb around other plants, and using them for support reach the air & sunlight without the expenditure of energy required in building up strong erect stems of themselves. These are known as climbing & twining plants.

Twiners afford and interesting method of struggling up to obtain light. The stem twists itself round and round some support. The tip of the stem of most twiners moves in a Counter Clockwise direction—for example the bind Weed (Convolvulus)—but in the honey suckle and black bryony the movement is clockwise. Twining does not always involve movement of the stem; some plants—for example clematis ascend by means of their leaf stalks, which twist themselves round any firm support.

climbing may be effected in various ways, frequently by means of organs called tendrils. These may be modified stems, leaves or parts of leaves. They are very slender and sensitive to Contact, when they touch a suitable support they twine round it and

it and raise up the part of the plant on which they are developed. These structures are specialized branches in the vine, passion flower, white bryony and virginia creeper. In most cases a tendril holds on to a cylindrical support, but in one kind of virginia creeper (Ampelopsis veitchii) the tip of the stem tendrils spell out into sticky disks, which adhere firmly to brick & or stone.

Leaves & parts of leaves are frequently modified into tendrils. Thus in the garden pea & many of its relatives the vetches, the tendrils represent the leaflets of a compound leaf. In some species of pea all the leaflets are specialized in this way and the functions of the foliage leaf are taken on by the stipules, which are large and green. In smilax the stipules are converted into tendrils. Other plants are enabled to climb without so much modification of their organs: the stem is covered with outgrowths — hooks, as in goosegrass, or prickles, as in bramble — which catch on to neighbouring plants.

Protective stems & leaves. Stem spines, or thorns are branches which have lost their apical growing point, become hard & pointed, and are adapted to function as protective structures against grazing animals. The true stem nature of the spines is recognized by their position in the axils of leaves and by the fact that they may bear lateral buds. In the gorse, a plant which grows in dry situations, and has accordingly a reduced leaf surface, the stem spines are green & help in the work of food manufacture.

Similarly, leaves or parts of leaves may take on the form of spines and serve as protective organs. The whole leaf may be thus specialized, as in the barberry or the stipule become spiny as in the false acacia or the spines may be out growths from the leaf base, as in the gooseberry. Stem are occasionally so modified that they are erroneously thought to be the leaves of the plant. The commonest example of this modification is the butcher's broom (Ruscus aculeatus). The flattened leaf-like stem is called a cladode. Each one arises in the axil of a small scaly leaf, and may bear on its upper surface a small leaf & flower bud. These green cladodes carry on the normal function of leaves. Certain other plants whose leaf blades are reduced or absent have the leaf-stalk flattened to look ~~like~~ like and function as a leaf-blade Such modified leaf stalks are known as "phyllodes".

A wing-like expansion of the leaf-stalk is seen in several members of the pea-family. It supplements the loss of leaflets which have been converted into tendrils.

Practical Work:— As many as climbing plants as possible should be studied & the morphology of the organs adapted for the climbing determined.

How Plants are Nourished from the Soil.

Water supply enters a plants' root-by means of root-hair Each root-hair is a slender tubular out growth of the wall of an epidermal cell. The cell is very delicate and is lined throughout its length with protoplasm. a vacuole extends throughout the cell and a nucleus is usually present about the middle or end of the hair. The root-hair region corresponds in position with the region of formation of wood & bast-in the

internal structure of the root. The water supply which enters via the root-hairs is then conducted up to the rest of the plant by the newly-formed conducting elements of the wood.

The under ground system of the land plant such as an oak tree, occupies a large area of soil, with the finest roots disposed round the outside of it. These fine roots clothed with root-hairs, present a very large surface in close contact with the soil, in the same way as the flat expanded leaves borne by the stem present a large surface in contact with the air. These large surfaces make for great efficiency in absorption of water from the soil in one case, and in evaporation of water into the air in the other case. This latter process is known as "transpiration" and the stream of water through the plant, which is present in all land plants, is called the "transpiration" stream.

Ordinary earth consists of particles of various sizes to which films of water cling, and this water constitutes a large part of the food of the plant. It contains small quantities of various mineral matters in very dilute solution. The nature of the food which is taken up from the soil can be determined by growing plants in artificially prepared solutions.

Varieties of Nutriment Required :— Water itself is of the first importance, for not only is it abundantly present as such in the living plant, but it supplies two of the chemical elements — hydrogen & oxygen — which enter into the composition of protoplasm &

are also essential components of many substances which are the products of vital activity, such as wood and starch. But the plant will grow and thrive if its roots are supplied with nothing but pure water. There must also be small quantities of simple mineral compounds containing seven other elements, i.e. nitrogen, sulphur, phosphorus, potassium, calcium, magnesium and iron. At least the first three of these help to build up protoplasm.

Some plants require still other kinds of food for their complete well-being. A well known example is afforded by the grasses - including our cereal crops which contain a considerable amount of flinty matter, or silica in other stems and leaves, taking this up from certain siliceous compounds in the soil. Apart from these cases like this, plants differ considerably among themselves as to the exact composition of the food they require, which is one reason why it is desirable for farmers to adopt a rotation of crops, instead of growing one kind of plant continuously in the same field. Since a given soil may from the first be deficient in one or other of the essential kinds of plant-food, or may have become exhausted of its supplies, the necessity for manuring also readily becomes apparent.

A minute quantity of cell sap diffuses out of the root-hairs. This is slightly acid, and helps to dissolve the particles of the soil i.e. assists in the preparation of more food, and the root-hairs come into very close contact with the particles in question. By placing a polished slab of limestone in the bottom of a flower-pot in which a plant is growing, an

illustration of this process can be observed. After a time the roots will spread over and corrode the limestone, etching their outline upon it.

Oxygen must be available to roots in order that they may breathe, and therefore a water-logged soil is injurious to the life of the plant as no air spaces remain between the soil particles. A good soil should be well aerated and well watered, and should allow easy penetration of the plant roots, in addition to containing in the soil solution a range of chemical substances necessary to plant growth.

The promotion of the upward current of water and dissolved mineral salts is of the utmost importance, for the amount of mineral matter dissolved in the water is so small that a constant stream is necessary to furnish the leaves with the requisite amount of their constructive work. The surplus water is given off in the form of vapour by transpiration through the stomata of leaves and young stems. This evaporation at the leaf surfaces is undoubtedly an important force in maintaining the stream of water through the plant, pulling up water through the wood from the roots.

Osmosis:— The root-hairs take in the food solution from the surrounding soil by means of the process known as osmosis. The proto-plasmic lining of the root-hair cell constitutes what is known as a semi-permeable membrane, i.e.

a thin sheet or membrane, that allows certain substances to soak through it, but prevents others from doing so. In the case of root-absorption the soil solution is on one side of this membrane, the cell sap on the other. The cell sap contains in addition to a weak solution of mineral salts sugar and other dissolved organic substances. The semi-permeable membrane allows ready passage of the water & weak salts, but will not allow the outward passage of the sugar, etc. Water tends to diffuse from a weaker solution to a stronger, to bring about equality of concentration, and therefore, in root-absorption, flow it from the weak soil solution to the relatively strong solution of cell sap.

Thus water with the necessary mineral elements passes ~~with the~~ into the root-hairs, which become distended with water, that is, turgid. The absorbed solutions pass by osmosis from the root-hairs through the cells of the cortex of the root-all of which become turgid, and in this distended condition exert considerable pressure on their neighbours. This pressure is known as root-pressure, and is responsible for driving the water into the conducting vessels of the wood, to which it cannot pass by osmosis, because the wood cells are dead and empty.

The tallest trees of the world — for example, the eucalyptus trees of Australia — are about 300 ft. high. Their roots also are very long. Thus, since it is only the young part of roots which absorb water, the distances through which water is carried in such tall trees can scarcely be less than 200 yards.

It is surprising how water is pulled up such enormous heights in trees is not yet satisfactorily answered. Osmosis explains its passage through the cortex of the root and through the living green cells of the leaf, but not through the vessels of the wood. Experiments have proved however, that by some force not fully understood the water passes up through these cells. Transpiration from the leaves supplies considerable 'pull' and root-pressure may assist indirectly in helping to make good the reserve of water in the vessels of the root.

A broad-leaved herbaceous plant e.g., a Sun flower, gives off a pint or more of water on a hot sunny day. A beech tree on any bright summer day transpires very nearly a 100 gallons. It has been calculated that a well grown oak tree gives off during the five months of its active annual life more than 200 tons of water, and that wheat transpires in its season of growth at the rate of 1,000 tons per acre.

Practical Work:—

Absorption:— Place the cut shoot of a White flower (e.g. lily) in red ink diluted with water. In a few hours the veins of the flower are coloured red. The same experiment can be performed with any woody shoot.

Transpiration:— Take any potted plant with well-developed leaves, e.g. geranium, and cover the pot and soil with tinfoil or mackintosh. Place under a glass bell-jar in a light, warm situation, & in a short time drops of moisture will appear on the inner side of the glass. This proves that the plant

qties of Water Vapour.

To show that transpiration takes place from the under side of the leaf, where the stomata are situated, can be made with the use of Cobalt-paper, which, blue, when dry, turns pink on being moistened. A piece of this paper is placed on a glass plate, and covered with a dry leaf underside downward. A second piece of Cobalt-paper is then put on the upper side of the leaf & a second glass plate over all. After exposure for a short time to sunlight - it will be found that the paper which has been in Contact with the underside of the leaf has become pink, while the other piece remains blue.

Plants' Food Factory

Though water is essential to plants for life and growth, they will not thrive if provided with pure water alone. Certain other elements are essential in addition to oxygen, and hydrogen. Chemical analyses of different parts of plants - seeds, stems, tubers, & leaves - show that the same chemical elements are contained in varying proportions in these diverse tissues. They are: Carbon, oxygen, hydrogen, nitrogen and certain mineral elements, of which the chief are sulphur, magnesium, potassium, calcium, phosphorus and iron. These of course, exist in the plant not in a free state, but in a Combined form, and, with the exception of Carbon, all are obtained by the plant from the soil.

The following solution Contains the inorganic elements commonly present in a natural soil:-

Distilled Water: : 1,000 Cubic Centimetres
Potassium nitrate: 0.25 grams
Calcium nitrate : 1.0
Acid potassium phosphate: 0.25 — Ferric chloride: a trace

Such a solution is known as a normal water-culture solution, and in it plants may be grown up to the flowering and fruiting stage, either in the solution alone, or in pure quartz sand watered with the solution. To show the importance of the various constituents, plants are grown in incomplete culture solutions from each of which one of the six mineral elements is omitted. The plants grown in the incomplete solutions not only do not thrive, but sooner or later die. Each of the six elements contained in the water-culture is, therefore, essential; three others commonly found in plants, but not essential, are sodium, chlorine and silicon.

The actual amounts necessary for healthy growth differ in the case of different elements. A relatively large quantity of a suitable nitrogen compound must be supplied, but a mere trace of an iron compound is sufficient. Without iron the leaves develop no chlorophyll, they remain a sickly yellow colour and are said to be chlorotic. If painted with a weak solution of an iron salt they turn green and the plant lives. The white patches of variegated leaves do not respond in this way; variegation is due not to lack of iron, but to an internal hereditary cause, which results in undeveloped chloroplasts.

The necessity of six elements obtained from the soil is appreciated when we consider the chemistry of the living plant. Nitrogen, phosphorus, sulphur and potassium all enter into the composition of proteins or their derivatives, which form the chief part of the living matter, protoplasm. Magnesium

is present in chlorophyll; iron is necessary for chlorophyll formation, and calcium enters the composition of cell-walls.

How plants obtain Carbon :— The important elements, Carbon, which forms about half the dry weight of a plant, is not present in a culture solution, nor is the plant able to obtain it from the soil. The source from which this elements is obtained is carbonic acid gas or carbon dioxide which makes up a small percentage of the atmosphere. one of the uses of the stomata is to permit this gas to pass readily into the interior of the leaf. The taking in of carbon dioxide by green leaves (or stems) under the influence of sunlight is spoken of as carbon assimilation or photosynthesis.

A chemical reaction take place between the water which the leaf receives from the root and the carbon dioxide it takes in from the air, resulting in the formation of an organic substance composed of carbon, hydrogen, and oxygen — a formation which could not be effected were it not that chlorophyll enables the energy of sunlight to be utilized for the purpose. In other words, through the protoplasm of the leaf does the up-building work, it has these very-powers for the purpose, and chlorophyll — how - is not clearly understood — alone renders this possible.

The further steps in the formation of plant-substance are too complicated, and is enough to say, that the visible product is starch, another compound made up of carbon, hydrogen, and oxygen. That grains of this substance are actually formed in the leaf. It is a well known fact that starch turns blue when subjected to the action of a solution of iodine (in potassium iodide). If we take a leaf that has

been exposed to the sun for some time, and place it in this solution, it will rapidly become dark blue, thus proving the presence of starch.

Elimination of oxygen:- When any organic substances is formed in the green parts of a plant by chemical reaction between water and carbon dioxide, a large part of the oxygen contained in these substances is not required for the purpose. This, as a sort of by-product, passes into the surrounding air, which, we know, is a mixture of gases, about 21 per cent being oxygen, an element which is constantly being used up in the breathing of animals and also in combustion.

Photosynthesis:- Certain conditions are necessary before a healthy plant can bring about photosynthesis. These are: the presence of chlorophyll in the cells, the presence of sunlight, and the presence of carbon dioxide.

Variegated leaves are useful material for proving that chlorophyll is essential for starch formation. If variegated leaves are exposed to sunlight and then submitted to the iodine test, only the parts which were green will turn blue owing to the presence of starch. No starch is formed in the white parts. The best way of performing the iodine test on green leaves is as follows: Plunge the leaves into boiling water to kill them, and then soak in alcohol (methylated spirits) to extract the chlorophyll. The leaves are thus rendered colourless. When treated with iodine the blue colour is seen to be not obscured by the green pigmentation of the leaf.

To prove that starch formation goes only in the

presence of sunlight, it is necessary to experiment with a plant whose leaves are devoid of starch at the first. If a plant is kept in the dark for a day and its leaves then tested for starch, none will be found present. Pieces of cork or opaque paper are now pinned above and below parts of some of the starch free leaves & exposed to sunlight. On testing for starch, the parts which were covered give no reaction, whereas the parts exposed to sunlight are deep blue.

Even a green leaf exposed to sunlight, it will not form starch if there is no carbon dioxide in the air. This can be shown by placing a starch-free potted green plant under a glass bell-jar, together with a dish containing caustic potash. This chemical substance absorbs carbon dioxide from the air, leaving none for the green leaves. If the apparatus is exposed to sunlight for some hours and the leaves then tested for starch, a negative result will be obtained.

In addition to chlorophyll, sunlight and carbon dioxide, there must, of course, be a suitable temperature and adequate water supply for the plant to bring about carbon assimilation. It may be repeated here that it is chloroplasts of the palisade cells of the leaf which are chiefly concerned with the photosynthesis of carbohydrates in the higher plants.

Necessity for Chlorophyll:—Were it possible to destroy all existing chlorophyll, and to prevent the formation of more, the organic world would soon be brought to a standstill and life would become extinct. For no more plant substance could be built up from non-living material, and the vegetable world would therefore, soon cease to be. Man, as animals directly

or indirectly depend on plants for food, they, too would soon die out.

Quite apart from this, the breathing of plants and animals and the processes of combustion continually exhaust the oxygen of the air and increase the proportion of poisonous carbon dioxide. The composition of the atmosphere is, in fact, only kept normal by the utilization of carbon dioxide as food by green plants, with concomitant liberation of oxygen. As we have seen, this process is absolutely dependent upon Chlorophyll.

The formation of Chlorophyll depends on a trace of iron in the nutrient solution and also on light. If seedlings are grown in the dark, the shoots which develop are pale yellow in colour, the stems being greatly elongated and weak, and the leaves much smaller than the normal. Plants showing these changes caused by growth in the dark are spoken of as "etiolated". If a large stone is placed on a grass lawn for a few days & then removed underlying grass seen to be almost white. This etiolated grass soon recovers its green colour on exposure to light.

Plants part in the Nitrogen Cycle:-

The majority of green plants obtain all their supply of nitrogen from the soil. The nitrogen is combined in the soil with other elements in the form soluble salts called nitrates. Even though nitrogen is one of the gases present in the free state in the atmosphere, the higher plants do not utilize it. The soluble nitrates which are absorbed by the roots are conducted up to the leaves and accumulate there till, on the exposure of the leaves to light,

they disappear and are placed by other nitrogenous compounds. This change depends in some way on the activity of the green cells; it does not take place in the colourless cell of variegated leaves. Thus the animal world, which lacks the power of bringing about this change, depends ultimately on the green plant for its nitrogenous foods as well as for its carbohydrates.

The change which takes place in the green leaves results in the nitrogen being combined with carbon, oxygen and hydrogen to form substances known as amino-acids and by the chemical union of many of these acids the proteins are formed. Chemically, the proteins are extremely complex substances; some of the simpler forms are used as food material by the growing plant, while the more complex actually enter the composition of protoplasm itself. Without proteins, then, protoplasm, the essential constituent of all living matter, may neither exist nor persist.

Activities of Bacteria. Some of the lowliest members of the plant kingdom play an all-important part in rendering nitrogen available to green plants and, hence, to the animal world; these important but inconspicuous plants are certain species of bacteria. When dead animal or plant bodies decay, the complex proteins contained in them are broken down to the simpler amino-acids, from which, by the activity of bacteria, ammonia is set free. This ammonia is washed into the soil by rains, and there, by the action of other bacteria, is chemically changed into a fresh supply of soluble nitrates, which higher plants

absorbe through their root. By means of these important bacteria, therefore, the nitrogen cycle of Nature is thus kept going.

Not all soil bacteria are so helpful to the green plant. There are other species which act on the soluble nitrates and convert them chemically to substances which the green plant cannot utilize, such as ammonia and free nitrogen — that is, they diminish the nitrate content of the soil. These harmful bacteria are only active in a soil which is badly aerated, such as water-logged soil. They are known as the denitrifying bacteria, as distinct from the useful ones, which are called nitrifying bacteria.

Nitrogen-Fixing Bacteria! — Certain types of bacteria also present in the soil, can make direct use of the nitrogen in the air, which green plants are unable to do. They take in the free gaseous nitrogen and build it up into the protoplasm of their cells. Some of these so-called nitrogen-fixing bacteria are of great importance in considering soil fertility, because of their association with the roots of all members of the pea and bean family — that is Vetches, Clovers, etc. If a pea plant is pulled up and examined it will be found to have numerous swellings on its roots. If a plant of pea family is grown in water-culture solution, no nodules (swellings) develop, they depend on the presence of a little ordinary soil for infection by the bacteria, which enter the root through the delicate root-hairs. Both the pea plant and the bacteria derive benefit from this association. The bacteria obtain their supplies of carbohydrate from the plant in whose cells they are established, and in return pass into the plant the complex nitroge-

-nous Compounds which they are able to build up. Such an association for mutual benefit is described as symbiosis.

Members of the pea family thus show a peculiar and almost-unique relation to nitrogen. As long as their roots develop nodules they are able to thrive in a soil which may lack nitrates. Although the discovery of the nodule bacteria and their power of fixing free nitrogen was only made about 50 years ago, the beneficial results to ground of growing vetches, clovers, etc, has been known and practised for centuries. Such crops restore the nitrate content of a soil; for when land previously under vetches, etc, is ploughed, the stores of nitrogen compounds contained in the roots are distributed throughout the soil and become available as nitrates for the next crop.

The activity of nitrogen-fixing bacteria, living free or in symbiotic union, has been found insufficient for the world's supply of nitrogen, and therefore other methods of have discovered for enriching the soil. Recently it was achieved by the utilization of stable manure (which is but an incomplete return to the soil of nitrogen taken from it) and the application of Chili saltpetre (potassium nitrate). The saltpetre deposits showed signs of exhaustion, and the possibility of nitrogen starvation seemed to threaten Mankind until the Chemist came to the aid of agriculture.

Other Functions of Bacteria! — Bacteria also play

a part in the circulation of carbon in nature though the cycle here is not so important as it is in connexion with nitrogen. When dead vegetable matter decays, certain bacteria are concerned with the breakdown of the carbohydrates, such as the cellulose which composes the cell walls and, hence, the whole plant framework. Such breakdown produces the humus of the soil and improves its water holding capacity, its aeration and general fertility. In the chemical processes which take place carbon dioxide is set free and is thus available to living green plants for further carbohydrate synthesis.

Fatty is known of the origin of fats & oils in plants. There is no evidence that they are direct products of synthesis as are the carbohydrates and proteins. They are probably produced from previously formed carbohydrates by chemical alteration.

How Plant Obtain Energy

The building of carbohydrates and nitrogenous food materials takes place in the green leaves of a plant. It is obvious that such substances cannot accumulate indefinitely in the leaves, to serve the plants' needs, they must be accessible to every living cell of root and stem, leaf and flower. In considering the problem of how the food materials are passed into the different organs, we are at once

Confronted with the question — how can insoluble substances, such as starch grains, move from cell to cell? This is by considering the actions on carbohydrates, proteins etc. of substances called "enzymes", which are present in all living cells of both plants and animals.

Activities of Enzymes: — There are number of different enzymes present in living cells, and each is responsible for bringing about a particular change. They can effect in living cells at ordinary temperatures chemical changes which the chemist may be unable to perform in the laboratory, or can only perform at a very high temperature. They may however be extracted from plant tissues by various means and purified, and will then perform, in the test tube, the reactions they performed in the plant cell. These important substances which bring the insoluble food material into a soluble form, which they will diffuse easily through the cellular tissues of the plant. They also bring about the reverse change - that is, convert the soluble substance again to the insoluble form — if the food is being passed into a storage organ. For example, in the potato, starch is formed in the green leaves in photosynthesis; the enzyme known as "diastase" converts the insoluble starch into soluble sugar, in which form it is conducted down the bast-cells of the vascular bundles into the underground tubers, where the diastase reconverts the sugar to insoluble starch, in which form the food is stored. By the actions of enzymes all food substances, carbohydrates, proteins or fats, are rendered available to the cells which will

utilize them, and are transported by the conducting cells of the bast-, and finally, by diffusion, from one cell to another in the tissues which are not specialized for conduction.

Constructive Uses of Food Materials:— When the food materials reach their destination, they are either used at once or stored for future requirements. There are two main uses to which they may be put immediately: Construction of plant tissues, and the liberation of energy for the plant. The work of construction of plant carried on by members of the plant world is very great. From a tiny embryo consisting one cell, there arises a gigantic tree. All the mass of its woody and other tissues is the product of constructive activity of the protoplasm. In order to grow, the plant must carry on an innumerable chemical operations, by means of which proteins and other food materials are incorporated with the protoplasm. The varied constructional work of the protoplasm is furnished by the amount and diversity of the waste products which are found deposited in a plant as the result of its chemical activities. These accumulate, because unlike animals, plants possess no definite excretory system for ridding the body of waste products. Some though their use to the plant is not known, are of value to mankind as stimulants, drugs and poisons, such as nicotine, caffeine, quinine and opium. Certain poisonous waste products are probably useful to the plant in protecting it from attacks of insects or they may act as natural antiseptics & preserve the wood from decay.

Respiration of Plants. The energy necessary for carrying on the plants vital activities is obtained by breaking down the food materials formed in photosynthesis. The process which is called "respiration", occurs in all living bodies, plant or animal. The main supply of energy for the green plant is obtained from the sugars it contains. The process involves the intake of oxygen by the stomata, the oxidation of the sugar molecules to water and carbon dioxide, the release of the latent energy of the sugar molecules and the liberation of the carbon dioxide through the stomata.

In day light it is impossible to demonstrate that green leaves give off carbon dioxide in breathing because this gas is utilized at once for photosynthesis. It is, however, easily proved in the dark. We can experiment place a vigorously growing pot plant in a cylindrical glass vessel just large enough to hold it, and close the mouth of the vessel by a greased glass plate. To prevent access of light, it is best to put the jar with its contents in a dark cupboard. If, next morning, a lighted taper is plunged into the jar, it will be extinguished, showing that the oxygen of the air ~~has been proved~~ has been completely used up. The gas given out is proved to be carbon dioxide by shaking up a little lime-water in the jar. The lime water at once turns milky.

Germinating seeds respire very rapidly, and from them the intake of oxygen and evolution of carbon dioxide can be demonstrated in the light, because no photosynthesis is taking place. Soak a number of peas in water for a day, and place in a jar lined with damp

blotting-paper. close the jar tightly with a stopper. After a few days test the air in the jar with a lighted taper and with lime-water turns milky, showing that the gas present is carbon dioxide. A Control jar, without peas, should be set up and tested for comparison. The taper will continue to burn, and no milkiness will be produced on adding lime-water. Some of the energy which is released in respiration takes the form of heat. If a funnel be filled with germinating peas packed round the bulb of a thermometer, the latter will soon record a higher temperature than one in a Control experiment in which cotton wool is substituted for the living peas. It is best to cover both experiments with bell-jars to eliminate the effects of draughts of air. The energy set free in respiration furnishes the driving power of the plant's machinery, supporting not only life itself, but all the vital functions as well.

Respiration entails a breaking down of Carbohydrates and loss of substance from the plant. In the light, assimilation is in excess of respiration and therefore the loss of weight is not noticeable, but it may be shown in the dark.

As a simple experiment two lots of peas may be weighted, separately soaked and placed to germinate, one lot in the dark, the other in the light. After about a fortnight the dry weight of the seedlings is determined and compared with the weight of the original seeds. Those grown in the light will be found to have gained weight because of the assimilation of foods in photosynthesis, but those grown

in the dark will have lost weight.

Respiration without Oxygen:- The plant unlike the ordinary animal, is not killed immediately by the absence of oxygen, although in these circumstances the normal vital activities are stopped. When there is no oxygen in the surrounding air, plants carry on a modified breathing process known as anaerobic respiration, during which the food substances are not broken down as completely as in ordinary respiration. Carbon dioxide is evolved as under ordinary conditions, and in addition, "alcohols" are produced. These accumulate in the living cells & poison the plant, as they would in the animal body, thus sooner or later inducing death.

Among the bacteria which are responsible for many virulent diseases (e.g. anthrax, Cholera, typhus) there are organisms which not only ordinarily exist without oxygen but to which the gas, except in minute quantities, is actually poisonous. Hence the importance of Ventilation in the prevention of disease.

Influential Factors in Plants Growth:

Part of the energy set free in respiration is employed in the process of growth, during which some of the food material produced in the course of nutrition are used in building up new tissues. There are three distinct phases of growth. first, the formation of new cells by the division of pre-existing cells in the growing points; secondly, the enlargement of the new cells; & thirdly, their modification to perform the different functions which they fulfil in the life of the plant. The second phase is the only one visible externally, & constitutes 'growth' in its popular sense.

The growing points, which are found at the extreme tips of the shoot and immediately behind the caps in the root, consist of numerous small cells which undergo repeated divisions. Some of the cells thus formed become gradually changed into mature cells; others retain their powder of division and persist as the growing point. Apart from growing points at the tips of roots and stems, some plants – for example, grasses & ferns – have similar growing point tissues along their mature stems near the nodes. These are called "intercalary" growing points, as distinct from the apical growing points. These intercalary growing points help the plants to raise their shoots when they have been flattened down by rain or wind.

Rate of growth:- By marking roots and plumules with Indian ink, we see that the region of elongation in roots is restricted to a very short portion just behind the tip, whilst in stems it is spread over a much greater length. In both we see that the rate of growth of different parts of the elongating zone is not uniform. The intervals near the tip of the root will have elongated very slightly, but as we pass further from the apex, the intervals become wider and wider, until they reach a maximum; after this they show gradual decrease up to the mature zone where no elongation has occurred. We therefore conclude that newly formed cells elongate but slightly at first, grow in length more rapidly as they get older, until when they approach maturity, their rate of elongation again decreases. This gradual rise and fall in the rate of enlongation is spoken of as the "grand period of growth", as is also well seen in the growing plumules of seedlings.

Effect of Darkness:— By means of different experiments, it has been established that growth in length is greater by night than by day, provided the temperature remain approximately uniform. This is well illustrated by reading or sprouting potato tubers which are allowed to grow in the dark: the plants become etiolated, that is have no chlorophyll, very small leaves, but exceptionally long internodes. Many herbaceous plants exhibit longer internodes when grown in shady places than when grown in the open. The acceleration of growth in darkness is of great advantage in Nature, as it enables plants rapidly to reach the light. In plants growing from a rhizome or root-stock the absence of light causes great elongation of the petioles.

As well as influencing the rate of growth, the intensity of light may also affect the extent of development of plants organs. The buds which are entirely shaded in a large tree usually fail to develop, whereas the majority of those at the margin give rise to branches. Flowers are rarely produced on the yellow dead nettle growing in the deep shade of a wood, but flowering is profuse when the wood is coppiced. In many plant leaf development is affected by light-intensity, sun leaves being smaller and thicker than shade leaves.

Effect of temperature:— Temperature has a marked effect on growth, as on all other vital processes. Plants grow slowly at a low temperature, the rate of elongation increasing as the temperature rises, until a degree of heat is attained which is unfavourable to further existence. Since at night the temperature is usually lower than in the day, the tendency to more rapid growth at night is not obvious in Nature. Apart from light & temperature the most important factor in growth is the supply of

oxygen for breathing. Other essentials are moisture and nutritive materials.

Effect of Injury: Injury to any living tissue of a plant causes the surrounding cells to undergo rapid division, and thus the wounded surface becomes covered up with a new growth. Injury due to insects or fungus pests is a similar stimulation to growth & leads to the formation of galls, such as the oak apple.

Influence of light:— The majority of plants assume the erect position in Nature, for the light-on direction of growth. If an erect plant is placed near a window, so that it receives one-sided illumination, the shoot will soon be found to have curved towards the light. If the plant is now turned through a right-angle, it will be found later that the shoot has again bent over to the light. Thus the erect-growth of the stem is dependent on its being exposed to equal illumination on all sides, and one-sided light causes bending until this condition is attained. The influence of light on the direction of growth of a plant is spoken of as "heliotropism" and stems which curve towards the light are positively heliotropic. The aerial roots of the ivy are common examples of "negative" heliotropism always growing away from the light; a few subterranean roots — for example, those of mustard react negatively to one-sided light, though the majority of roots are unaffected.

Influences other than light play a part in determining the erect position of the shoot. If a potted plant is placed horizontally in the dark for some hours the tip of the shoot gradually curves upwards till it

again assumes a vertical direction. Evidently some agency other than light is responsible: this is the force of gravity, which in stems causes a growth in a direction opposite to that in which gravity acts. The influence of the force of gravity on the direction of growth of the plant is spoken of as "geotropism", and stems are "negatively geotropic". Main roots, which always grow downwards, are "positively geotropic"; lateral roots, which grow obliquely from the main axis, are not so strongly influenced by gravity, while this force has no influence on the finer ramifications of the root system — these spread through the soil in search of water.

If a seedling with plumule and radicle marked with ink is placed horizontally in a dark box, it will be found after 24 hours that the geotropic curvature has occured in the region of maximum elongation. It has, however, been shown that the region of curvature is not the region in which the influence of gravity is first felt. The "perceptive" region is at the extreme tip, and in experiments with roots whose tips are cut off, no curvature results. The stimulus which is received at the tip of a root or shoot must, therefore, be transferred by some means or other to the zone of elongation. In the case of heliotropic curvature, the bending also takes place in the region of elongation, though the perceptive power is localised elsewhere. Here must, therefore, again be conduction of the stimulus to the region where bending occurs.

EFFECT OF MOISTURE. The distribution of moisture markedly

influences the direction of growth of roots, especially of finer branches of the root system. This influence of one-sided moisture on the direction of growth of roots is known as "hydrotropism" and roots which grow towards the moisture are "positively hydrotropic". "Negative hydrotropism" is a much rarer phenomenon and has not been observed in the higher plants.

The curvature of roots towards water is easily shown by growing some cress seeds in damp sawdust in a fine wire sieve. The sieve should be tilted at an angle of 45°. When the radicles of the seedlings emerge into the air at the bottom of the sieve, they then turn through a right angle to reach the damp sawdust which lies on one side of them. The influence of moisture is stronger than the influence of gravity. If a similar sieve be hung up horizontally, there is no such ~~hydro~~ hydrotropic curvature; this is due to the fact that all sides of the radicle are equally stimulated by the moisture.

PARASITIC AND INSECTIVOROUS PLANTS.

We have already considered the way in which the ordinary green plant builds up its body from simple chemical compounds obtained directly from the soil and the air. There are plants, however, which, like members of the animal world, are dependent upon elaborated food substances, and can only thrive when these are available in the form of either living or dead organic material. In such plants the leaves are always small, and frequently without chlorophyll. When some or all of the food is obtained from another living organism, the plant is called a "parasite" and the organism which feeds it the "host". Where the source of nourishment is

dead organic matter, the plant living on it is known as a "Saprophyte".

Parasitic plants. Some parasites are only partly dependent upon their hosts and are described as "Semi-parasites". Their leaves, though relatively small, are often green, and consequently the plants can grow independently, though in these conditions growth is not vigorous. Common examples are found among our meadow plants in the yellow rattle, cow-wheat and eyebright, which are parasitic on the roots of other plants, particularly grasses. The roots of the parasite are attached at certain points to those of the host by minute suckers which appear as slight swellings. These penetrate into the roots of the host as far as the central conducting tissues, and thus absorb nourishment.

Complete parasites are comparatively rare amongst British flowering plants; the best examples are the dodder, the toothwort and the broom rapes. The dodder is parasitic chiefly on gorse and heather. The fine reddish-coloured stems entwine the stems of the host, penetrating it with small suckers through which nourishment is absorbed. The stems bear minute scale-like leaves completely devoid of chlorophyll, and rosettes of pink flowers which produce an enormous amount of seed. This feature of extensive seed production is common among parasites, as it minimises the risk of a host not being near one or the other of the numerous offspring. When the dodder plant is mature, it has no roots; it is exceptional among British parasites in being attached to the stem of its host.

The toothwort and broom rapes (neither genus is common) are root parasites, that is they attach themselves by suckers to the roots of a suitable host. The toothwort, an early spring plant with pinkish flowers on a pale brown ~~shoo~~ shoot, usually grows at the foot of hazels or elms. The species of broom rape, which are somewhat similar to toothwort

in their overground organs, are usually parasitic on clover. In common with all parasites, these plants show a much reduced leaf surface and extensive seed production.

Owing to reduced transpiring surface, parasites may receive too much water from their hosts, hence many are provided with water-exuding glands.

The reduction of the vegetative parts is well seen in a small family of parasites, found in tropical forests, some of them remarkable for their enormous flowers, which are the only conspicuous part of the plant outside the host. The strangest species in this respect, Rafflesia arnoldi, is native to Sumatra, where it grows on the roots of wild vines, and bears gigantic flowers over a yard in diameter.

The mistletoe is a parasite which grows on apple, oak and poplar. It resembles the semi-parasites in having green leaves, and sends its suckers deep into the branches of the host.

Saprophytes:- There are rare amongst British flowering plants, the commonest being the bird's-nest orchid which grows amongst the humus (decaying organic matter) in dense beech woods. Although the parasitic and saprophytic habits are rare amongst flowering plants, a large number of the more lowly members of the plant kingdom adopt these methods of nutrition. Everyone is familiar with the fact that organic substances such as bread jam and fruit soon become mouldy in the state of decay. These moulds are saprophytic fungi with thread-like bodies, through which they obtain nourishment from the decaying matter. Similarly, many other fungi such as mushrooms, toadstools & puffballs, live as saprophytes on the humus of woodlands where

Many other fungi are parasites and cause serious diseases to plants of economic importance, and occasionally also to animals. The bacteria as also are parasitic or saprophytic plants of simple structure, the former being responsible for many virulent diseases, while the latter are frequently very beneficial in furthering processes of decay in nature.

All the higher plants which are saprophytes are unable to utilize the humus directly, but require the help of fungi which live in the soil intimately associated with the saprophyte. Such an association with fungi is not confined to saprophytic plants, but occurs in many other forms, such as beech, conifers, and heaths.

The surrounding fungus is spoken of as "mycorrhiza", and possibly helps in water absorption by the roots as well as in the taking up of organic matter from the humus. This association is one of mutual benefit to both organisms such as the association of nitrogen-fixing bacteria with roots of members of the pea family.

Carnivorous Plants:- one other special method of nutrition remains to be considered viz. that of the flesh-eating plants, which have adopted the habit of feeding upon small insects and are thus frequently termed

insectivorous plants. One of the most familiar is the Sundew, which grows in peaty bogs. The plant consists of a small rosette of reddish leaves, which have long petioles expanding into a round or oval blade. The upper surface and edges of the leaf blade are studded with reddish tentacles, whose swollen ends glisten with a sticky fluid. This attracts insects, which alight on the leaf and get held by the sticky substance. The more distant tentacles then curve in to come in contact with the insect's body, and digestive juices are exuded which convert the soft parts of the insect's body into a soluble form for absorption by the plant. Later only the undigestible hard portions of the insect remain, and the tentacles are ready for another victim.

The butterwort also grows in peaty bogs in association with Sundew. It captures and digests its prey in a similar manner, by means of numerous sticky glands on the upper surfaces of the flattened radical leaves. Another example is the bladderwort, a submerged water-plant which bears numerous little bladders on its deeply divided leaves.

Each bladder has a narrow aperture closed by a little trap-door which only opens inwards; hence minute water-insects which finds their way into the trap remain imprisoned there till they ultimately die, when the products of their decay are absorbed by the plant.

The Venus's fly-trap is a North American relative of the Sundew, possessing leaves specialized to capture insects. Each half of the leaf-blade is fringed with long spines and also bears sensitive hairs. If an insect touches one of these, the leaf rapidly folds up, the two sets of spines interlocking so as to render escape impossible. A digestive fluid is then poured out from other minute hairs on the surface of the leaf. In the well known pitcher plants of which numerous species inhabit the warmer parts of the globe, the blade of the leaf is modified to form a pitcher. The inner walls of the pitcher are very slippery and covered with scales which slant downwards; any insects which venture on to the inner walls are unable to retain a foothold and, having fallen in, are imprisoned till they ultimately die and become digested.

Some of the branches of the stem of a flowering plant, instead of giving rise only to ordinary foliage leaves, bear one or more flowers, into the nature and use of which we must now inquire. Generally the flowers appear towards the end of the season's activities. In an annual, they herald the termination of its life cycle and provide for the formation of fruits and seeds, which are all that remain through the winter to perpetuate the race. In some cases, flowers appear early in the season and before the leaves, as in many trees, e.g., hazel, and in several herbaceous plants, e.g. wood anemone and coltsfoot. Whether early or late, however, the chief object of the flower is to produce fruits containing seeds, which may produce a new generation.

An idea of the nature and use of the different parts of a flower may be gained by considering a "pattern flower", which answers to the general plan of which all flowers are variations.

The flower is, in reality, a greatly specialised shoot, concerned with the production of healthy seeds, capable of growing into fresh plants. Like all shoots, it is a stem bearing leaves, though these differ more or less from ordinary foliage leaves, in accordance with their different use. It is borne on a flower-stalk, which may also bear simplified and often scale-like leaves, or bracts.

Parts of the flower: The central stem part, the receptacle, is very short, owing to the suppression of its internodes, so that the different flower leaves which it bears are crowded together, much in the same way as

are the foliage leaves in the ~~sm~~ rosettes of the dandelion and daisy. The flower leaves are of four kinds, arranged in two sets, (a) the perianth, or Covering leaves externally, and (b) the essential or reproductive leaves internally.

The two sets of leaves of which the perianth is composed are an external circlet or whorl of five Sepals – Collectively termed the Calyx – and an internal whorl of five petals – the Corolla – alternating with the Sepals.

The Sepals are firm and green, being more like foliage leaves than their associates. They protect the delicate internal parts of the flower, and specially do they afford protection in the bud. The petals are larger in size and are more delicate in texture than the sepals, and they are brightly coloured. They help to protect the essential leaves, but their chief use is to make the flowers conspicuous in order to attract insects.

Reproductive structures. In the essential or reproductive leaves, again we have two sets of structures – i.e. two whorls of stamens, five in each whorls, and a whorl of 5 Carpels. The member of each whorls alternate with those of the preceding one.

The stamens which are to be regarded as the male

infinitisimal amount of what may be called male protoplasm fuses with it. It is the office of the pollen grain to supply this. And it may be stated, once for all, that sexual reproduction, in plants and animals alike essentially consists in the coalescence of two minute masses of living matter, or protoplasm, one male and the other female. We do not at present precisely know why fertilization should be necessary, or exactly how it makes it possible for the egg ~~shall~~ cell to develop.

A pollen grain is a small mass of protoplasm containing two nuclei when ripe, and covered by two skins, of which the inner one is very delicate. It may be regarded as consisting of two cells — as indicated by the two nuclei — though in the higher seed plants, these are not separated from each other by a party-wall. The first step towards the attainment of fertilization is the transfer of pollen grains to the stigma. This is pollination

Fertilization:— Supposing this transfer to have been accomplished, the pollen grain germinates in the sticky fluid of the stigma, and sends out a delicate pollen tube, which grows down through the style into

the ovary, where its tip passes through the micropyle. Meanwhile, both of the nuclei of the pollen grain have passed into the pollen tube; one nucleus has divided into two, which are the all-important male nuclei or male gametes. The tip of the pollen tube is ruptured and one male nucleus enters the ovum, with the nucleus of which it fuses, and thus effects fertilization. The other male element fuses with a nucleus which lies centrally in the embryo sac, and causes the development of endosperm, a nutritive tissue, which nourishes the developing embryo. In some plants this tissue is present in the ripe seeds, which are then described as albuminous.

Supposing that the pollen grain of our simple flower has been transferred to the stigma of the same flower it will be a case of self-pollination, followed by self-fertilization. But if the pollen grains on the stigma have come from a flower on another plant, we have cross-pollination, followed by cross-fertilization.

<u>cross-fertilization</u>:- As a result of very numerous observations and experiments it has been clearly proved that-

healthier and more vigorous seeds are produced when cross-fertilization takes place than when the egg-cells are self-fertilized. Even pollen from another flower on the same plant is better than pollen from the same flower, while it has been produced in a different plant of the same species, the results are still more favourable.

Cross-pollination:—As cross-fertilization is necessary, preceded by cross-pollination, we naturally expect to find many devices for securing this. Pollen may be transferred from one flower to another by various agencies. If we suppose our simple flower to be a conspicuous one, the transfer will most likely be effected by insects.

The colour and odours of our native flowering plants are simply to be regarded as means for attracting insects. Flowers, however, do more than merely attract insects by suitable colours and odours. They provide them with what may be called flower food, upon which, indeed, some of their guests are entirely dependent. This partly consists of the pollen which is produced in abundance, and partly of the sweety fluid known as nectar. The latter

oozes out from little wellings – nectaries – situated deep down in the flower, and varying also a good deal in number, character, and exact position.

The fertilized ovum divides and again and again to produce a small mass of cells, which enlarges and increases to form a minute plantlet, outside or within which is a store of food in the form of starch and albuminous matter, or possibly other nutritive substances, which render growth possible until such time as the young plant is able to draw on the supplies of the outside world. The delicate investments of the ovule become tough seed coats.

Formation of fruit:– While the seeds are ripening the ovary enlarges and becomes the fruit. This may be hard and dry, as in buttercup, poppy and sunflower, or fleshy and succulent, as in the plum, orange, and grape. Other parts besides the ovary may undergo changes, and contribute to the formation of what is then termed a false fruit. The red pulp of a strawberry, for instance, is formed by the enlargement of the stem part of the flower – i.e. the receptacle. The brown pips are the real fruits – in this case dry, and each formed from an ovary. The diverse characters of seeds and fruits are often associated with the

necessity for giving the young plants a chance of finding some suitable spot in which to grow up, and for preventing them from competing too vigorously with their parents. There are, in fact, all sorts of arrangements by which the scattering or dispersal of seeds is facilitated.

Methods of Pollination

The transference of pollen from the stamens to the stigma is essential for the production of seeds. If the egg-cells of a flower are fertilized by the agency of pollen from the same flower, or from another flower of the same plant, they are said to be self-fertilized; if by pollen from a flower of a different individual, cross-fertilized. In many plants a greater number of seeds and frequently more healthy offspring are produced from cross-fertilization, and, therefore, it is not surprising to find that, in the course of evolution, innumerable devices have come into existence by which self-fertilization is hindered and cross-fertilization promoted. Such devices are connected with the transference of pollen to the stigma i.e. with pollination, the process preceding fertilization.

Most flowers contain both stamens & ovaries and are

described as hermaphrodite. In this the male & female organs rarely ripen at the same time. In the Canterbury Bell, for example, the stamens ripen first and discharge their pollen before the stigmas are capable of receiving it, in the plantain, on the other hand, the stigmas in each flower wither before the stamens appear. In this latter plant the small flowers grow closely together in a dense spike, and ripening of ovaries and stamens occurs in the basal flowers first. The tip of the spike may, therefore, bear ripe ovaries, while at the bottom the stamens have begun to ripen. Since, however, the flowers in the female stage are always above those in the male, the falling pollen cannot effect pollination.

Some flowers are spoken of as self-sterile, such as many members of the pea family. In these cases the pollen has no effect at all on the female organs of flowers of the same individual plant. In other cases we find that stamens and ovaries occur in distinct flowers, which are then said to be unisexual. The flowers of different sexes may be found on the same individual, as in hazel, or on different individuals as in dog mercury and willow. In the latter case self-pollination is out

the question. Unisexual flowers probably arise from the hermaphrodite condition by suppression of the organs of one sex. quite commonly commonly the remains of the other essential organs can be recognized.

The modes of distribution of male, female and hermaphrodite flowers are very varied. Quite a number of plants have unisexual and hermaphrodite flowers side by side. Thus in the daisy the outermost flowers (popularly known as the 'petals') are female while the central yellow flowers are hermaphrodite. In the campion male, female & hermaphrodite flowers occur on distinct plants, whilst the ash bears all three types on the same individual.

Since pollen-grains are not themselves capable of movement, they must, to secure crossing, be transferred by some outside agency from the anthers of one flower to the stigma of another. The commonest agencies for conveying the pollen are wind, insects and more rarely, water.

Wind pollen:— This frequently occurs among herbs which have inconspicuous flowers, and among most of the ordinary trees of temperate regions.

it is evidently a method of pollination which depends largely on chance, and therefore, to ensure success, an enormous amount of pollen must be produced. This is brought about in various ways; either the flowers contain many stamens (e.g. poplar & elm) or the anthers are very large (e.g. sedges and grasses) or the number of male flowers greatly exceeds that of the female (e.g. scots pine & hazel) The grasses further ensure successful pollination by possessing a richly branched and feathery stigma, by which the pollen is easily caught.

Wind-pollinated trees open their flowers in early spring before the new leaves have unfolded, and when, therefore, the pollen-grains are most likely to reach the stigmas. It is essential that the pollen should be readily shaken out of the flowers by the wind, & related to this is the frequent occurrence of loose hanging catkins or of anthers which swing freely on long filaments, as in the grasses and plantain. The pollen itself is dry and powdery and thus wide distribution is facilitated.

Insect-Pollination:- The vast majority of Conspicuous flowers are cross-pollinated by the agency of insects.

and in the course of evolution an immense number of mutual adaptations have arisen between them. The first features to be noticed in insect-pollinated flowers are the devices which induce insects to visit them, and foremost among these are the nectaries. Vary greatly in size and shape in different flowers and may be situated on almost any part of the flower, but generally near its base. Quite commonly dark streaks or spots, known as honey guides occur on the petals converging to the point where the nectary is situated. These may be seen in the pansy and several members of the pea family, and may possibly indicate the position of the nectary to the pollinating insect.

Some insect-pollinated flowers, however, produce no honey and offer only pollen to their visitors. The poppy and broom are common examples of such 'pollen-flowers' and, in common with their type, possess a large number of stamens, so that pollen is produced in sufficient quantity both for pollination and as food for the insect.

Protection of Pollen:— Many plants are able to

protect their pollen and honey from the injurious effects of rain or dew. the simplest method is the more or less complete closing of the split anthers when the air is damp. Protection is also obtained through the so called 'sleep-movements' of flowers, i.e. the closing of flowers at night, as occurs in the tulip, Crocus, Wood anemone etc, and the closing of the Compound flowerheads of members of the ~~daisy~~ daisy family. Protection of moisture is also attained by the hanging position of many flowers, e.g. Harebell, heather & lily of the Valley.

In addition to honey and pollen, other sources of attraction to insects are the Colours & odours of flowers. As a general rule it is the perianth which is the showy part of an insect-pollinated flower, but occasionally other parts, such as stamens or bracts may become expanded & brightly Coloured. Different insects are attracted by different Colours. Pale tints or white are characteristic of flowers which open in the evening and are pollinated by moths, for they render them as conspicuous as possible. Flowers of small size are rendered conspicuous by being massed together in large numbers to form a flower-head, as in the daisy and the guelder rose.

Since pollination is almost a certainty in insect-pollinated flowers, a relatively small number of stamens is usually formed. The pollen itself has a rough or sticky coat, to adhere the more easily to the insect's body, whilst the stigma is not richly branched as in wind-pollinated forms, but has a very sticky receptive surface.

Insect Agents.—The insects which most often serve as pollinating agents are the various types of bees, and bumble-bees, butterflies, moths, flies, and beetles. All these, except beetles, have a special sucking organ, the tongue or proboscis, of very diverse length, short in flies & very long in butterflies & moths. Flowers whose petals form a long corolla-tube with a nectary at the base are visited only by long-tongued insects, whilst wide-open flowers provide honey to both long and short-tongued insects. In the majority of cases the insects alights on the perianth of the flower it is visiting, with the result that some part of its body becomes dusted with pollen. Sooner or later the stamens & stigma in an insect-pollinated flower occupy the same

positions within the perianth, and, therefore, the pollen taken from one flower will probably get rubbed off on the stigma of another.

Water Plant Pollination:— In certain aquatic plants the movements of the surrounding water bear the pollen to its destination. The best-example is probably that of Vallisneria (eel grass), commonly grown in aquaria in this country. Self-pollination is entirely prevented by a method which is adopted by many other forms. The stamens and carpels are developed in different flowers, borne by separate plants. The female flower is placed at the end of a spiral stalk, which uncoils and brings it to the surface.

Meanwhile, the ripe male flowers have broken off their stalks, and float about like so many little boats, being drifted here and there by the wind. Their perianths expand and the stamens project, lifting up their anthers so that the pollen is kept dry. Should one of them be driven against a female flower, some of the pollen is likely to adhere to the sticky surface of one or other of the three projecting stigmas, and thus cross-pollination is brought about. When the

egg-cells are fertilized, the stalk of the female flower coils up again, and the seeds mature in a sheltered situation.

Land Plants:— In the case of land plants pollen may occasionally be transfered by mammals, birds, snails & slugs, but the vast majority of conspicuous flowers are cross-pollinated by the agency of insects. In a large number of small regular flowers, mostly of white or yellow colour, which cater for a miscellaneous crowd of short-tongued insects, the nectar is fully exposed to view. We find this state of things in most members of the parsnip and carrot-order and in some saxifrages. Not unlike these, but somewhat more specialized, are flowers which partly conceal their nectar, and lay themselves out for a rather more select circle of guests with somewhat more elongated mouth parts. Such are most members of the Wallflower order, buttercups, stitchworts and their allies, barberry and cinquefoil. Lastly we have flowers which ~~have~~ completely conceal their nectar ~~in~~ keep in deep recesses or long spurs, and attract the most intelligent and highly specialized insects,

such as bees and butterflies, in which the mouth parts are drawn out into a long proboscis, which forms a very efficient sucking organ. Many such flowers are irregular and adapted to the shapes of particular guests; while red blue and violet are the favoured, though not the only, colours. Here belong foxglove, honey-suckle, larkspur, monkshood, and the orchids.

Methods of Cross-pollination - Many members of the Pea and bean order are adapted for visits of bees or humble-bees, and possess a special mechanism by which transfer of pollen is secured. The butterfly-shaped flowers of our native species possess five petals — namely, an upright standard, two wings, and two lower petals united into a 'keel', which shelters the stamens surrounding the simple pistil. There are four chief kinds of mechanism by which cross-pollination is furthered: (a) In clover there is a simple valvular arrangement. If a bee alight on the flower and probe for nectar, its weight causes the stamens and stigma to project from the keel and touch its under surface, the former dusting the insect with pollen, while the latter is likely to receive pollen grains brought from another flower.

(b) A piston device is possessed by such forms as bird's foot-trefoil and lupin. Here the pollen accumulates in the tip of the keel, and is pushed forward by the thickened ends of the filaments as the result of pressure (c) In vetches, pea, broad bean, and scarlet runner the style bears a brush of hairs which, on the application of pressure, sweeps out pollen against the body of the visitor. (d) The flowers of gorse and broom are in a state of tension, and explode from the pressure brought to bear by the insect visitor. In gorse the under, and in broom the upper, side of the insect is dusted with pollen and touches the stigma.

Pollination by bees:— The dead-nettle order contains many forms which are cross-pollinated by bees. In white dead-nettle, for instance, the irregular corolla possesses a convenient platform on which a large bee can alight, and while it is probing for the nectar secreted near the base of the ovary, the four anthers and the forked stigma — which are sheltered under a hood — come into contact with the upper side of its body. Meadow sage and scarlet sage possess but two stamens, of which the anthers are modified into a sort of

curved swinging apparatus. Should a bee settle upon one of the younger flowers, it presses against the lower ends of these anthers, and the upper parts of them, containing the pollen, swing down and dust its back. In older flowers the forked stigma bends down so as to touch the back of a visitor and take up any pollen sticking to it.

The foxglove can be cross-pollinated only by humble-bees. The four stamens and the stigma lie along the upper side of the bell-shaped corolla, the former maturing first. If a humble-bee creeps into a young blossom its back is dusted with pollen, and some of this is likely to be received by the stigma of the next or older flower it may chance to visit. In somewhat similar arrangement is found in Snapdragon, but here the humble-bee has to force open the curiously shaped corolla in order to secure the nectar which lies within.

The more specialized members of the buttercup order are also bee-flowers. One of the most interesting examples is afforded by monkshood, in which the two upper petals are modified into tubular nectaries, which can only be sipped by a humble-bee. The stamens mature

first-, and after them the stigmas, these successively occupying as position in front of the flower which has the effect of bringing them into contact with the under side of a visitor.

As a last example of a bee-flower, we will take the spotted orchis, of which the purple spikes are often seen in meadows from May to July. Three sepals and three petals are all brightly coloured, and one of the latter expands into a large lip, which serves as an alighting platform for guests. It is drawn out into a long spur, the delicate inner wall of which is perforated by bees to get the honey. Facing the entrance to the spur is a broad stigma, above which is a sticky knob, the rostellum. Only one stamen is present, united to the lip of the pistil, and devoid of filament. Its anthers contains two cavities, the pollen in each of which is bound together into a club-shaped mass (pollinium) possessing a slender stalk, which runs down to the rostellum. If now a humble-bee alights upon the flower and probes for nap, it will strike against the rostellum, and on withdrawal, will carry off the two pollinia on the

lip of its head. These quickly bend forward, & adhere, in whole or part, to the stigma of the next-flower visited.

Pollination by Butterflies & Moths:— Butterfly-flowers are mostly of red Colour, and very fragrant. Pinks afford a typical example. Nectar is secreted at the bottom of the long, narrow tube formed by the stalks of the petals, and is only accessible to the slender proboscis of a butterfly.

There are also flowers reserved for moths. These are white or pale in colour and conspicuous in the dusk, at which time they usually add to their attractions by exhaling a fragrant odour. Honeysuckle is pollinated by Hawk-moths, which possess a very long proboscis, and suck nectar while on the wing. In accordance with this, the Corolla is drawn out into a nectar-containing tube, and there is no alighting platform. The stamens first-mature, and project from the blossom in such a way that some of their pollen is readily shaken on to the visitor, which will be likely to transfer some of it to the stigma of an older flower that occupies the position taken up by the stamen in an earlier stage.

the primrose and dog violet are visited chiefly by bees and butterflies. The former flower is of great interest, because it possesses two kinds of blossoms in one (thrum-eyed). The five anthers occupy the mouth of the corolla tube, and the rounded stigma is borne upon a short style. In the other kind ('Pin-eyed) the anthers are deep down in the tube, while the stigma is on a long style and occupies its entrance. It naturally follows that the pollen from one kind of flower is likely to be transferred to the stigma of the other.

Pollination of the Daisy:— The pollination mechanism in the daisy family is quite different from those we have already considered. Usually only the hermaphrodite flowers produce seed. The five stamens of these flowers are united to form a tube, inside which the pollen is shed. The stigma grows up as a straight rod through this pollen, which is caught upon the hairy style below the stigma. When mature, the stigma opens out into a Y shape, and the inner receptive surfaces await cross-pollination. If this fails to occur, the stigma lobes, when old, curl right back till they

come in contact with the style on which are entangled pollen grains. Thus self-pollination is ensured if cross-pollination fails.

Flowers as fly-traps:— A number of flowers possess traps by which small flies are caught and held prisoners until they have done the work required of them. Our common wild arum presents us with a striking arrangement of this kind. The flowers are enclosed in a chamber formed by the lower part of a large green bract (spathe), which opens to display a thickened purple stem (spadix), upon the base of which these flowers are arranged in two crowded sets, of which the lower are female and the upper ones male. Above the latter are a number of downwardly directed trap-hairs. There are no other than modified male flowers which have lost their original function. Small flies are attracted by the dull purple colour of the spadix and by an ammoniacal odour which is exhaled. Creeping down the spadix or runs side of the spathe, they easily make their way past the trap-hairs, and find themselves prisoners in the chamber containing the flowers.

At this time the stigmas are mature, and should any arum pollen be sticking to the bodies of insects visitors, they are likely to receive some of it.

When this takes place the stigmas wither, and each of them exudes a drop of nectar as payment for services rendered. The stamens next shed their pollen, and some of this is likely to stick to the guests, which are at last allowed to escape, because the trap-hairs wither. The pollen is, in a certain proportion of cases, carried by them to another arum.

Classification of fruits.

The ovary and the ovules contained in it undergo great changes as a result of fertilization. The union of the two elements, a nucleus from the pollen-grain and the nucleus of the egg-cell, results in a stimulus to growth, which is the starting point in the life history of a new plant. The ovary enlarges while the character of the ovary wall becomes changed, and at maturity the structure is known as the fruit. The fertilized ovules within the changing ovary become the mature seeds. A seed can always be distinguished from a fruit by the fact that it only exhibits one scar,

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According to the changes undergone by the ovary wall after fertilization, fruits may be classified as dry or succulent. Some plants produce what are known as false fruits, for in them some part of the flower other than the ovary has contributed to fruit formation. If the ovary consists of only one carpel (e.g. pea) or of more than one carpel united (e.g. lily) the fruit is spoken of as simple, but if the ovary consists of several separate carpels, the resulting fruit is compound (e.g. buttercup).

Dry fruits:— two types of dry fruits may be distinguished: one usually remains attached to the parent plant and splits open to liberate the contained seeds; the other type does not split open, but the fruit wall merely decays away after the fruits reach the ground. These types are described as dehiscent and indehiscent respectively. Common examples of dry dehiscent fruits are the pods of pea, gorse, & broom, the pod like follicles of Columbine

and mouseear. The flattened fruits (Siliquas) of honesty and wallflower, and the globular fruits (capsules) of lily, bluebell, iris, Campion, Violet, poppy, and pimpernel. Many different modes of dehiscence are seen among the capsule fruits, some opening by simple splits, some by teeth, others by valves, pores, or a complete lid.

Good examples of dry indehiscent fruits are furnished by nuts, such as hazel, sweet chestnut beech and acorn. Of the same type are the fruits of members of the daisy family (eg. sunflower + dandelion) the grasses and the buttercups. Fruits of the indehiscent type often contain but one seed. The reason for this is to avoid overcrowding and competition among many seedlings germinating in one spot. The seeds usually have a thin seed coat, in contrast to the thick covering of seeds which are liberated from fruits and are thus without the protection of the fruit wall.

Succulent Fruits: — There are two chief kinds of fleshy fruits, known respectively as drupes + berries, both types being indehiscent. Examples of berries are found in currant, gooseberry, tomato and cucumber — the characteristic feature of this type of fruit being that the wall is fleshy throughout and forms all the succulent portion. The seeds are held within the fleshy middle region. Other examples of berries are orange, lemon, grape, banana, vegetable, melon and dates. In the case of the orange + lemon the ovary wall forms the coloured

outer skin, the underlying white skin & membranous skin round the fleshy sections. The fleshy part consists of a great development of juice-containing hairs, which grow from the skin-like lining. The structure commonly known as the date-'stone' is the true seed, rendered very hard by the store of cellulose in the cell walls of the endosperm. Common examples of drupes are the cherry and plum. The drupe differs from the berry in that the ovary wall does not become entirely fleshy but the innermost region of it forms a hard stony layer in which the seed is enclosed. On cracking open the stone, the white seed is revealed, contained in a thin brown seed-~~box~~ coat. Other typical drupes are damson and peach, etc. also the almond, walnut and coconut in which, however, the layer outside the 'stone' are generally removed before they are placed on the market. The raspberry and blackberry furnish instances of compound fruits composed of several small drupes.

False fruits: — In some plants the fruit is not composed of ovary alone, but other parts of the flower (specially the flower stalk) take parts in its formation. When this is the case we speak of the resulting structure as a false fruit. Thus in the strawberry the true fruit is compound, consisting of a number of minute dry fruits (technically called achenes), borne on the much enlarged and fleshy flower stalk, which is the actual edible part. In the apple and pear ~~&~~ (fruits known as pomes) the flesh is formed by the flower-stalk in which the ovary wall forming the core. The rose hip is another false fruit, in which the ~~&~~ coloured flask-shaped portion is formed from the flower-stalk and the true fruit is constituted by the dry achenes within.

Complex Fruits: — The fruits of fig, pineapple, mulberry and hop differ from those we have already considered because a complex fruit is formed from a whole inflorescence ie. from a group of flowers. The fig is really a swollen stalk bearing numerous small male and female flowers on its inner surface. The female flowers produce minute fruits, popularly regarded as seeds. The Composite fruit of the pineapple is formed from a spike of flowers, the fleshy flower-stalk and flowers all fusing together. The areas on the surface of the fruit represent the flowers. Above the flowers the stalk produces a number of leaves forming the crown. The mulberry is also formed from a spike of flowers whose perianth members became fleshy and enclose the true fruits, which are achenes. The fruit of the hop (the cone) is formed from an inflorescence whose stalk bears numerous membranous scales.

In all cases the object of fruit formation is the production of seeds containing a young plant-bud capable of growth.

Nature's Methods of Seed Disposal

It is necessary that seed should be widely dispersed from the parent plant, so that some at least of them may be able to find a suitable spot where they can germinate without overcrowding, and may in their turn continue to perpetuate the race. Certain plants are able, by the structure of their fruits, to disperse their own seeds, while others depend on the help of wind, water and animals.

The fruits of a number of plants are in a state of tension when ripe, and finally open or split

suddenly in such a way as to eject the seeds to a considerable distance. One of the commonest examples afforded by broom, the flat, black pods of which may often be heard exploding in late summer. The two halves curl up suddenly, so that the seeds are scattered in all directions. A similar case is that of the "popping' balsam (touch-me-not), the ripe capsules of which split into four twisting strips at the least touch, with the same result. Violets and pansies also throw their seeds some distance; in them the ripe fruit breaks open into three boat-shaped portions, in each of which are two rows of seeds. The seeds are squeezed out of the 'boats' by the sides pressing in to meet each other above the seeds. The pressure brought to bear on the seeds in turn frees them out to a distance of two or three feet.

Several species of wild geranium flang their seed from them by sudden rupture of the fruits, and a not closely allied fruit plant the stork's bill, ensures that its seeds are sown in the ground. The entire fruit of the stork's bill consists of five free carpels, each containing one seed in its swollen base, and having the style formed into a stiff, pointed awn. The awns curl up when dry, and this brings about the scattering of the fruits. When moist the awns uncoil, and this alternate coiling & straightening in dry and damp conditions pushes the fruit down into the soil.

Agency of Wind:— Many plants have no special modification either in their fruits or seeds, but secure the scattering of the seeds by the elasticity of the dry fruit-stalks when the seeds are ripe. The ripe fruits open by large splits or small holes, so that the seeds are exposed, but some disturbance is necessary

to liberate the seeds. This is effected by gusts of wind, or by the contact of animals or birds which bend the dry stems; directly the bending strain is removed, the elastic stem swings back to the upright position and the seed are jerked out in various directions well away from the parent plant. Examples of this method are the campions. foxglove and bluebell, whose fruits open by wide splits at the upper end; poppies and snapdragon, which open by pores; most members of the dead nettle family whose fruits are held in a little cup formed by the calyx.

Wind is a very effective agency in dispersal. If seeds are very small and light, they remain suspended like dust in the air, and may be carried great distances by the wind without any structural modifications. This is the case with many orchids and heaths. The majority of fruits and seeds which are carried by the wind have some special device, such as a parachute or wing, to enable them to be carried long distances. Winged seeds are rare among the best examples being the pines and firs, whose winged seeds are readily seen on breaking open a ripe fir cone. The wing is a flattened expansion of the seed coat. The keys of maple, sycamore, ash, and elm are common examples of winged fruits, the wing being an outgrowth of the ovary wall, while the hornbeam and lime achieve similar ends by attaching a modified leaf (bract) to the fruits.

Parachute contrivances are found on the seeds of willow herbs, willows and poplars and on the fruits of clematis, wood-anemone and many members of the daisy family, e.g. dandelion, thistles, goat's-beard etc. The fruit of the willow herb is an elongated capsule, which dehisces when ripe, exposing the small seeds, whose seed-coats form a little parachute of hairs at one end. Cotton is an example extreme growth of this kind, the fibres being long, fluffy parachutes attached to the seeds. Clematis develops a feathery style as the fruit ripens, & in wood-anemone the ovary wall becomes woolly. The 'clock' of the dandelion is a group of fruits, each formed from one of the many minute flowers of which the flower-head is composed. The parachute (pappus) of each fruit is the modified calyx which in the flower, is situated directly on the ovary. But as the fruit ripens, is carried up on a slender stalk. The pappus is sensitive to moisture. When damp, it folds upwards and allows the fruit to come to ground in conditions when it is most-probably able to bury itself in the soil.

Dispersal by Water:- The dispersal of fruits and seeds by water is the method naturally adopted by plants which live and ripen their fruits in the water. It is also used by some land plants which grow near running water, the fruits and seeds being furnished with contrivances which prevent them from sinking. For example, the fruits of sedges are surrounded

by an inflated sac; those of many Water plants contain a number of thick-walled air-cells in their outer layers.

The dispersal of the Coco nut is also effected by means of Water; the fruit has a large air-cavity, containing much tangled fibrous hair, between its outer tough wall and stone. Coco nuts may be carried thousands of miles without getting Waterlogged.

Birds and Animals as Dispersal Agents.

Seeds of the greater Celandine, Violet and gorse have small swellings (Caruncles) on them near the micropyle and are often carried by ants to their nests. When the caruncles are used for food and the seed left uninjured.

Succulent fruits depend chiefly on birds for the dispersal of their seeds. The bright-Coloured attract the birds, which eat the fleshy portions and either scatter the seeds in the process of pecking at the fruit (as in the rose hip where the achenes are hairy and unpalatable) or swallow the seeds and disperse them more Widely in the faeces.

Many small seeds are carried far in the mud adhering to the feet and lower feathers of birds which seek their food in damp places. Other fruits and seeds are specially provided with hooks or spines, which catch in the hair or fur of passing animals, or the clothes of human beings. Such hooked fruits are usually known as burrs. The hooks are situated on various places in different plants: on the ovary in

goose grass, on the tip of the style in avens, or the calyx in agrimony, and on the bract of the flower head in burdock. In all burs the separation from the parent plant is very easy, so that a mere touch by a passing animal will carry the ripe fruit away.

Two Classes of Angiosperms.

We already know that the seed-plant phylum is divided into angiosperms, whose seeds are protected in a seed case and gymnosperms, which are naked-seeded plants.

Angiosperms are divisible into two classes: dicotyledons and monocotyledons. The seedlings in the first-class are provided with two cotyledons or seed-leaves, and the vascular bundles of the young stem are arranged in a ring, each of them containing cambium, which is able to bring about increase in thickness. The veins of leaves are arranged in net-like fashion. Whorls of the perianth are in fours or fives.

The seedlings of the monocotyledons are each provided with only one cotyledon and the vascular bundles of the stem are scattered & devoid of cambium. The chief veins of the leaves are generally more or less parallel. Whorls of the perianth are in threes. The monocotyledons are in the main a herbaceous group exhibiting a high perfection of means for perennation and hibernation (e.g. bulbs, corms etc.)

Of over 250 families are recognised, embracing something like 100,000 species, it is obvious

that- We must- limit ourselves to the consideration of facts of leading importance. The characters used in classification are of the most- various kind; and though in most- cases there is no doubt-, some particular meaning to be attached to them, our knowledge as to this is often incomplete.

We find that- foliage- leaves vary greatly in arrangement and shape, while stipules may be present or absent. As to the first- point, which largely has reference to advantageous disposition with reference to light, we may find either only one leaf per node, the successive leaves being arranged in a spiral, or there may be two leaves at each node. In these two cases the leaves are said to be respectively alternate & opposite. The ~~so~~ shape is often also related to the supply of light-. In simple leaves the blade is one piece; in compound ones it is cut up into a number of distinct- leaflets. Leaves devoid of stipules are said to be exstipulate.

Flower structure: — Great importance attaches to the arrangement and structure of the parts of the flower, in which we can often detect- some connection with the way in which pollination is effected. In pattern flower (P. 368) the parts of each whorl of the perianth were all alike, and disposed in a star-like manner. Such a flower is regular. But in flowers which are pollinated by the higher insects such as bees & butterflies, we find that these parts are more or less unequal, & disposed

in a two-sided fashion. These are termed irregular — e.g. pea, pansy.
In similar cases the receptacle (that part of the flower stalk which bears the floral organs) is more or less conical, so that the sepals, petals and stamens clearly spring from beneath the pistil. The flower is then hypogynous. But the receptacle may be modified into a sort of cup, from the edge of which sepals, petals, and stamens arise, while the pistil occupies the interior of the cup, as in the rose. Such flowers are perigynous. And if this cup fuses with the pistil, so that the sepals, etc, appear to grow from the top of ovary, as in the snowdrop, the flower is epigynous, and is still further specialized. In the first two cases the ovary is attached to the receptacle by its base only and is said to be superior, while in the last case, the attachment is more extensive, and it is termed inferior.

Parts of Flowers: — There are many variations as to the number of flower leaves. The most primitive case is where they are relatively numerous, and arranged in a spiral. This is beautifully seen in the sepals, petals and stamens of the White Water lily (Nymphaea alba) which pass gradually into one another.
In most flowers, however, the parts are in successive whorls, as in our pattern case, but there are many variations as to number. The inner whorl of stamens is often suppressed altogether, and in extreme cases (e.g. most orchids) only one stamen may be present.

Such reductions have reference to increasing certainty of pollination, & that there may is no need for a large quantity of pollen to be produced. The carpels, too, for similar reasons are often reduced in number, and many flowers e.g. pea and gorse have but one.

The perianth is badly developed, reduced and inconspicuous, or even absent where pollination is not effected by insects (or birds) there being no need for conspicuousness. In such cases there is usually an absence of colour, odour & nectar.

In simpler cases the flower-leaves of a particular kind are not united together, i.e. are free. With increasing specialization we find sepals, petals, stamens and, more particularly, carpels, ~~stamens~~, ~~androecium~~ are respectively united. Flower-leaves of different kinds may also adhere together e.g. stamens with petals as in the primrose. There is further a great deal of variation as regards the number of ovules and the way in which these are arranged in the ovary. Seeds may be exalbuminous or albuminous.

Classification Of Angiosperms: class I. Dicotyledons

Division # I. Archichlamydeae.

All plants in this division have the petals free from one another or absent i.e. the petals are not united in a tube. The order of this division comprise families containing many well known plants.

Order 1. Ranales. Flowers hypogynous. Carpels free.

(a) The buttercup family (Ranunculaceae) leaves generally alternate and exstipulate. The buttercups and others have regular flowers with numerous free stamens and carpels, while some forms i.g. larkspur and monk's hood, have irregular flowers specialized in relation to pollination by the higher insects.

(b) The Water lily family (Nymphaeaceae) Conspicuous with spiral arrangement. A notable species is victoria regia a South American form with leaves 6 feet and flowers 16 inches in diameter.

(c) The magnolia family (Magnoliaceae) Woody plants considered to be most ancient type of existing dicotyledons.

Order 2. Rhoeadales. Flowers hypogynous. Carpel joined.

(a) The poppy family (Papaveraceae) herbs which yield a sticky juice. Leave alternate and exstipulate. Sepals 2; petals 4; stamens numerous. The carpels are united by their edges and the ovules attached to the outer wall of the ovary. This arrangement is also found in the Wall flower & violet-families.

(b) The Wall flower family (Cruciferae), leaves alternate, exstipulate. sepals 4 in two whorls; petals 4, in the form of a cross; stamens 6, four long & two short; Carpels 2. The ovary is divided into two

cavities by a partition growing out from the edges of the joined carpels. It is this partition which forms the decorative silver 'leaf' of dried honesty. In this family occur the wallflowers, stocks, shepherd's purse, watercress and garden cress, mustard, radishes, turnips, cabbage - etc.

(C) The violet family (Violaceae), leaves alternate, with large stipules. Flowers irregular, carpels three.

Order 3. Centrospermales. Flowers hypogynous. Carpels joined.

The pink family (Caryophyllaceae) The ovary contains but one compartment in the centre of which is a vertical projection, to which the ovules are attached. Examples are found in pinks, carnations, campions and chickweed. The docks and beet which have no petals are in other families of this order.

Order 4. Geraniales. Flowers hypogynous, carpels joined. The geranium family (Geraniaceae): the parts of the flower are mostly in fives, the carpels united at the centre and the ovules borne at the central junction. The cultivated pelargonium belong to this family and the wild crane's bill and stork's bill. In a nearly related family are the garden nasturtium, (Tropaeolum), balsam, wood sorrel and flax, one species of which (Linum usitatissimum) is of economic value in providing fibres for



linen, linseed oil and cattle-cake.

Order 5. Malvales. Flowers hypogynous, Carpels 5 joined. The mallow family (Malvaceae): flowers regular, with parts in fives. Stamens variable in number, often united by their filaments. Carpels 3 or more, with the ovary in compartments. Well known examples are the mallows & tree-mallows, hollyhocks, and the cotton plant (Gossypium).

To the same order belong the lime tree as do also the plants from which Cocoa & Cocoa.

Order 6. Rosales. Flowers mainly epigynous or perigynous.

(a) the rose family (Rosaceae), leaves usually alternate with stipules. Flowers regular with 5 petals & 5 sepals, numerous stamens and a variable number of carpels which may be free or united. Examples are the rose, hawthorn, plum, cherry, peach, pear, apple, strawberry, gooseberries, and currants occur in the and the family of this order and nearly allied are the hydrangea and the cultivated shrub philadelphus (commonly called syringa).

(b) the pea family (Leguminosae) leaves usually compound and with stipules; Flowers irregular with 5 joined sepals and 5 free irregular petals. stamens 10, either all united by their filaments or 9 united in one and one free. One carpel which ripens into a pod (legume); seeds exalbuminous with large embryos. Some of our commonest members are the gorse, broom and clovers. Many are valuable for fodder & human food e.g. Vetches,

beans, peas, and lentils.

Many exotic species yield useful timbers & other products e.g. senna, liquorice pea nuts & indigo dyes.

Order 7. Amentiferae. This order comprises the catkin-bearing families. The plants are mostly shrubs or trees with minute flowers in pendulous catkins or heads. The flowers are usually unisexual, the male & female being on the same or different plants. The perianth is usually wanting, and pollination is effected by wind. Examples are the plane, poplar, willow, birch, alder, hazel, oak, elm, beech, sweet chestnut, stinging nettle and hop.

Order 8. Umbellales. Flowers perigynous or epigynous.

The carrot family (Umbelliferae). The small flowers are arranged in umbels i.e. a number of flowery stalks radiate from the same point and in this way the flowers are rendered conspicuous to insects for pollinating purposes. Examples are the carrot, parsnip, parsley, celery and hemlock, fennel, goutweed, caraway whose fruits are commonly called caraway seeds. The ivy belongs to another family of this order.

Dicotyledons: Division II Sympetalae.

This division contains plants whose petals are united in a tube to form a corolla.

Order 1. Ericales. Flowers hypogynous. Carpels three to ten; united. The heath family (Ericaceae); evergreens with exstipulate leaves. Flowers nearly or quite regular. This family includes all kinds of heather, rhododendron and azaleas. Nearly allied are the cranberry and bilberry.

Order 2. Gentianales. Often trees or woody shrubs. Flowers hypogynous.

(a) The olive family (Oleaceae); to this family belong the olive tree (of value in yielding olive oil) the ash and several ornamental shrubs, e.g. jasmine, forsythia, privet and lilac (Syringa).

(b) The periwinkle family (Apocynaceae); with the exception of the periwinkle, the members of this family are mainly tropical plants.

Order 3. Rubiales. Leaves Opposite, usually with stipules. Stamens growing on the corolla tube. Flowers epigynous.

(a) The goosegrass family (Rubiaceae): here belong the common hedgerow plant, goosegrass (Galium aparine) madder, once important as the source of a red dye, and plants which yield quinine, coffee and ipecacuanha.

(b) The honeysuckle family (Caprifoliaceae). Many ornamental shrubs belong to this family in addition to the sweet-smelling honeysuckle (Lonicera), e.g. the elder, the snowberry, Weigelia and guelder rose.

Order 4. Campanulales. Leaves ex stipulate; the flowers are small, but being aggregated together in large numbers, are conspicuous. they are epigynous and the inferior ovary contains but one ovule. The flower heads are usually surrounded by a sheath (involucre) of bracts. The daisy family — and (Compositae); what looks at first sight like a single flower in a number of this family — and entire order — really consists of a number of very small flowers (florets) crowded together into a head, around which is a protective covering of bracts likely to be mistaken for the calyx.
The parts of the flowers are in fives, except the carpels, of which three are two united. The stamens are attached to the corolla, and their anthers united into a tube, which surrounds the style. The calyx, sometimes absent is often represented in the form of a ring of hairs.
Numerous plants belong to this large family e.g. Sun flower, aster, dahlia, cineraria, chrysanthemum, dandelion, all kinds of daisy. groundsel, thistles, Coltsfoot and hawkweeds.

Order 5. Primulales. Flowers hypogynous. regular with 5 stamens opposite the petals to which they are attached. Carpels, five, joined. The superior ovary has but one cavity, and the ovules are attached to a vertical projection within this. The primrose family (Primulaceae): here belong the primrose, its many varities in horticulture, the Cowslip, and the cyclamen.

Sea-thrift and sea-lavenders belong to a nearly related family.

Order 6. Tubiflorales. Flowers hypogynous. Sepals and petals 4-5. stamens 2-5, pistil of 2-5 united carpels. The superior ovary contains two or more compartments

(a) The borage family (Boraginaceae); to this family belong borage, anchusa, comfrey, & forget-me-not.

(b) The potato family (Solanaceae); flowers regular. The potato plant (Solanum tuberosum) and the tobacco plant (Nicotiana) are of obvious importance, also tomato and capsicum. Petunias and salpiglossis also belong here.

(c) The foxglove family. (Scrophulariaceae); flowers generally irregular and stamens four, sometimes two or five. There are two compartments in the ovary and many small albuminous seeds. The mullein (Verbascum) posses nearly regular flowers with five stamens, generally of yellow colour arranged in tall handsome spike. The conspicuous flowers of the foxglove (Digitalis purpurea) are arranged along one side of the main axis. The blue speedwells (Veronica) posses but four petals and two stamens. Toadflax (Linaria) and snapdragon (Antirrhinum) have irregular flowers, which have to be forced open by bees in search of honey.

Order 7. Labiatales. one axis of symmetry: leaves exstipulate and usually opposite. stems four-sided. Flowers markedly irregular, with five sepals, five petals, 4 stamens (usually) and two united carpels. The ovary is deeply divided into four. Seed exalbuminous. Including dead-nettle family (Labiatae). The White

and purple dead-nettles (Lamium album & purpureum) and ground-ivy (Nepeta glechoma) are common types. Many members of this order are aromatic, and yield essential oils. Among these may be mentioned mint (Mentha), sage (Salvia), thyme (Thymus) marjoram (Origanum) and basil (Ocymum).

Angiosperms: Class II. Monocotyledons.

Order I: Helobieae. Aquatic forms, in which the stamens and carpels are commonly more numerous than in other monocots. The ovary is usually superior. Examples from the families in this order are: Water-Thyme (Elodea), Water-Soldier (Stratiotes), frogbit (Hydrocharis), flowering rush (Butomus), Arrowhead (Sagittaria), and pondweed (Potamogeton).

Order II. Glumales. Inconspicuous flowers in which the perianth is absent or reduced. Groups of them are enclosed in and protected by scale-bracts.

(a) The grass family (Graminae): herbs with hollow jointed stems and alternate narrow leaves, the bases of which are in the form of sheaths grasping the stem. There is a little membraneous outgrowth (ligule) at the junction of blade and sheath. Stamens usually 3, and one carpel with 2 feathery stigmas. The superior ovary contains a single ovule. The seeds are albuminous. All grasses are included here, as well as our cereal crops, wheat, barley and oats, together with the bamboo and sugar cane.

(b) The Sedge family (Cyperaceae); these differ from grasses in the

possession of solid stems, while the leaf has no ligule. The members of this family abound in marshy places, and are common on the edges of streams, ponds and lakes.

order 3. Palmales: The Stamens and Carpels are generally in separate flowers, which are small and crowded together on fleshy axes and protected by a covering sheath (Spathe). ovary superior.

(a) The palm family (Palmaceae): large woody plants, nearly all of which are tropical. The large leaves commonly form a tuft on the top of a long cylindrical stem. The flowers are inconspicuous: Stamens 6; Carpels 3, joined. Two useful species are the date palm and the cocoanut palm. Palm oil, sago and vegetable ivory are obtained from other members.

order 4. Arales. Arum family (Araceae): Mostly tropical plants, with minute flowers on a fleshy brightly coloured axis (Spadix) and protected by a Spathe, which is often showy. The so-called arum lily is a well known example with white spathe and deep yellow spadix. Our native species 'lords and ladies' (Arum maculatum), has a green spathe and a dark or red or cream spadix and, in autumn, a spike of brilliant red berries. The reed mace family may also be placed in this order.

order 5. Liliales. Here the flowers are regular with parts in 3, and the Carpels are united. In most cases both sepals and petals are either white or brightly coloured. The seeds are albuminous. There is generally a thickened underground stem.

(a) The lily family (Liliaceae): Stamens 6 in number and ovary superior. The order includes many ornamental plants, such as lily (Lilium), tulip (Tulipa), Squill (Scilla), hyacinth (Hyacinthus), lily of the Valley (Convallaria), and 'red-hot poker' (Kniphofia); also Asparagus, onion, garlic, leek and shallot (Species of Allium). New Zealand flax (Phormium tenax) is of considerable economic importance. Nearly all members of the order are herbs, but there are exceptions, such as

yucca and the dragon tree (Dracaena) of the Canary islands, which grows to an enormous size and is also very long lived.

(b) The rush family (Juncaceae): Plants with narrow leaves and small brown inconspicuous flowers resembling in structure those of the last order. Rushes (Juncus) and wood-rushes (Luzula) are included in this family.

(c) The Snowdrop family (Amaryllidaceae): as Liliaceae but with an inferior ovary. Snowdrop (Galanthus nivalis) and daffodil (Narcissus) are examples.

(d) The Iris family (Iridaceae): as last family but only 3 stamens. Iris, crocus, gladiolus, and saffron (Colchicum) are good examples.

Order 6. Scitaminales. Tropical plants, with large leaves and irregular flowers, of which the inferior ovary is generally divided into 3 compartments. Belonging to this group are the following: banana (Musa sapientum), plantain (M. paradisiaca), ginger (Zingiber), Indian shot (Canna) and arrowroot (Maranta).

Order 7. Orchidales: Flowers irregular and of remarkable form. The stamens are reduced in number and united with the pistil. The orchid family (Orchidaceae): this is the second largest family of seed-plants, only being excelled in size by the Compositae, and including over 8,000 species. There is usually but one stamen. We have a few British orchids, but the headquarters of the family are in the tropics.

LESSON 23.

WATER PLANTS.

In Nature, plants generally grow together in communities, the individual members mutually affecting one another and accommodating themselves to all the circumstances of their environment. The

different conditions afforded by the environment are spoken of as factors, which are both physical (those due to soil and climate) and biological (those produced by other plants & animals). The situation in which a plant grows is termed its habitat. We have already seen that there is a certain relation between the plant and its surroundings. Thus plants growing in the shade spread their leaves in the best position to receive light, climbers depend upon the presence of some suitable support, and animals are often necessary for pollination or seed dispersal.

The condition of the soil have a very marked effect on determining the character of the vegetation present. Among the most important soil factors are the texture and the amount of humus (organic matter from decayed plant & animal remains); on these depend other important factors: the water & air content, as well as the chemical nature of the soil, specially whether its reaction be acid or alkaline.

Rain fall is the most important climatic factor. Variation in temperature in different regions of the earth or at different altitudes also has a pronounced effect. Other climatic factors which influence the vegetation are intensity of light and degree of exposure to the wind.

The effects of the biological factors are many and varied. Plants compete with one another to obtain food and light; twiners get support from their erect companions while parasites, insectivorous plants & herbivorous animals are further obvious examples of the ways in which a plant is influenced by its relations with other plants and animals.

Many plants possess means of defence against herbivorous animals. These may take the form of spines, as in holly, (whose lower leaves usually have spiny margins, while those near the top of a tall bush are without spines), or of distasteful substances, such as poisons in foxglove and deadly night-shade, or of stinging hairs.

Characteristics of Water Plants. In a consideration of environmental influences, water occupies an all-important position, and we now turn to some of the characteristics shown by plants which grow submerged or partially submerged in water. Such plants are collectively spoken of as hydrophytes and examples are furnished by the water lilies, water buttercup, pondweeds, arrowhead, duckweed water soldier, frogbit and bladderwort. We shall not here consider the Algae (green pond-scums, brown and red seaweeds), which live almost entirely in water, but confine our attention to the higher flowering plants.

In the case of streams, the rate of flow markedly affects the character of the flora. Where the current is rapid, all the forms are fixed by their roots in the bed of the stream, but in quiet water free-floating (i.e. not-fixed) aquatics will be present. Again many species that grow above the water level in quiet water remain completely submerged in a rapid current.

The submerged parts of all water plants are surrounded by a medium very different from that which surrounds the overground organs of ordinary land plants, and

in this connexion there are many modifications of their structure. First- Water is far denser than air and consequently, can give support to the plants inhabiting it. Water plants therefore, never possess an extensively developed vascular system. The chief strain to which their stems or leaf stalks are subjected is a longitudinal pull due to currents in the water, and thus the small amount of mechanical tissue which the aquatic possesses is arranged as a central core, as in the root- of a land plant.

Water plants do not depend on their roots for the absorption of water and mineral salts. The roots serve chiefly for attachment, and absorption is carried on over the whole of the submerged surface. This then, is a second reason for the lack of development of woody tissue, since conduction from the roots by way of the wood vessels is not necessary.

Respiration of Water Plants. The oxygen essential for respiration is present in very small amounts in water, but carbon dioxide, which dissolves readily in water, is present in abundance. There are no pores on the submerged parts of the plants, so that all gaseous exchange must take place by diffusion through the cuticle (the outer wall of the epidermal cells.) The difficulties concerning gaseous exchange are compensated by very thin foliage leaves, or extreme division of their blades, which thus creates a large absorptive surface. Owing to the relatively great amount of carbon dioxide, photosynthesis takes place readily, and the oxygen which is set free in this process is stored up within the plant for use in respiration. This reserve of oxygen is held in the numerous large air spaces which traverse all parts of the aquatic plant. These air-chambers are also useful in rendering the plant buoyant, thus helping to maintain it in an

erect- position. A similar system of air passages is present in the underground organs of marsh and swamp plants, which have the same difficulty of obtaining sufficient oxygen.

Submerged aquatics are obviously exposed to very reduced illumination, owing to much light being reflected from the surface of the water, and the remainder being rapidly absorbed as it penetrates to deeper levels. Most water plants therefore, bring their leaves (the assimilatory organs) as near to the surface as possible. It is the light- factor which determines the depth at which submerged plants can grow.

Foliage & Roots of Water Plants. We have already mentioned that the submerged foliage may consist of finely divided leaves; this is well seen in the water buttercup. Such deep division has also a mechanical advantage, in that the water flows readily between the segments without tearing them. The fennel- leaved pondweed has long linear, undivided leaves which readily trail out with the current.

The water buttercup illustrates well the general rule that when floating leaves are produced they are quite different in form from the submerged leaves. The yellow water lily is the most familiar exception to this: the leaves are similar in form, but the submerged ones are very much thinner. Floating leaves mostly agree in having an entire edge, and the petiole attached more or less centrally, so that the pull of the leaf stalk keeps the blade flat on the water. Unlike submerged leaves, they bear stomata. The latter are, however, confined to the upper

surface, which usually has a covering of wax (leaving the pores free); the covering prevents wetting and blocking of the pores. Connexion is thus maintained between the air spaces of the submerged organs and the outside atmosphere. The floating leaves also form a supporting platform round the base of the flower stalks, which in the majority of aquatics, bear the flowers above the water level.

The roots of water plants serve mainly for attachment. Some have no roots at all (e.g. bladderwort), while in free-floating forms, such as the duck-weed, the roots dangle into the water and not only absorb, but also act like a weighted keel to keep the plant properly balanced.

Reproduction:— The abundant supply of water, and often of mineral salts as well, enables water plants to grow rapidly and prolifically. In view of this, vegetative reproduction is generally a marked feature. A simple method, common in the Canadian pondweed (which was at one time a serious pest in canals on account of its rapid growth), is the mere detachment of branches, which grow into new plants. Many forms produce winter buds, which, when the parent plant dies, sink to the bottom of the water and give rise to new plants in the following spring.

Flowers. The flowers are, in the majority of cases, borne above the water level, which indicates that water plants are derived from land plants. They may be pollinated by insects (e.g. water buttercup) or by wind (e.g. water milfoil); usually the flower stalks bend after flowering is over and carry the ripening fruits under water, so that they are well protected. A few aquatics are so highly adapted to live in the water that they even produce submerged flowers. The pollen is conveyed to the

stigmas by currents of water. Corresponding with this uncertain method of pollination, a large amount of pollen is produced, as in the case of land plants pollinated by wind.

PLANTS OF DRY HABITAT.

Now we will consider the plants which inhabit dry situations, such as dry heaths, shingle banks, sand dunes and deserts. Such plants are termed xerophytes, and the problems confronting them are entirely different from those which have had to be solved by the aquatics. The soil of such places retains very little water, it is often so loose that it is shifted by the wind: organic matter is scarce, and the rainfall often small. In such places also there is little or no shade from the sun, and no protection from the wind. Water supplies are, therefore very meagre, and risk of loss of water by evaporation is very great. The plants must obtain water somehow from the soil, and retain as much of it as possible, in order to maintain their cells in a turgid condition.

Deep roots are an obvious necessity for plants growing in such habitats. With sufficient depth of root a plant can remain fixed even if the surface layers of sand are blown away by the wind; also at the depth of a few feet the roots are bound to come on soil in which there is a certain amount of moisture. Some transpiration must take place in order to make

use of the water which is absorbed, but it must be reduced to a minimum. The development of special water-storage tissue is an advantage; the plant with reserve supplies is then enabled to withstand periods of drought.

All plants that thrive in dry habitats do not adopt the same solution for the problem of their water supply. The possession of deep roots or underground stems bearing roots is very general, but more than one device is shown for lessening transpiration.

Devices for Reducing Transpiration:— The marram grass is an excellent example of a xerophyte possessing deep underground stems. The plant abounds on sand dunes, and is often planted to bind together the loose shifting sand by means of its long rhizomes & roots. The leaves are about 3 ft. high with very sharp hard tips, which can force their way up without injury through the sand, should it bury them. The aerial stems also force their way up to the surface, and frequently send out new rhizomes a few inches below the new surface. The extensive underground system of rhizomes bearing roots is occasionally brought to view by wind blowing away much of the sand.

The leaves of the marram grass are beautifully adapted for reducing transpiration to a minimum. In damp weather the blades are flat, like those of an ordinary inland grass; but in dry weather the two edges of each leaf roll together, so that the leaf appears as a long narrow cylinder. The leaf bears its stomata (through which water vapour is lost) on one surface only, and it is this

surface which lies on the inside of the cylinder. The surface of the leaf is deeply grooved, and the stomata are still further protected from currents of air by lying near the bottom of the grooves, and by having hairs growing from the intervening ridges. The curling up of the leaf in dry weather and its flattening in moist conditions are caused by changes in turgidity of the thin-walled turgid cells situated at the bottom of the grooves.

Rolled leaves which serve the same purpose are characteristic of many plants growing on exposed heaths e.g. the cross-leaved heaths (Erica tetralix) The leaves of these plants are usually small and thick-skinned. The ling (Calluna vulgaris) has very small leaves, which are V-shaped in cross-section and arranged in four vertical rows on the stem. In dry weather they fold in tightly, one upon the other, and thus each is protected from the surrounding air by its neighbour below.

Gorse is very abundant on heaths & Commons. It is enabled to withstand dry conditions by the possession of very small leaves, many of which are modified into dry hard spines. Thus not only is the transpiring area of the plant reduced, but the plant is also protected from browsing animals. When leaf area is reduced, it follows that the assimilating area is also diminished. To compensate this, the younger parts of the stem are green and thus able to help with Carbon assimilation. It is of interest to note that the first foliage leaves produced by the seedling gorse plant resemble clover leaves

This suggests that gorse once had compound leaves and its success in dry habitats is due to suppression of its transpiring organs.

Broad-leaved plants which occur in dry situations have various devices for checking transpiration. The leaves of the yellow-horned poppy are covered with a felt of hairs; those of sea holly bear a bloom of wax; those of the sea pea and sea bindweed have a very thick cuticle. The plants just mentioned grow on shingly beaches or sand dunes.

Water-storage Tissue. The development of special water storage tissue resulting in "succulent" fleshy leaves or stems is met with in many xerophytes. Succulence is most highly developed in cactus plants, characteristic of desert floras, in these the leaves are greatly reduced and represented only by prickles or spines, while the stem swells up, stores water and does the work of the leaves. Frequently a waxy bloom is combined with the succulent habit. The most common xerophytes showing succulence are the stonecrops (sedum) and the house leek (sempervivum), often seen on rockeries, walls and ~~roof~~ roofs, where the roots have little soil which rapidly dries up.

Many plants which grow in salt-marshes near the sea exhibit the same modification as do those in dry places, and particularly, possess the succulent habit. Examples of salt-marsh plants are the glasswort (Salicornia), the cord grass (Spartina) sea lavender (Statice) and sea plantain (Plantago maritima). Salt-marshes are areas which are periodically inundated by the tides and left as large tracts of mud
~~intersected~~

intersected by water-channels and pools. There is obviously no shortage of water, but the content of sodium chloride is very high. If therefore the plants were to absorb large quantities of sea-water and transpire rapidly, great accumulation of salt would occur in their cells and be injurious to their tissues. It is probable that salt-marsh plants, although surrounded by water, really absorb very little of it, possibly only at such times as the salt-content is sufficiently reduced by the addition of fresh water at heavy rainfall.

Wood land plants. - In all woods, trees are the most conspicuous feature of the vegetation. Beneath the larger trees there are usually stunted ones, saplings and shrubs, forming an undergrowth, and a carpet of herbaceous forming the ground flora. The dominant type of tree in a wood depends usually on the type of soil, e.g. beech and ash on chalky (calcareous) soil, birch and oak on non-calcareous soil. The character and amount of undergrowth depend on the dominant tree. In a beech wood, there is very little undergrowth; this is due to lack of light caused by the extensive branching and perfect leaf-mosaic of the beech trees. The beech leaves rot down very slowly, and thus there is not much available humus in such a wood. In the autumn many fungi are seen on the ground; these being saprophytes devoid of chlorophyll, can flourish in the deep shade.

Of a different character is an oak wood. These trees cast far less shade than the beech;

Consequently, there is abundant undergrowth. Usually hazel is the commonest shrub, and with it often occur bushes of hawthorn, sloe, dog-wood, spindle willows and the climbing briars and honeysuckle. In early spring the ground flora consists of dog's mercury, wood anemone, violets, lesser celandine, primrose, and many others, to be followed by the bluebells, and a little later by the pink campion, white and yellow dead-nettle, wood sparge, foxglove, etc. It will be noticed that the earliest flowering herbs frequently possess underground storage organs. These food stores enable the plants to make a rapid growth as soon as the weather permits, and, therefore, to build up fresh foods for the following year before the taller plants overshadow them. Again those that depend on insects for pollination are able to show their conspicuous flowers before the overhead canopy obscures them.

The numerous plants found in such a wood are necessarily competing with one another for food from the soil. Owing, however, to the different depths to which the roots of trees, shrubs and herbs penetrate the soil, this competition is not as great as it might be. The chief benefit which small wood-land plants derive from their habitat is in the form of shelter from sun and wind; they can therefore afford to spread their leaves as much as possible to facilitate the process of photosynthesis without running any risk of excessive transpiration. The dying down of the ground flora and subsequent rotting of leaves and stems enrich the soil with humus, which is greatly to the benefit of the larger trees.

Classification of the Gymnosperms.

All living seed-plants are grouped as phanerogams, which class is sub-divided into angiosperms and gymnosperms, according to the way in which the ovules are born. It has been mentioned that gymnosperms are naked seed-plants, that is the ovules are not borne within an ovary. They include the following four groups:

Group 1. Ginkgoales, represented by only one living species, the maiden-hair tree (Ginko biloba) a native of eastern Asia.

Group 2. Cycadales, the cycads, a small group of comparatively lowly forms, which in past-geological times were very numerous and widely distributed. They are limited to the hotter parts of the globe, specially Central America and Australia. A cycad somewhat resembles a palm in appearance, but has usually a much shorter trunk.

Group 3. Gnetales, a small group of only three genera which differ greatly from one another and general appearance and are limited to the hotter parts of the globe. ~~Welwitschia~~ Welwitschia which occurs in the deserts of South-Western Africa, somewhat resembles a giant radish in having a swollen underground hypocotyl, which may exceed four yards in circumference the plant bears only two leaves, which are over two yards long, and lie flat along the surface of the soil. Ephedra may be described as a switch plant, having thin, long-jointed green stems and minute scaly leaves. It occurs in the deserts of Western Asia. Members of the 3rd genus, Gnetum are mostly climbers (lianas) from tropical Asia and America.

their leaves resemble those of angiosperms in being broad with a net-work arrangement of the veins. This entire group shows an approach to the angiosperms in the fact that their small flowers possess a perianth, which is absent in other gymnosperms.

Group 4. Coniferales. The Cone-bearing trees. The great majority of gymnosperms belong here, familiar examples including the monkey puzzle (Araucaria), pines (Pinus) firs (Abies) spruce (Picea) Cedar (Cedrus) larch (Larix) Cypress (Cupressus) Juniper (Juniperus) and yew (Taxus). Many of them are forest-trees of considerable size, and in some parts of the World they cover large areas as for instance in the cooler parts of the northern hemisphere. Among them are the gigantic Wellingtonia (sequoia gigantea) and Red-wood (S. sempervirens) of N. America. The former may attain a height of over 460 ft. with a trunk of 112 ft. in circumference. Many Conifers are of very great economic value, furnishing soft-wood, timbers, turpentine, resin etc. There are about 350 known species of which more than a fifth belong to the genus pinus.

All the members of this group are Woody, and the majority are evergreen trees, with leaves which persist for three or four years. The larch, however, is deciduous i.e. sheds its leaves annually. The most distinctive external feature of the Group is the Foliage, which in general, consists of small needles. The simple flowers are of two kinds, male & female which in nearly all cases are in the form of Cones and possess no perianth:

Structure of Vegetative organs. The general anatomy of stem and root of the Conifers shows close agreement with

that of the dicotyledons. Which are considered the distribution of tissues is similar, and both show increase in thickness from year to year by the activity of a layer of Cambium. A striking feature in the cortex of the stem of a Conifer is a ring of large resin canals. Each canal is an in the intercellular space surrounded by small cells, rich in protoplasm, which secrete the resin into the canal. These canals are found in all parts of the plants (except in yew, from which they are entirely absent). The resin is a protection to the plant against animals; it renders the young twigs distasteful.

A detailed examination of the Wood and bark shows some marked differences in structure between the Conifers and angiosperms. For example, in the Wood of the Conifers there are no Conducting Vessels, but Conduction of Water etc, is performed by single elongated cells known as tracheids. This and other structural differences show that the group is fundamentally distinct from dicotyledons.

The leaves differ greatly from typical leaves of dicotyledons, being usually of simple structure and often traversed only by one small vein. The needles show many characters which are associated with reducing ~~from~~ transpiration e.g. a thick cuticle and protected stomata. The lack of side-veins is compensated for by a special tissue, known as transfusion tissue which surrounds the the veins and is a characteristic feature of the Conifers. In several common genera (e.g. Pinus, Cedrus, Larix), the needles are borne on special dwarf shoots, which arise in the axils of scale leaves on the ordinary long shoots,

and bear a few brown scale below and a variable number of foliage leaves above. In the pines the entire dwarf shoot falls from the tree when the leaves are shed.

Reproductive Organs. It is in the flowers and the processes of pollination and fertilization that the gymnosperms show the most marked differences from the dicotyledons, and to illustrate this, we will take as our example the Scotch fir (Pinus sylvestris). The male and female flowers are borne in separate cones, but both sexes occur on the same plant. The male cones are small yellow oval structures, usually borne in clusters. The central axis of each cone bears numerous scale-like stamens, obviously more leaf like than the stamens of angiosperms. On the ~~lower~~ underside of each scale are two large pollen sacs. Which when mature, split widely open to liberate the pollen, which is distributed by wind. Each pollen grain is provided with two bladder-like expansions of the cell-wall which act as wings and so enable the pollen to be carried long distances.

The female cones of the Scotch fir first appear as small reddish structures just beneath the apical bud of a shoot. Each is borne on a short stalk. The central axis of the cones bears the ovuliferous scales, each of which bears two ovules on its upper surface near to the cone axis. Beneath each ovule-bearing scale is a small sterile bract. Each ovule lies with its micropyle towards the cone axis; each is surrounded by a single protective coat or integument and contains a large embryo sac. At the time of pollination, the scales of the female cone are slightly separated from one another, so that the pollen grains

can get blown between the scales and reach the micropyle. A small quantity of liquid is secreted just within the micropyle, and to this the pollen grains adhere. A long interval occurs between pollination and fertilization, amounting to over a year in the pines. Where pollination takes place in May one year, but fertilization is not effected until June of the next year. Pronounced growth of the female cone occurs in this interval, with complete development of the ovules.

Fertilization of Gymnosperms. When ready for fertilization the ovule presents a very different structure from that seen in Angiosperms. The large embryo sac is filled with tissue rich in food material. This feature is characteristic of all gymnosperms and is one of the most important distinctions between this class and all other flowering plants. Embedded in this tissue (the female prothallus) at the micropylar end, are a few flask-shaped organs known as archegonia in which the egg nuclei are held.

A short time before fertilization the pollen grains germinate and put out long tubes which grow down to the archegonia. The nucleus of the pollen grain has undergone several divisions its most important products being the two male nuclei, one of which fertilizes the egg nucleus in the archegonium, while the other degenerates. The outcome of fertilization is the development of a young embryo within the ripening seeds; the entire cones undergo enlargement, becoming very woody. When ripe the cone-scales gape apart to set free the winged seeds, which are dispersed by wind.

Transition Methods:— Ginkgo (the maidenhair fern)

tree) and the cycads are of great interest, because they show a transition from the methods of fertilization of the phanerogams and the methods we shall notice in considering the lower types of plants. Pollen tubes are produced from the pollen grains but the female nuclei have to complete their journey to the egg nucleus by means of their own movements. They are provided with thread-like appendages called cilia, and by moving these threads they swim to the archegonia in a slimy fluid which is secreted by the female organ. Such motile gametes are known as spermatozoids, and with them fertilization is dependent on the presence of a certain amount of liquid. In the Conifers, which have no necessity for the presence of liquid at fertilization, we may see the loss of the last traces of the probable aquatic ancestry of the vegetable kingdom.

Short Study of the Algae.

Now we will consider some of the lowest forms of plant life, leading from the simplest to those of increasing complexity, and so gain some idea of the enormous range of structure and mode of life exhibited by members of the vegetable kingdom.

The group of lowest plants, thallophytes, embraces an enormous number of species, which are so varied in kind that some are to be found almost everywhere. The plant body is technically known as <u>thallus</u>, namely, an expansion which is not divided into root, stem and leaf. Thallophytes are conveniently divided into three great groups algae, or green thallophytes, fungi, or non-green thallophytes, and lichens, plants of a mixed nature consisting

of an alga and a fungus living together.

Colouring of Algae. Though all green thallophytes or algae, possess the green colouring matter of Chlorophyll, this is in many cases obscured by the presence of brown and red pigment. The group. therefore, may be conveniently divided into the "green" 'brown' and 'red' algae, according to which pigment is dominant. The seaweeds which cover the rocks between tidemarks are the best known brown algae, while the red algae are the red seaweeds which frequent deeper waters. Green algae are abundant in fresh water, nor is free water their only habitat; for many of them can thrive on any damp surface, such as soil, rocks, tree-trunks, and wooden fences. Generally speaking, the larger and more complex forms are marine; the fresh water and terrestrial ~~repres~~ representatives are both smaller and simpler. Among the brown seaweeds there are forms which rank with the most gigantic members of the vegetable kingdom one (Macrocystis pyrifera) native to the non-tropical southern seas, attaining the length of several hundred feet; in contrast, other algae are entirely invisible as individuals to the naked eye. The whole plant body of these most minute forms consists merely of one single isolated cell.

Types of Algae — Everyone must have noticed how frequently the trunks of trees, palings etc, are covered by a bright-green powdery layer, which is particularly conspicuous in damp winter weather. This green substance is chiefly made up of vast numbers of the unicellular green alga called Pleurococcus viridis. Each plant is a

single rounded cell, bounded by a thin cell wall and containing dense protoplasm, a nucleus, and a large chloroplast. The plant reproduces itself by simple division of the original cell, and the resulting cells often remain densely grouped together in clusters for some time. On account of its chlorophyll it is able to form starch in the presence of sunlight, and therefore, given adequate water supply, this single-celled organism is quite capable of leading an independent life.

As our second illustration, we will take a plant which passes its ordinary vegetative life in a state of active movement. This state of affairs is found in the single-celled green alga, Chlamydomonas, which occurs in ponds and puddles, often in such quantity as to give a bright-green colour to the water, though the single cells are invisible to the naked eye, being only about $\frac{2}{100}$ millimetre long. The cells are usually oval and rather pointed at one end; to this end are attached two cilia or fine threads of protoplasm by means of which the plant swims about. Within the cell wall at the pointed end there is a little red spot called the eye-spot, which is considered to be sensitive to light and possibly in fluences the plant to swim to conditions where illumination is best-suit. Most of the cell is occupied by a large cup-shaped chloroplast; in this is imbedded a special protein mass called a Pyrenoid, whose function is not definitely known, but round which starch is deposited as it is formed by the chloroplast. The cell contains a nucleus and two small vacuoles near the pointed end. The plant

multiplies by its contents dividing up into two, four, or eight exactly similar 'daughter cells' which are set free by breaking through the cell-wall.

Reproduction:—In addition to this method, this very simple plant shows a definite sexual method of reproduction, important differences being shown by different species. As before, the cell contents divide up, but this time to as many as 64 individual units, which, except for their smaller size, are very similar to the vegetative cell. They swim about by means of their ~~smaller~~ cilia, and when two meet they get entangled by their cilia and ultimately fuse together. These little cells which fuse in pairs are called the gametes, and the cell which results from their fusion the zygote. The latter forms a thick wall round itself and can resist cold or drought. When conditions are suitable its contents divide up to form two, four, or more new individual Chlamydomonas plants.

In some species the gametes which fuse are all of similar size; in others, however, e.g. C. Braunii, there is a definite size difference; a large and a small sexual cell always fuse together, the contents of the smaller one passing into the larger. The smaller ~~one~~ more active cell is the male element, and the larger receptive one the female.

Motile unicellular Algae. It is not easy to draw a hard-and-fast line between the motile unicellular algae such as Chlamydomonas and a somewhat similar

group of flagellate Protozoa. Some of these show wholly animal characteristics, while others show a mixture of plant and animal characters. Such forms probably indicate that both plants and animals have had a common origin in the very remote past, and their common ancestors were possibly very similar to the flagellate forms which abound in water today.

According to this suggestion plant life began in the water and then passed through the earliest stages in its evolution, acquiring the essential green pigment & developing forms of many different kinds, all minute, free swimming and relatively simple in structure. 'Chlamydomonas' may be a present-day survivor of this stage. As we consider plants which come higher in the evolutionary scale, we see that many of them reflect the habits of their aquatic ancestors in that the presence of water is essential for fertilization to occur.

Spirogyra. Many thread like green algae live in ditches and ponds, some attached by one end, & others floating freely. One of the commonest of the latter is "spirogyra" which consists of a row of cylindrical cells each bounded by a cell wall. The whole filament is enclosed in a sheath of mucilage, which makes the alga feel slimply to the touch. Each cell is lined with protoplasm, and the nucleus is suspended by delicate strands of protoplasm in the centre of the cell. The large "chloroplast" is in the shape of a spiral band, and has embedded in it many pyrenoids.

During spring and summer 'spirogyra' is constantly increasing in length by division of the constituent cells, and pieces are frequently separated to form new and distinct plants. On approach of autumn a

sexual reproduction takes place, though with no structural difference between male and female cells. The process is known as "Conjugation": two filaments lie together, and their adjacent cells send out processes which fuse together at the tips and form a conjugating tube or canal between the two cells. Meanwhile, the cell contents have rounded up to form the gametes. one of them (male) passes through the connecting tube and fuses with the other (the female) to form a resting spore. This remains dormant through the Winter; in the following spring it germinates.

Desmids: — If during spring or summer, some of the mud from the bottom of a pond is examined under the microscope, it will almost certainly be found to contain some of the remarkable little plants known as desmids, each of which consists of a single cell. The desmids show great diversity of form, and include some of the most beautiful of microscopic objects. Many of them are of complex outline, and present a formidable exterior of spines & processes which serve as a means of defence against small aquatic animals. Some of them possess the power of movement. The usual method of multiplication is by cell-division, but occasionally the cells conjugate in pairs to form resting spores, which tide over the Winter season like those of "Spirogyra".

The seaweeds: — The best-known brown algae are those which cover the rocks between tide-marks; they attract the attention of every visitor to the seaside. The popular name for them is "Wrack," and there are many common species round our coasts.

One of the most abundant is bladder-Wrack (Fucus vesiculosus) the forking thallus of which is attached at

one end, and when covered by the tide, is buoyed up by numerous air-containing swellings. If a small piece of this or any other brown seaweed is placed in alcohol, the brown pigment will rapidly dissolve out, and a green hue will be assumed, i.e. the chlorophyll will become visible. In winter and early spring, the tips of wrack branches swell up and assume a yellow or orange tint. If such a swelling be held up to the light, a number of little round dots of darker tint will readily be perceived. Each of these is in reality a pit, or 'conceptacle', lined with hairs, some of which are modified into egg-organs, sperm-organs or both (according to the species). In a female conceptacle, containing only egg-organs, each of these is an ovoid body on a very short stalk, containing eight egg-cells. The sperm-organs are minute bladder-like structures borne on branched hairs, and giving rise to large numbers of excessively minute sperms. When a ripe egg-cell is liberated, numerous sperms are attracted to it, and one fuses with it, bringing about fertilization.

Laminaria. — Beginning near low-water mark and extending some distance into shallow water we find the Laminaria zone, so called after brown seaweeds of that name. They are large and broader than the wracks, and the thallus is smooth or corrugated, according to the species. It is these plants which are so often taken home by seaside visitors to serve as 'weather glasses', as owing to the pull which clings to them, they become damp on the approach of rain.

Large masses of seaweed are to be found drifting about in the ocean, specially in the Sargasso sea, a huge eddy occupying several thousand square miles of the North Atlantic. The most notable form to be seen here is the "gulf weed" (Sargassum bacciferum), which is buoyed up by stalked

floats resembling berries in appearance. A huge brown seaweed (Macrocystis pyrifera), with pear-shaped floats, native to the non-tropical parts of southern seas, attains the astonishing length of several 100 ft. Fucus and Laminaria are largely used as manure and under the name of 'Kelp' were formerly employed in the manufacture of potash. As a source of iodine they (specially Laminaria) are still valuable.

Diatoms: The almost-infinitely varied microscopic forms known as diatoms, which possess flinty coverings of great beauty and exquisite geometrical symmetry of pattern, may be reckoned as the humblest of the brown seaweeds. They are to be found in both salt- and fresh water, and even on the surface of damp earth. Large tracts of the ocean floor, specially in the Antarctic regions, are covered with fine 'ooze' principally composed of their remains. Some diatoms are stalked and immobile, but most of them are free, and like many of the lowest plants, possess the power of movement. When examined under a microscope they may be seen gliding along in a very interesting and curious fashion.

The surface layers of the sea and of lakes are inhabited by countless myriads of diatoms, which constitute the chief food of innumerable minute animals, specially the lowly cousins of shrimps and prawns. These little creatures in their turn are devoured by herrings and many other sorts of fish, so that man himself is indirectly indebted to diatoms for an important part of his diet. And this becomes still more obvious when we remember that oysters, cockles, and mussels feed upon these lowly plants wholesale.

Large numbers of fossil diatoms are known. Not only are these minute plants actively engaged at the present

time in forming deposits on the ocean beds, but similar 'diatomaceous earths', found associated with rocks of Tertiary age, are a proof of their activities in former eras. Such earths are white or grey in colour, often so soft as to crumble readily in the fingers, and they are composed almost entirely of the flinty remains of diatoms. Some of the deposits are of economic importance, being used as polishing powders and in the manufacture of dentifrices.

Red Seaweeds:— Most red seaweeds live habit moderate depths in the sea, and are unsurpassed for their beauty of form and colour. Many of them are torn from their moorings and cast up on the shore by storms. The reproductive processes are too complex to be discussed here. Some of the red seaweeds are strengthened by calcareous matter, and are represented on our own coasts by branching forms and pinkish crusts which are to be found on rocks between the tide marks. "Carragreen moss" (Chondrus crispus) is a stoutly built-forking red seaweed which grows on the coast of Britain, and has been used in much the same way as isinglass. 'Laver' is another edible species, with a fairly broad, branching thallus. It is exposed for sale in Scotland, and in South Wales is mixed up with oatmeal and baked into a sort of bread.

Though the majority of the red algae are seaweeds, a few genera are found only in fresh-water streams. These do not usually possess the striking red colour of the marine forms, but appear nearly black or even green, on account of fainter red pigment being present to mask the chlorophyll.

Blue-green Algae.— These plants of very simple structure resemble the algae in their habit and mode of life, but their real relationships with the group are still

open to doubt. As their name indicates, they have characteristic colouring. Some are terrestrial, some aquatic, occouring both in the sea and in fresh water. These plants must rank amongst the lowest members of the vegetable world, the only others which are equally simple being the "bacteria". The unicellular forms usually occour as colonies united by a mass of mucilage; a large number of forms have the habit of simple or branched filaments also surrounded by mucilage. The facts that the cells have no well defined nucleus and that sexual reproductive organs are entirely absent are both features indicating extreme simplicity.

The blue-green algae possess a very marked power of existence under adverse conditions. They form the principal vegetation of hot springs and have been stated to occour at as high a temperature as 87°C. In contrast, they can flourish in Antractic lakes. Certain of the algae are active in rock formation by precipitating carbonate of lime from the water in which they live.

Ancestors of Land Plants. — It is now commonly supposed that plant life began in the sea, and there went through the earliest stages of evolution. Many different minute and simple forms all containing chlorophyll, were developed and all were free to swim or float in the water. Such free plants are known collectively as plant plankton and Chlamydomonas, not far removed from organisms with animal characteristics, and yet with green pigment and cell-walls.

In the earliest phases of the Plantan period, there was

probably no distinction into plant and animal kingdoms, but in the late Plankton there organisms with plant or animal characteristics had been evolved and were present in the seas together. How long the primitive World of life consisted only of Plankton cannot possibly be known, but it must have been for a very long period. In time, however, the plant World developed a new kind of organism or some of the primitive Plankton plants gave up their free-swimming mode of life and became fixed organisms or "benthos" With a specially developed hold fast at their lower ends which anchored them firmly to the rocks or ooze. With these benthos plants lay the future: the free end grew out into a thallus of threads or a mass of tissue composed of many cells; in some cases it even became differentiated into an axis bearing lateral expansions, perhaps the first foreshadowings of stem and leaves, which later became fixed in the higher plants.

Fungus forms & their effects.

The fungi group is a subdivision of the Thallophyta and contains an enormous number of forms, being by far the largest group of the non-flowering plants. up to the present time about 50000 species have been described. All the members of this vast and heterogeneous group are distinguished by the absence of chlorophyll. Hence all fungi are incapable of assimilating the carbon dioxide of the air and must obtain their carbonaceous food ready-made from other sources. The parasitic fungi obtain their organic Carbon

food from living organisms, the saprophytic forms from dead organic matter.

In addition to the fungi of essentially parasitic and saprophytic habit, there are intermediate forms which are capable of changing their method of nutrition according to circumstances. A form which is usually saprophytic but capable of a parasitic existence is called a facultative parasite and one in which these habits are reversed a facultative saprophyte.

Symbiosis: — Fungi may also establish a symbiotic relationship in which the two associated organisms derive mutual benefit from each other. The lichens are an example of such a partnership, the entire lichen plant being composed of the cells of a green or blue-green alga and those of a fungus. The term mycorrhiza is given to the structures formed by the association between a fungus and some organ (usually the roots) of the higher plants. When associated with the roots it is probable that the fungus in some way assists the plant to obtain nourishment from the soil.

An interesting case of dependence of the higher plants on fungal infection is shown by many orchids. Under natural conditions the germination of the seeds of these plants depends on the presence of the appropriate fungus. It is found that sterilized seeds can germinate if supplied with fairly concentrated solutions of sugars which indicates that in Nature the fungus probably influences the uptake of nourishment by the seeds. The Japanese orchid Gastrodia elata contains no chlorophyll and obtains all its nourishment from a fungus. The orchid produces no flowers and weak tubers, and if isolation is maintained for several

reasons the plant dies.

Importance of Fungi:— Many of the fungi are of great practical interest, and the study of their physiology and mode of life is one of the most important branches of Botany. Very many of them are destructive parasites, and cause the most worst diseases of field and garden crops, & forest trees. the rust, smut and bunt of wheat, apple scab, & potato blight are examples of fungal diseases of great economic significance; to these innumerable others might be added, some such as the dry-rot fungus, do harm by injury to the timber in building; others destroy articles of food which are attacked by mould.

Fungi, however must not be regarded as entirely injurious to higher organisms. Those which live in symbiotic union with other plants are obviously beneficial to their associates, several of the large kinds are good for food, and the Saprophytes are extremely useful in bringing about decay and thus ridding the earth of the dead remains of animals & plants. The microscopic yeasts owing to their power of forming carbon dioxide and alcohol from sugar, play an important part in the brewing and bread making industries.

General Structure:— The vegetative plant body of a fungus is known as the mycelium, and is made up of a tangled weft of colourless filaments or hyphae, which may be divided by cross-walls into many cells, or may be completely devoid of cross-walls in the lower forms. In the protoplasm of these hyphae are contained numerous small nucleii, which have the same structure as the nucleii of the plants and animals. Reproduction is brought about by spores, of which there are many kinds, some being formed without any sexual process, others are the result of fusion of male & female cells. In the case of moulds the actual mycelium is visible as the white or coloured downy mass described as mould; in the large fungi (e.g. mushrooms, puff balls, bracket fungi) the part popularly called the

fungus is in reality only the fruit-body concerned with spore production.

Diseases Caused by Fungi:- The fungus Pythium de Baryanum causes damping off of seedlings, attacking them at ground level and softening the tissues so that the seedlings fall over. The disease is favoured by excessive moisture and overcrowding of the seedlings. The branched mycelium of the fungus produces spherical swellings (sporangia) in which spores are formed. These spores are known as zoospores as like animals, they possess the power of movement being provided with two minute cilia by means of which they can swim in a drop of moisture. In dry conditions the sporangium can germinate directly to a new mycelium without the formation of zoospores. Pythium also has well-differentiated sexual organs, the male and female being known as the antheridia and oogonia respectively. The oospore which results from fertilization is a thick walled resting-spore, and can tide over unfavourable periods till it germinates, either with or without for making zoospores according to the conditions. Pythium is fungus which starts life as a parasite and continues as a saprophyte after the death of the infected seedlings.

The disease of potato blight is caused by Phytophthora infestans. It first became notorious in 1845-46, when it caused the potato famine in Ireland. The mycelium is widely distributed within the host-plant, causing black blotches on the stems and leaves and rolling of the tubes. Branched hyphae protrude from the host-tissues into the air, and bear egg-shaped sporangia which are readily detached and carried away by the wind to spread infection.

Moulds:- Jam, cheese, bread, fruit as well as leather etc are liable to become mouldy if kept in a damp

place. This is due to infection by the spores of lower fungi. The common form of green mould (Penicillium glaucum) is often seen on oranges and bread. A recent discovery shows that a product of penicillium mould (penicillin) can inhibit the growth and even cure of certain diseases. The mycelium is made up of delicate branching threads, some of which grow into the air and give rise to spores that are disseminated by the least breath of air. The blue mould (Aspergillus) of cheese is broadly similar, but the spore-bearing branches end in swellings, from which long chains of spores radiate. White mould (Mucor) is often to be seen on bread and horse-dung.

Moulds of Two Sexes:— It has been shown that some species of Mucor and its near relatives have two kinds or strains of mycelium. These when grown apart, produce only sporangia but when the mycelia of two strains are brought into contact, zygospores are produced. Species in which conjugation depends on the interaction of two strains of mycelia are said to be heterothallic in a single mycelium, and described as while those which can form zygospores in a single mycelium are described as homothallic. The distinction between the unlike strains is equivalent to the difference of sex in other plants and animals, but must be regarded as a physiological rather than a morphological difference, as the sexual organs of the heterothallic mycelia appear alike. The distinction of sex is thus expressed in its simplest form, as the capacity to produce zygospores with a different individual only.

The mould fungi may be regarded as definitely higher in the evolution scale than such types as Pythium and Phytophthora. They are adapted to a terrestrial mode of life, for at no stage in their life history are motile zoospores produced.

The mycelium is made up of whitish, cobwebby hyphae from which long spore-bearing branches rise into the air. Each of these ends in a rounded sporangium, within which numerous spores are produced: there is also a process of conjugation between specialized mycelial branches, by which resting-spores (zygospores) with firm investments are produced. These are able to remain dormant for some time, and thus enable the fungus to combat unfavourable surroundings.

Edible and harmful Fungi

The leaves of a number of common plants e.g. strawberry gooseberry are subject to attack by species of fungi, which cause the condition known as white or powdery mildew or blight. The fungus sphaerotheca morsuae which causes the highly destructive disease known as American gooseberry mildew. A spore on germination forms a white web-like coating over the leaf and sends hold-fasts into the epidermal cells. During summer infection is spread by the liberation of large oval spores which are produced in rows on the external hyphae. In the late summer sex organs are formed on the mycelium and, as a result of fertilization, thick-walled spherical fruit bodies arise. When mature these are dark brown or black, and may easily be seen with a hand lens on infected leaves. Within each fruit body are egg-shaped spores which spread the infection in spring. Immediate outcome of fertilization is the formation of a large sac-like cell which is called the ascus; in this the ascospores (usually eight in number) are produced. The formation of an ascus, in this, is one of the important features in the classification of the fungi and a large number (over 15,000 sp.) are grouped together as the Ascomycetes. These vary

greatly in habit, but all develop the characteristic mother cell or ascus in which the spores are formed. Some of the ~~former~~ more familiar Ascomycetes are the edible morels and truffles, and the common Coral-spot- so frequently seen on dead sticks.

Yeast- (Saccharomyces) is a very simple type of fungus which belongs to the Ascomycetes, though its relationship to other members of the group is somewhat obscure. Unlike other members of the groups, it possesses no well-developed mycelium but occurs as separate cells. They are found naturally on the surface of fruits, eg grapes and apples, and on other plant tissues. Some forms have been domesticated notably those used in the manufacture of beer and in bread-making. ~~If a little yeast is examined under the high high power of~~ Both the

Alcoholic Fermentation — The most remarkable fact in regard to the yeast- vital processes of yeast- is that when placed in a solution containing glucose sugar, it is able to break up the sugar molecules and form carbon dioxide and alcohol, as expressed by the equation.

Rust-Fungi:— These fungi, together with the larger familiar forms (mushrooms, puff balls, etc) are classified as the Basidiomycetes and include over 13,000 species. Their spores are produced very differently from those of the Ascomycetes. The spores are known as basidio-spores and are produced externally on little stalks from the mother cell or basidium. At present there is no member of the Basidiomycetes known in which normal fusion of male & female elements occurs.

The rust-fungi are without exception, obligate parasites on the leaves and stems of higher plants. They cause very destructive diseases of cereals

Rust-Fungi — These fungi, together with the larger familiar forms (~~mush~~ mushrooms, puff-balls etc) are classified as the Basidiomycetes and include over 13,000 species. Their characteristic spores are produced externally on little stalks from the mother cell or basidium.

The rust-fungi are, without exception, obligate parasites on the leaves and stems of the higher plants. They cause very destructive diseases of cereals and grasses, their name being derived from the fact that at a certain stage they are revealed by the appearance of rust-red streaks on the stems & leaves. as for example puccinia graminis, the black rust of Wheat which, although not the commonest, is one of the most interesting of its kind. The delicate mycelium grows within the host-tissues and in summer produces pustules of rust-red spores which break through the epidermis and are exposed to the air. These spores (uredospores) are easily detached from their stalks by the wind and rapidly infect other plants.

Barberry - a Rust-Host. Later on in the season the diseased patches turn black owing to the production of dark-walled spores (teleutospores) in the place of the uredospores. These represents the resting stage of the fungus. in which it passes through the winter. these spores germinate in spring while still attached to the straw. Each ~~cell~~ sends out a small hyphae (the basidium) which produces four minute basidio spores. these are incapable of infecting any cereal or grass ~~plant~~ plant, but depend on a totally different host, the barberry for further development. When the mycelium is established on a barberry leaf, small orange coloured 'cluster cups' appear as swellings on the lower surface. In these still another type of spore (aecidiospore) is produced in large numbers.

these spores will grow no further on the barberry, but when transferred by wind or rain to wheat or grasses will produce a mycelium from which the uredospores are formed, the life cycle being thus completed.

Mushrooms and toadstools:— these popular names denote representatives of a group of over 11,000 species. The mushroom is a saprophyte growing in pastures and in richly manured soil, but some of its near relations are parasitic on trees, to which they do great damage. Some toadstools are very poisonous. The mycelium (popularly known as spawn) is very inconspicuous and remains hidden in the soil. This gives rise to the stalked spore-producing body, which is seen above ground and which is made up of closely interwoven and compacted hyphae. When fully developed, the under side of the expanded top of a mushroom or toadstool will be seen to possess a large number of radiating plates or gills, on the surface of which minute basidiospores are produced in great numbers. From spore counts, it has been calculated that a fruit body of the edible mushroom (Pasalliola campestris) 7½ centimetres in diameter produces about 1,800,000,000 spores. The gills vary in colour with the species, being in the edible mushroom, pink in the young specimen and turning brown and then black with age.

Bracket fungi & Puff balls:— Many of the bracket fungi do considerable harm to trees. The mycelium ramifies in the wood & the fruit bodies project as semicircular plates from the trunk. Instead of under surface being composed of gills, in some of these fungi (and also in some toadstools

it consists of tissues studded with minute holes. These are the ends of little tubes which are lined with spore-bearing basidia. The spore-producing body of the puff-ball is a structure in which spores develop, to be liberated later by the bursting of the mature wall.

Lichens, Bacteria and Slime-fungi

The familiar plants known as lichens are found in the form of various coloured crusts on rocks, roofs, and walls, or on the trunks of trees and so forth. A lichen is a compound plant consisting of an alga associated with a fungus, both of which can clearly be seen in a thin section under the microscope. The algal cells containing chlorophyll appear healthy and are capable of vegetative multiplication; but the fungus alone is concerned in the development of a definite fruit-body, which indicates that the fungus is the dominant partner in the association. It is the fungus, indeed, which forms the framework of the plant, and with the captive green algal cells grows into a definite and often conspicuous thallus, very different from the body of an ordinary fungus or alga.

A lichen, as a whole, is neither a parasite nor a saprophyte. The green cells of the alga are capable of carbon assimilation in the light, and being surrounded by the fungal hyphae, are protected from desiccation. The fungus obtains its carbon foods from the alga, and in turn passes to the algal cells water and dissolved mineral salts, which are absorbed all over the surface of the fungal threads.

Nearly all lichen-fungi belong to the class of fungi called Ascomycetes and produce a fruit-body often cup-shaped and brightly coloured, in which many asci and ascospores are embeded. The ascospores on germination form a new fungal filament, which must come in contact with the appropriate algal cells to build up a new lichen thallus. In some members of the group, special little masses of both fungal and algal cells become isolated for propagation, and when detached from the parent thallus serve at once to reproduce the necessary constituents of alga and fungus.

The characteristic colours which many lichen possess e.g. yellow, orange, or red, are due to acids formed in the thallus as a result of vital activities of the constituent partners. Over 140 different acids are known occur in these plants, and from them are obtained litmus & many other pigments used in dyeing. The Iceland moss is eaten and the other the reindeer moss of high latitudes, which during the Winter forms the exclusive food of the reindeer.

Structure of Bacteria. bacteria are an extensive group of minute and structurally simple organisms. Most are unicellular and have no well-defined nucleus. They are destitute of Chlorophyll, as are the fungi, and are as a rule adapted to a parasitic mode of life. On this account they may be regarded as a sub-division of the fungi, being quite different in structure and development they really constitute a wholly distinct class of organisms.

Both as saprophytes and parasites, the bacteria are important in the life of the World. Certain parasitic

members are known to be the cause of many of the infectious diseases of men, animals and plants. As saprophytes, they are the great agents of decay of all kinds, owing to the fact that they set up rapid chemical changes in the organic substances on which they feed. For example when meat becomes putrefied, or milk turns sour, or wine is converted into vinegar, the change in each case is due to the action of a definite species of bacterium bringing about chemical alterations. The whole subject of the fermentations set up by these organisms has of recent years become of the greatest practical importance both to medicine, regarding the parasitic forms, and to innumerable branches of industry in which the saprophytic forms are involved.

The average sized bacterial cell is only about one-thousandth m.m. in diameter, and a convenient classification is based on the shape of the individuals. Some are rod shaped and are termed bacilli; others spherical, the Cocci; others comma shaped, the Vibrios; and again, others appear as a spiral, the Spirilli. By means of prefixes the arrangement of the cells can be indicated; thus a Coccus type in which the cells are attached together in a chain is a Strepto-coccus; if the Coccus cells are grouped together as a bunch of grapes they are referred to as Staphylococcus.

BACTERIAL REPRODUCTION: Each cell is surrounded by a cell wall, not, however, of cellulose, but of a substance resembling protein. As already mentioned, there is no definite nucleus, but the application of suitable stains reveals the presence of granules of nuclear material scattered throughout the protoplasm. Some species of bacteria possess cilia (protoplasmic threads protruding through the cell-wall) which enable them to swim about in a liquid medium. Others are non-motile, possessing no cilia.

When in suitable conditions, bacterial cells multiply by the simple process of dividing into two parts, i.e. by simple fission. In some species the daughter cells don't readily separate, so that dense masses of dividing cells become aggregated together in colonies

known as Zoogloea or masses. Fission can go on with great rapidity, and many bacteria divide every 20 minutes or half an hour.

Nutrition of Bacteria. The principal food of bacteria is found in the substances excreted matter by living animals or in the complex organic matter resulting from the decomposition of the dead bodies of animals and plants. Nutrition of all plants and animals has a two-fold aspect; the material taken in must supply (1) substances for growth of the organism, (2) a source of energy for vital processes, i.e. it must be respiratory material. In animals organic food supplies both these needs, and in the green plants the process of photosynthesis yields carbohydrates which are used for both purposes. In certain classes of bacteria, however, the case is quite different, and two entirely distinct classes of material are necessary, one type for body building, the other for respiration and release of energy.

Mosses and Moss-like plants.

The next sub-division of the vegetable kingdom is that of the Bryophyta, or moss-like plants. It includes two great classes, the true mosses and the liverworts. The mosses, the general appearance of which is familiar to everyone, have a vegetative growth much like that of small higher plants, with well formed stem and leaves. The liverworts, perhaps less generally known to those who are not botanists, sometimes have a habit not unlike that of the true mosses. Consisting merely of an undifferentiated green thallus. The are commonly found on wet banks or walls, or under water. One of the commonest is Pellia epiphylla, ~~the structure and life history of which well~~

General structure of liverworts. The plant of Pellia epiphylla in its vegetative condition is a green, flat, lobed thallus, repeatedly branched, the ~~lobes~~ lobes or glimmer lapping one another. The plants grow together in masses and may cover a considerable patch of ground. The thallus has an upper and under surface, the former being the darker green, while from the latter emerge numerous brown hair-like rhizoids, which fix the plant to the ground. The cells of the thallus show scarcely any differentiations; all are thin walled, except; a few central ones; and there are chloroplasts in the superficial cells.

Fertilization of liverworts. The thallus produces both male & female sex organs on its upper surface. The male organs are known as ~~anther~~ antheridia; when mature, they are globular bodies attached to the thallus by a very short stalk. Each antheridium is enclosed in a sheath of thallus tissue, which leaves only a small opening at the top.

The female organs or archegonia, as they are called, are found in a group just behind the tip of the thallus, ~~are~~ and are almost covered by an overlapping sheath of thallus tissue. The archegonia are flask-shaped organs. When

mature, there is a long neck consisting of many cells, down the centre of which a canal passes to the swollen basal portion. In this basal part is the egg cell awaiting fertilization.

As in the lower plants generally, fertilization must take place under water. After rain or dew the surface of the thallus is wet enough for this to be accomplished when moist, the antheridium bursts and its contents, a mass of male cells are set free. Each male cell (spermatozoid) is provided with two cilia, and can therefore swim through the liquid towards the archegonia. The result of this union is the development of a spore-producing fruit called a sporogonium.

Spores of Liverworts. This structure appears as a dark green ball, about one sixteenth of an inch in diameter, attached to the thallus by a light green stalk which is fixed lightly in the thallus tissue. The length of the stalk varies greatly according to the habitat of the plant & may attain several inches. The mature fruit body rather resembles a long, thin pin with a round almost black head. In this head or capsule ~~[illegible]~~ numerous spores are developed & with them some curious elements called elaters, which are long narrow cells with spiral thickening. The wall of the capsule splits open to release the spores, & the elaters are of use in loosening the mass of spores so that they are readily dispersed by the wind. In many liverworts there are special organs for vegetative reproduction. Small green cups appear on the thallus, and in these are born minute germ cells or buds, capable of growing into distinct plants.

General structure of Mosses: The true mosses are more highly organized plants than the liverworts, possessing a perfectly distinct stem bearing spirally arranged leaves. We will base our description on the common moss Funaria which usually grows on the ground and is specially abundant in places where there has been a fire. The moss grows in close, bright-green tufts, each minute plant consisting of a slender, erect stem densely clothed with small, simple leaves. At the base of the plant are a number of brown rhizoids, which fix the plant in the soil and absorb water. True roots do not exist in any of the Bryophyta. The tissues of the stem show a simple but well-marked differentiation into three regions: the epidermis, the cortex, and a central cylinder of long, thin-walled cells for water conduction. In some of the larger mosses the tissues are more complex and are possibly analogous to the xylem and phloem of the higher plants. The leaves of Funaria are very thin, being only one cell thick except in the position of the conspicuous mid-rib. The cells are densely packed with chloroplasts. The conducting tissue in the stem is not continuous into the leaves; this is compensated for by the fact that the leaves themselves can absorb water. On this account mosses which may be completely dried up in hot weather revive very rapidly when rain falls.

Fertilization of Mosses: — Male & female organs are borne on the same plant in Funaria, but

this is not the case with all mosses. The antheridia are borne terminally on a shoot in a dense cluster surrounded by a tight rosette of reddish or orange leaves. The rosette strikingly resembles a flower, especially in the larger mosses, such as Polytrichum, common on heaths. The antheridia are club-shaped, and produce a vast number of motile spermatozoids.

The archegonia are formed terminally on branches below the male rosette. When mature they have the same form as the archegonia of the liverworts. Here, again, fertilization depends on the presence of water, and is effected by the mobile spermatozoids ~~swim~~ swimming down the neck canal and one uniting with the egg cell. In the mosses cane-sugar is secreted in the neck cells of the archegonium to lure the male gametes ~~to~~ ~~the~~ towards the egg. The result of fertilization is the development of the sporogonium.

This, the moss fruit, consists of a long, thin, red-brown stalk attached to the plant & bearing at its top a nodding pear-shaped capsule, which is first green, but finally turns brown. On top of the capsule is a conical membraneous hood, the calyptra. This hood is really the upper part of the archegonium which has ruptured and had its tip carried up by the developing sporogonium. When the calyptra is removed, the top of the capsule can be seen as a neat conical lid. The internal structure of the capsule is rather complicated. The upper part is fertile and produces the spores, while the more solid basal portion performs the nutritive function of carbon assimilation

Spores of Mosses:— As the spores ripen the capsule begins to dry up and the lid at its apex becomes detached. The spores, however, are not all set free at once. Beneath the lid there has developed a double row of little teeth, which partly close the mouth of the capsule. These teeth are sensitive to moisture and only open to allow escape of the spores in dry weather.

A spore does not germinate alone into a new moss plant, but forms a very simple branched filamentous growth somewhat like a green alga. This is called moss protonema. It is attached to the ground by Colourless rhizoids, and the young moss plants arise from it lateral buds. In this way many new moss plants are produced from the germination of a single spore.

Alternating Phases:— The life cycles of Pellia & Funaria

We see that the life story of the Bryophyta includes two distinct phases: the one concerned with the production of the sexual organs (the moss or liverwort) the other concerned with the production of asexual spores (the sporogonium). The plant which produces the sexual organs is relatively highly specialized compared with the Thallophyta. It is also self-supporting, absorbing its own water and mineral salts & performing carbon assimilation. The sporogonium is always in some way dependent for nourishment on the plant to which it remains attached. In most liverworts it is entirely parasitic, and in mosses partly parasitic, obtaining water and dissolved salts from the sexual plants while the capsules form their own carbon foods. The sexual phase is technically called the gametophyte and the spore producing phase the Sporophyte. These two phases normally alternate with

one another and arise from one another, and a similar alternation is encountered in all the higher groups of plants, with the sporophyte becoming the dominant phase.

Some Familiar and unfamiliar Ferns

More highly organized than any of the Bryophyta as regards their vegetative structure is called the Pteridophyta and includes the ferns, the horsetails and the club-mosses.

The fern are a vast group including about 150 genera and over 6,000 species. In some parts of the southern hemisphere the ferns grow to the size of trees, and may even make up forests. They somewhat resemble palms in appearance, with their long, bare trunks, bearing crowns of feathery leaves.

A fern plant consists of an underground stem (rhizome) which may creep horizontally at some distance below the surface, as in bracken (Pteris aquilina) or may be obliquely embedded in it, as in male fern (Aspidium filimax). The stems of other species are attached to the bark of trees or find a home in the crevices of walls or rocks. Brown branching roots grow out from the stem and serve, the double purpose of fixation and absorption of a part of the food. The leaves or fronds grow in the contrary direction into the air and light, and do the same work as in seed-plants. They are sometimes broad and unbranched as in the ~~heart~~ hart's tongue (scolopendrium) but their shape is more or less feather-like. Young fern fronds are rolled up in the shape of a bishop's crozier, and can thus force their way up through the soil without damage.

Chaibassa:

the remainder of the division, consisting of a small area in the north of Leda & Santana and the whole Saitba block lies in the basin of the Sanjai river and with the exception of Jue gara the drainage is to the north & east. Important streams are the Hamsada gara, Rukwab gara and Buru Sarbil gara from Leda block; the 1st two being perennial in the forest.

Strobilanthes scaber flowered in Saranda in 1934; so presumably it also flowered in Kolhan in that year and may expected to flower again in 1940 or 41. Strobilanthes auricuatus has not flowered since 1929 or 1930 and may be expected to flower next year.

Calcutta (213 miles from Goilkera) This a good market for green and dry sal logs and poles.

Coal fields — These lie within 200 miles by rail and provide a market for pit poups, logs etc.

Jamshedpur (61-50 miles distant) is a market for green logs, poles and fuel.

The division lies in two drainage systems separated by watershed 1,000 ft in elevation which runs South from Goilkera to Lagra, Kendbai, Lambari Buru and Kurkutta, the East through the ~~South~~ North of Santara block to Saitba; and then South to Jaganathpur. The Catchment area of the Karo, Deo and Koina rivers lies to the South and West of this line and the bulk of the division is drained by these rivers and their tributaries. The Koina joins the Karo outside the division at Manharpur and only drains the West portion of Ambia block; The Deo river joins the Karo at Patung, and is responsible for the drainage of the greater part of Santara, Latua and the South-East part of Leda blocks. Its more important feeders are the Sangajata gara from Santra, the Patung gara from Leda and the Malsukura, Jharjar, Karanta and ~~Udla~~ Udalkam nalas from Latua block. The Banki and Rajabasa garas join the Karo direct just above its confluence with the Deo at Patung. The Rauli nala from Leda & the Ambia & Tamba garas from Ambia are the most important feeders. The last one is the only truly perennial stream in Ambia & Leda blocks flowing directly into the Karo.

below.

Porhat is covered by a group of rocks known as the Iron-ore series, consisting of a lower division of phyllites merging to mica-schists, tuffs, calcareous rocks, quartzites and haematite quartzites, with an upper division of igneous intrusives known as the Dalma lavas.

Kolhan -

The Kolhan forests are situated to the north of the main line of the Bengal Nagpur Railway which separates them from Porahat; Chaibasa division and the open cultivated plains of the Kolhan lie to the East and South; on the West the Karo and Koina rivers form the boundary between them and the forests of Saranda division.

The division comprises 143,828 acres of reserved and 14,669 acres of P.F. or about 248 sq. miles in all.

Apart from the Saitba group of hills which are 2,000 to 2,500 feet above sea-level the area consists of a series of hills seldom exceeding 1,800 feet high and having fairly consistent north east-to South-West strike. The valleys are mostly narrow in the north of the division with the hills rising sharply on their flanks but those of the Karo and Des rivers are generally more open and contain numerous villages. Except for the Saitba hills the topography is on the whole less rugged than in the neighbouring divisions of Saranda & Porahat. The elevation varies from 750 ft. at Kamarbera in the Koina valley to 2,550 ft. on Hararargi Buru in Saitba block.

from the district board road.

These forests occupy a part of the catchment area of the Subernarekha river and cover hilly or undulating ground; to improve agriculture of the lower lands and to assist in reducing damage from floods, is very important.

Porahat:-

Porahat is a compact area in the triangle formed by the Bengal Nagpur Railway main line between Chakradharpur and Posaita stations to the south, the public works department pacca road from CKP to Bandgaon on the east, and the South Koel and Karo rivers from near Posaita station N. W. & the Bendgaon tributary on the west. There are contiguous projections in the Girga R.F. and P.F. blocks nos I. III – V – VIII West of the Karo river and in part of the Songa block east of the public works Dept. road between Nakti & Hesadih. With the reserved blocks, except for Birda in the north & Girga to the West, from a continuous link in this tract, the whole tract is interlaced with numerous villages and their holdings.

The tract is a section of the southern rise to the Ranchi plateau from the S'bhum valley through which the Bengal Nagpur Railway main line runs and is from about 1000 to 2,400 feet in elevation. It comprises a net work of irregular ridges whose slopes are usually steep in the higher elevations but which become more gradual where the broader and less tortuous drainages splay out into the B. N pur Railway valley

Dalbhum :- The Forest

The crop is very poor and open having been ruthlessly cut and over grazed in the past. The principal species is sal and the usual associates are those found in drier parts of S'bhum. Generally trees are malformed and ought to be cut back immediately so as to allow accumulation of growth on better stems. The forest in Taraf Athkoshi and generally in the remote parts, are slightly better, but in Bahragora and Chakulia rides where the country is flat and much settled destruction of forest has been more or less complete.

Geologically Dalbhum forms a closer unit with the Eastern States Agency. Iron ore is the most widespread and consists essentially of lower series of sediments which are generally found to support fairly good quality vegetation.

The total area of Reserved forests is roughly 169 sq. miles and the area of protected forests is about 23 sq. miles

Much of the forest produce is used locally, the produce is fit for house building, agricultural implements and for fire wood etc. The Indian Copper Corporation also consume a large quantity of sal pit, props and sleepers and green poles of various species. Seraikela state where forests have been utterly destroyed also take large quantities of forest produce from the West Dalbhum. The surplus is exported to Cal, which is the most important outside market.

The most important lines of export is the Bengal Nagpur Railway ~~mail~~ line. A district board road runs into Jamshedpur and to the borders of S. Kela state in the West and into Midnapur ~~state~~ district in the east. But the important forests are distant from rail head and also

Internal Structure:— The rhizome of the fern when examined under the microscope, it will be seen to consist of a large number of vascular strands or steles ~~surrounded by a ring of phloem. Among the steles~~ embedded in thin-walled tissue whose cells are filled with starch grains. The steles consists chiefly of the xylem cells almost surrounded by a ring of phloem. Among the steles are seen bands or groups of thick walled fibres, which are additional strengthening tissue. other strengthening cells appear near the epidermis, which is thick-walled and bears characteristic brown membranous scales. Such a stem is described as Polystelic and is found in most, though not all ferns.

The leaf stalks show very much the same structure as do the underground stems, though usually there is less development of extra strengthening fibres. Here again there is variation in the internal structure, and some members of this group possess only a single stele in the petiole.

The roots & leaves show the same general structure as do those organs of the flowering plants. The root of most ferns have but two xylem groups, and owe their wiry character to an extremely thick-walled fibrous cortex.

The life cycle of a fern, like that of the Bryophyta consists of two distinct alternating phases, sporophyte and gametophyte. In the fern, however, each phase is a separate self-supporting plant. The sporophyte is the familiar fern plant, often of large size, with highly organized internal structure. This plant produces the asexual spores which on germination, give rise to the very small, inconspicuous gametophyte phase.

spore production:— There are regularly arranged brown patches on the backs of fern ~~p~~ fronds. Each of these is termed a sorus, and species differ considerably according to the shape of sori and their manner of distribution. In bracken they are close to the edges of the frond, and follow its outline; in hart's-tongue they are long streaks diverging from the middle of the leaf, and in polypody (Polypodium), so common on tree-~~bunk~~ trunks and male-fern, they are round patches. A sorus may have no special invest-ment, as in polypody, or it may be covered by a membrane (indusium) as in male fern. In some cases there are special fertile fronds of different shape from the others, upon which the sori are borne, e.g. the hard fern and royal fern, the latter being our largest native species.

Examination of a sorus under the microscope shows that it is made up of a number of stalked sporangia, in which are contained a quantity of angular brown spores. A sporangium is of biconvex shape, with a thickened ring (annulus) running round the greater part of its margin. This band is in a state of tension, ~~to~~ & when the spores are ripe it tears ~~upon~~ open the sporangium and scatters them.

Germination of spores:— The spores are cells of simple structure and are not, like a seed the result of a process of fertilisation

but are asexually produced. Should one reach a damp spot, it at once germinates. Its form bursts split, and two outgrowths make their appearance a delicate, colourless rhizoid which grows down and a green thread that makes its way upward.

The growth of the spore But few spores are able to effect their work of continuing the species. On the average, only one spore per plant succeeds in doing this each season. The germinating spores gives rise to a small heart-shaped green expansion, the 'prothallus' attached to the soil by numerous rhizoids.

Prothalli may often be seen in quantity in greenhouses, growing on the soil in which ferns have been planted. The artificial conditions are very favourable to their production. This prothallus is the gametophyte plant, that is, one undergoing a sexual phase. Upon the underside of the prothallus, in its central region, which is thicker than its edges, will be found a groups of archegonia, each of which consists of a basal part embedded in the prothallus and containing an egg-cell, and a projecting neck. Scattered about on the same side of the prothallus, but restricted to its thinner part, are a number of very minute hemispherical projections, the antheridia, in each of which are produced many small spermatozoids.

Fertilization:— Within the mature egg-organ a sort of slime is produced, which swells up and forces apart the cells making up the neck, so as to leave a passage down to the egg-cell. Meanwhile, the ripe antheridia

have been burst-open in similar fashion, and the liberated spermatozoids swim actively about ~~m~~ by means of their numerous cilia. The slime which oozes from the archegonia exerts a chemical attraction upon them, and should a sperm succeed in making its way down to an egg-cell, it fuses with it. ~~The knowledge the way of the plant is very~~ As soon as this happens, the fertilized egg-cell begins to divide, and soon gives rise to a young fern-plant (sporophyte), which remains attached to the prothallus, but ultimately takes root in the ground. The prothallus now perishes.

Alternation of Generations in Ferns:— The life history of the fern includes two alternating stages: (1) the ordinary fern plant, which produces spores asexually, and (2) the prothallus possessing archegonia and antheridia. We may call these two stages the sporophyte generation and the gametophyte generation.

This remarkable phenomenon is known as 'alternation of generations,' and is typically seen in fern-like plants, mosses, etc., and many lower plants, particularly some red and brown seaweeds. It is also characteristic of seed-plants in a somewhat modified form.

The adder's-tongue and moonwort possess but a single leaf which divides into a sterile and fertile part, while each sporangium develops from a group of cells, and not from a single one as is the case in an ordinary fern. In the adder's-tongue (Ophioglossum) the sterile part of the leaf has a simple outline, while the elongated fertile portion is practically a mass of crowded sporangia. But in moonwort both parts of the leaf are branched in a feather-like manner.

Water ferns:— The water ferns make up a small but interesting

groups of litth plants which are either purely aquatic or grow, with some exceptions, in ground of a swampy character. All the ferns have sporangia of two kinds, which respectively contain small spores and large spores, and having regard to the fate of these, we may call the leaves which produce them male spore-leaves and female spore-leaves. For a small spore germinates to produce a minute male prothallus with a single antheridium, while a female spore gives rise to a rather larger female prothallus, which bears a few archegonia. One member of this group is 'Salvinia', a small aquatic plant, it is entirely devoid of roots, and consists of a stem bearing two kinds of leaves, some being oval and floating on the surface, while the others are finely divided and submerged. The latter play the part of roots, and they are also fertile, having rounded sori at their bases, containing large and small sporangia. This plant is native to South Europe.

~~[illegible]~~ Mosses and Moss like plant

Hey! What are they – they were not here, when I visited the pond in the winter.

"Why? We are water babies, the tadpoles. We live here, in the pond – and we swim about and breathe with gills just as fishes do. We would die if you take us out of the water."

"But you were not here in the winter?"

"Quite right. We have an interesting story behind it. As soon as winter came, my mother, the toad went to sleep. She just ~~crawled inside~~ crept into ~~the~~ a hole in the ground, where the wintery blasts ~~could~~ did not harm her. That's why you did not see my mother flopping along the muddy bank of the tank. ~~One warm spring morning~~ Then spring came and warm sunshine woke her up, from her long winter sleep. ~~So~~ She crept out of her hole, ~~an~~ made her way to the pond. Here in the water she snaped insects and worms, as she was very – very hungry. Oh! she was very happy ~~to~~ find herself out and ~~on~~ about in the warm, wet world once more. Don't think, she spent, all the bright spring days in just idling & playing out. She first chose her mate, my father. Soon she got busy laying eggs." ~~In this~~

"In this very pond, among the floating weeds she laid her eggs – at first the eggs looked strange lump of pale greyish jelly. If you had look carefully then, you could have seen ~~that each~~ that the jelly was made up of a small rounded balls about the size of a pea, all tightly pressed together. And in the middle of each ball was a tiny dark speck. You know in one lump there are thousands eggs – as they all hatched out, it is no wonder that there are so many of us, ~~crowding about.~~ pollywogs – crowding about".

Tadpoles are water babies. They live in the ponds and streams, where they swim about and breathe with gills just as fishes do. The little things would die if you took them out of the water. Grown-up toads on the other hand, are land creatures. They live on the banks of the pools and streams, in damp meadows, or in any muddy, marshy place; and they have lungs to breathe with like all other land animals.

So toads are not reptiles. They are called amphibians because they have a double life, for originally the word was used of creatures living both on land and in the water. They spend their early days like fishes in the water; and then, after going through the most astonishing transformation, they hop ashore and turn into land animals. But all their lives ~~to~~ toads continues to be fond of water. You never find them in dry woods or hot, sandy fields. They would shrivel up if there were not enough puddles and wet weeds or moss about to keep them comfortably damp.

Amphibians, like reptiles, are cold blooded creatures. But instead of being covered with scales, most of them clothed with a soft skin, which is very elastic and can be stretched in a most astonishing manner. They do not drink in the usual way, but absorb moisture through the skin; and there is nothing an old toad enjoys so much as sitting in a puddle and soaking up the water in undisturbed calm. A toad has a rough, dry skin covered with little warty lumps. Every two or three weeks all amphibians shed their outer dead skins just as reptiles do. The old skin splits and peels off in ragged flakes, and its owner almost always makes a meal of it. It is one of the funniest of

of nights to see a portly toad trying to get rid of his tattered old suit. He works away with his sturdy little hands, rubbing the loose pieces from his back first on one side and then on the other; then he stuffs them into his mouth and swallows them with gulps of satisfaction.

In the winter months there are no toads to be seen squatting by the wayside or flopping along the muddy lanes. For as soon as cold weather sets in all the toads go to sleep. They crawl inside hollow trees shuffle under large flat stones or creep into holes in the ground where the wintry blasts are not likely to harm them. Warm spring sunshine wakes them from their long winter sleep. They creep out of their holes and corners, and they all make their way to the ponds and ditches around about. There they soak themselves in the water and snap up insects and worms. They choose their mates and are pleased to find themselves out and about in the warm, wet world once more.

But they do not spend all the bright spring days in idling and playing out. Soon all the mother toads are busy laying their eggs. In the shallow pools and ponds, in the ditches by the wayside, and in the gently rippling streams that wander through the land, strange looking lumps of pale grayish jelly appear, floating among the weeds, just below the surface of the water. If we look carefully, we can see that each lump of jelly is made up of a quantity of small round balls about the size of a pea, all tightly pressed together and in the middle of each ball is a tiny dark speck. The spawn is laid in a long ribbon of jelly instead of in a lump, and the dark round eggs in it look like strings of tiny beads. There are several thousands

eggs in each lump, or ribbon, of jelly; and as they all hatch out at about the same time, it is no wonder that so many ponds and ditches are crowded with little polliwogs in the spring of the year. The tadpoles are smaller & darker than frog tadpoles.

At first the tiny polliwogs have feathery gill tufts to breathe with, which stand out on each side of the head like little waving plumes but are so very tiny that you can hardly see them without magnifying glass. As they grow bigger the tadpoles lose their feathery plumes, and their breathing gills are hidden under little folds of skin, just as fishes gills are.

By this time the tadpoles are big enough to be seen, and what funny looking creatures they are! they seem to be all head and tail and to have nothing at all in the way of a body. But the big round headlike thing is really head and body both; and hidden under its dark skin are the legs and all the other parts on which it is going to grow. In the meantime the odd water babies have all the organs they need for living in a pond — gills to breathe with, a pair of horny lips to eat with, and a long flat tail with which they swim through the water by striking out to right & left, just like a fish.

Tadpoles are very restless little beings. They are hardly ever still. When they are not wiggling big about all over the place in a state of wild excitement they cling in bunches to the water weeds, where they do a pushing and shoudering each other out out of the way in order to get into the middle of the bunch which seems to be the favorite spot. the nibble the water weeds all swallow all sorts of tiny soft things that float in the water — and even their own brothers & sisters — now & then.

When the tadpoles are full grown they begin to change in appearance. their heads and bodies take shapes, their legs — first the hind pair and then the front pair — break through the skin, and the little creatures now look small toads that have somehow grown long tails.

By this time they have acquired a pair of lungs to breathe with — while their gills are shriveling up and are no longer of much use. So they now come often to the top of the water and push their little nose above the surface to take in drafts of fresh air. Their tails, too, begin to shrink, growing smaller and smaller every day. But before the tail disappear altogether, the little amphibians scramble out of the water as wee toads no bigger than your thumb nail, and start hopping and crawling about in the damp grass around the edge of the pond.

Crowds of tiny toads often swarm on the banks of ponds and streams in the summer time. Toads are very independent beings. Each one goes his own way. Mostly they go about and feed in the evening, and spend the day hidden in the grass or in the mud. But after a spell of dry weather large numbers of them leave their hidden places on a dull wet day and assemble to enjoy the refreshing rain; in the spring time, too, they gather at the water's brink for their nightly choruses. Toads are not full-grown until they are three or four years old, and before that time they have many dangers to meet. If they hop back into the water for a swim they run the risk of being snapped up by hungry fishes. While on land they may be eaten by the snake and birds and beasts. So out of all the thousands of polliwogs that hatch out of each batch of eggs, only two or three are likely to grow up.

Toads have big beautiful eyes that shine like precious jewels in their heads; they have huge wide mouths and long sticky tongues. They feed on small creatures such as insects, worms etc. As a rule they will not touch anything until they are quite sure it is alive. You may see an old toad sitting bolt upright on its haunches, gazing with intense excitement at a big fly resting on the ground. Presently the insect moves a leg: that seals its fate. Quicker as a flash the toad makes a dart with his

long sticky tongue, and the fly disappears down his throat.

His hind legs are not so long, and he can not skip about with agility. His usual mode of progress is a jerky crawl though when he is in a hurry he can get along more quickly by taking little hops. He is rather a poor swimmer, and does not spend much time in the water. As a rule, he prefers to sit in a puddle or squat in damp grass.

Many people are afraid of a toad. They call it a horrid creature and think it is poisonous. But the common toad is a harmless fellow, and a very useful one to have about the garden; for it destroys many a troublesome insect. They do exude a disagreeable milky fluid through the pores of the skin when they are roughly handled. This fluid is quite harmless to man, as a rule, although it leaves an unpleasant smell on your skin and will make your eyes smart if you rub them just after you have touched one of the creatures. But to many animals it is really poisonous. No wise dog will touch a toad, and if he does pick one up while he is still a foolish puppy, he will drop it in a hurry and never repeat the experiment.

As a rule toads are not very noisy. They make some kind of sound when they are pleased or alarmed. It is the male that croaks so lustily when they gather around the ponds on warm spring nights. When he croaks he keeps his mouth shut his throat swells up like a blown-out paper bag. In his throat is a pouch of very fine skin called a "vocal sac." When it is filled with air, this pouch adds to the volume of the sound; and that is why so loud a noise comes from so small a creature.

There is a small European toad, called the "midwife toad," which is a good and careful father. He winds the long strings of bead-like eggs, laid by his mate, around & around his hind legs and retires with them to a hole in the ground. There he waits patiently, coming out only at night to feed.

When the eggs are ready to hatch, off he waddles down to the water and lets all the babies baby polliwogs go free.

Another toad — a mother toad — carries her eggs about on her back. The male lifts them and places them in position for her, and they sink into her soft, thick skin. Each eggs lies in a separate little pocket, and the sticky film on top of it soon becomes hardened and forms a tight-fitting, horny lid. For nearly three months the patient toad moves about with her strange burden. Then one by one the little lids are pushed up, and seventy, eighty, tiny toads scramble out and tumble off mother's back. This toad is called Surinam toad.

They have no image of gods; nor they do they worship symbols, but they believe that though invisible to mortal eyes, the Gods may, when propitiated by sacrifice, take up for a time their abode in places specially dedicated to them. Thus they have their 'high places' and their 'groves' - the former, some mighty mass of rock to which man has added nothing, and from which he takes nothing; the latter, a fragment of the original forest - the trees in which have been for ages carefully protected lest when the clearance was first made, lest the sylvan Gods of places, disquieted at the wholesale felling of the trees that sheltered them, should abandon the locality. Even now, if a tree is destroyed in the sacred grove (Jāhirā or Sarna) the Gods evince their displeasure by withholding seasonable rain. Sing Bonga, the creator and preserver is adored as the Sun. Prayer and sacrifice are made to him as to a beneficent deity, who has no pleasure in the destruction of any of his creatures, though as a father, he chastises his erring children. He is said to have married Chandra Omol but she deceived him once and he cut her into two; but repenting his anger, he allows her at times to shine forth in full beauty. The stars are her daughters. The worship of the Sun as the supreme deity is the foundation of the religion of the Kols & Uraons, who address him, as Dharmi, the Holy one. The other deities are all considered subordinate to Sing Bonga; but they possess supernatural powers, but when they are invoked in such cases, it is their duty to intercede with Sing Bong, and so obtain for their votaries the solicited relief. Chanala Desum Bonga and his wife Pangora have

in been included among the minor deities of the Hos, but these are the styles under which Sing Bonga and his wife Candra Omol desire to be worshipped by female Vataries. Chanala is to women what Sing Bonga is to men -

There were formerly people in Heaven who served Sing Bonga. They absented themselves from work because, seeing their faces in a mirror, they found they were in God's image, and therefore his equals. Thereupon God expelled them from Heaven and they fell in a place that goes by the name of Terasi Pirhi Ekasibasi. They found there quantities of Iron ore, and immediately made seven furnaces & commenced smelting it; the fire burnt the trees and the grass, and the somke and the sparks ascended to Heaven. This went on night and day - not disturbed Sing Bonga, and he gave orders that if they worked all day, they must stop all night or if they worked all night, they must stop all day; but they would not obey. Sing Bonga then sent two king crows and an ~~out~~ owl to warn them, but they did not attend; and they tried to catch the birds with their furnace tongs; and spoil their tails. Then he sent a crow and a lipi (Lark). The crows were formerly white, but the vulcans caught the crow sent by Sing Bonga and smoked it black; but they made the lipi red & flattened its head; but the orders of Sing Bonga were not carried out. Other messengers were sent with no better success. Then Sing Bonga resolved to go himself, and he stopped at the house of Lut Kum Haram and Lut Kum Buri, an old ~~cog~~ couple who made charcoal and he served them incognito for some time, and amused himself by playing with the smelter's children. They played with balls of

[illegible] iron balls, [illegible] he with eggs, but the eggs smashed the iron balls. When the old man & and his wife went to the woods to make charcoal, they left Sing Bonga in charge of the hut, and told him to watch the dhán laid out to dry; but he played all the time, and the fowl ate up the dhán except a few grains, and when the old couple returned, they mourned for the loss of the dinner. But Sing Bonga consoled them, and taking the few grains that were left, he fried all the pots with them; and when the old people accused him of having stolen rice to make good what was lost by his carelessness, he answered mildly, 'No, God gives it.' The furnaces of the smelters were now continually falling in, and the smelters sought an oráh to ascertain the cause; but as they could not find one, they placed rice on a winnowing-fan, and it led them to Sing Bonga, and they asked him what they should do. He replied, 'You must offer a human sacrifice.' But they could find a man and returned to Sing Bonga, who said that he himself would be the sacrifice. Then they made a new furnace and instead of iron-ore, they put Sing Bonga into it and blew the bellows; and when there were sufficient heat, as they had been told, they sprinkled water on the fire, and Sing Bonga appeared uninjured but from the furnace flowed streams of gold & silver, and precious stones shining like the sun. Then Sing Bonga said, 'See what one person has done! If you all pass through the furnace, what a heap of wealth you will have!' They all

agreed and ~~entered~~ entered the furnace and were shut up, and Singbonga made their wives blow the bellows. When the people inside began to howl the women were alarmed, and would have stopped but Sing Bonga said "Blow away! They are only quarrelling over the division of the spoil. Thus they were all destroyed, ~~because~~ because they had not obeyed the word of Singbonga. Then the women said, "You have killed our husbands what we are to do?" Sing Bonga gave to each of these women a locality, and they became the minor deities or bhuts, male and female. Some had rocks, some grove, some pools, some rivers, as their abodes; and thus originated the Naiads and Dryads, the Marang Buru or Bird Bonga of the hills, the Desauli of the grove and the Naga Eras of the streams.

"The next in order among the Gods after Sing Bonga is Marang Buru or Buru Bonga, the mountain God. The highest hill or rock in the neighbourhood is the shrine of this deity or Spirit. The Kols recognise the importance of wooded hills in securing the needful supply of rain; and ~~have~~ trusting entirely to rain for irrigation, and regarding Buru Bonga as the head of the heavenly Water department, they annually pay him special attention. Every third year in most places, buffaloes are sacrificed in his honour, and fowls and goats every year. He is also invoked in sickness. In Chota Nagpur near the village of Lodhma, is the Marang Buru or Maha Buru for a wide expanse of country. Here people of

all castes assemble and sacrifice. Hindus & even Muslims, as well as Kols. The sacrifices are offered on the top of the hill, a bare semi globular mass of rock. If animals are killed, the heads are left there and afterwards appropriated by the pâhn or priest. Hindu says that the Marang-Buru as a deity is the same as Mahâdeo; but under what name Muslims pay devotion to him I know not. Every village has in its vicinity a grove reputed to be a remnant of the primeval forest, left intact for the local gods when the clearing was originally made. Here Desauli the tutelary deity of the village and his wife, Jhâr-Era or Mahârii, are supposed to sojourn when attending to the wants of their votaries. There is a Desauli for every village, whose authority does not extend beyond the boundary of the village to which his grove belongs. If a man cultivates land in another village than the one in which his home is, he must pay his devotion to the Desauli of both. The grove deities are held responsible for the crops, and are specially honoured at all the great agricultural festivals. The next is Nâga-Era or Nâgas, who preside over lakes, wells and any bodies of stagnant water, called Ekhir-Borga; and Garhâ-Era the river goddess. They are too frequently denounced as the cause of sickness, and propitiated by sacrifices to spare the suffer-

The remaining spirits are the ancestral shades, who are supposed to hover about, doing good or evil to their descendants. They are often denounced as the cause of calamitous visitations and propitiatory offerings are made to them; but besides, a small portion of the food prepared in every house is daily set a part for them. The ancestors are the Penates and are called Ham-ho. The ancestors of the wife have also to be considered they are called Hovatan-ho, because sacrifices to them are always offered on the path hova, by which the old woman came as a bride to the house.

on the first day of the feast, the villagers must not break their fast till certain ceremonies have been performed. In the evening, a party of young men and women proceed to the forest and cut a young karam tree or the branch, and they return with it in triumph - dancing, and singing and beating drums, and plant it in the middle of the akhra. After the performance of a sacrifice to the karam Devta by the pahn the villagers feast and the night is passed in dancing and revelry. Next morning all may be seen at an early hour in holiday array, the elders in groups, under the fine old tamarind trees that surround the akhra, and the youth of both sexes arm-linked in a huge circle, dancing round the karam tree. Preparatory to the festival the daughters of the headmen of the village cultivate blades of barley in a peculiar manner. The seed is sown in moist, sandy soil, and the blades sprout and unfold of a pale yellow or primrose colour. On the karam day these blades are taken up by the roots and carried in baskets by the fair cultivators to the akhra. They approach the karam tree, and prostrating themselves reverentially, place before it some of the plants. They then go round the company and like bridesmaids distributing Wedding favours, present to each person a few of the yellow barley blades, and all soon appear wearing, generally in their hair, then all join merrily in the karma dance. The morning revel close with the removal of karma.

it is taken away by the merry throng and thrown into the stream or tank;

Sarhúl

At the season of the marriage of Dharti the earth is celebrated; and this can not be done till the Sal trees give the flowers for the ceremony. It takes place towards the end of March or in April. On the day fixed the villagers accompany their pahn to the Sarna, the sacred grove a remnant of the old sal forest in which a popular deity called the Sarna Búrhi, or woman of the grove. To this dryad who is supposed to have great influence on the rain, the pahn arriving with his party at the grove, offers five fowls. These are afterwards cooked with rice, and a small quantity of the food is given to each person present. Then they collect sal flowers and return laden with them to the village. Next day the pahn with some of the males of the village pays a visit to every house, carrying the flowers in a wide open tank. The females of each house take out water to wash his feet as he approaches, and kneeling before him, make a most respectful obeisance. He then dances with them, and places over the door of the house

and in the hair of the women some of the Sal flowers. The moment that this is accomplished, they throw the contents of their Water-Vessels over his venerable person, heartily dousing the man whom a moment before, they were treating with such profound respect. But to prevent his catching Cold, they ply him with as much of the home-brew as he can drink. The feasting and beer-drinking now become general, and after the meal the Youth of both sexes decked with Sal flowers flock to the Akhra, and dance all night and best-part of next-day.

They make no images of their gods, nor do they worship symbols;

Order — Passeriformes

Family - Corvidae

" — Paridae

" - Sittidae

" - Timaliidae

" — Aegithinidae

Pycnonotidae

Orthidae

Troglodytidae

Cinclidae

Turdidae

Prunellidae

Muscicapidae

Pachycephalidae

Laniidae

Campephagidae

Artamidae

Dicruridae

Sylviidae

Oriolidae

Sturnidae

Ploceidae

Fringillidae

Hirundinidae

Motacillidae

Alaudidae

Zosteropidae

Nectariniidae

Dicaeidae

Pittidae

Eurylaimidae

Order - Piciformes
Fam - Piciidae
- Capitonidae
Indicatoridae

Order - Cuculiformes
Fam - Cuculidae
Order - Psittaciformes
Fam - Psittacidae
Order - Coraciiformes
Fam - Coraciidae
Meropidae
Alcedinidae
Bucerotidae
Upupidae

Order - Trogoniformes
Fam - Trogonidae
Order - Apodiformes
Fam - Apodidae
Order - Caprimulgiformes
Fam - Caprimulgidae
Podargidae
Order - Strigiformes
Fam - Tytonidae
Strigidae
Order - Falconiformes
Fam - Pandionidae
Accipitridae
Falconidae
Order - Columbiformes
Fam - Columbidae

Order - Galliformes
Fam - Phasianidae
Order - Gruiformes
Fam - Turnicidae
Rallidae
Heliornithidae
Gruidae
Otididae
Order - Charadriiformes
Fam - Jacanidae
Rostratulidae
Burhinidae
Glareolidae
Stercorariidae
Laridae
Rynchopidae
Charadriidae
Recurvirostridae
Scolopacidae
Order - Pelecaniformes
Pelecanidae
Phalacrocoracidae
Anhingidae
Sulidae
Order - Ciconiiformes
Threskiornithidae
Ciconiidae
Ardeidae

Order — Anseriformes
Anatidae
Order — Podicipitiformes
Podicipitidae

Serial No	Biber List No	FBI No	Plates	Scientific Names	English
				Order PASSERIFORMES Family CORVIDAE	
1		55		Corvus macrorhynchos levaillanti	
2		11		Corvus splendens splendens	
3		26		Gymnosirina vagabunda	
~~4~~				Family PARIDAE	
4		~~No~~ 55		Parus ~~xanthogenys~~ major ~~aplonotus~~ nabaltarum	
5		76		Parus xanthogenys aplonotus	
				Family SITTIDAE	
6		119		Sitta frontalis frontalis	
~~7~~					
				Family TIMALIIDAE Sub-family PELLORNEINAE	
7		240		Pellorneum ruficeps ruficeps	
		?			
				none { Sub-family POMATORHINAE Sub-family TIMALIINAE	
				Sub-family CHAMAEINAE	
		? 229		Dumetia hyperythra	
		234		Chrysomma sinense hypoleucum	
				Sub-family TURDOIDINAE	
		183		Turdoides somervillei terricolor	
		191		Turdoides earlii	
		192		Turdoides caudata	

	Hindi names	Bengali names	Uraon names	Munda names	
Jungle Crow	KAG				
House Crow	KAWA				
Treepie	MOTRI				
Southern ~~Yellow~~ Grey cheeked Tit					
Southern Yellow-cheeked Tit					
Velvet-fronted Nuthatch					
Spotted Babbler					
Yellow-eyed Babbler					
Bengal Jangle Babbler					
Striated Babbler					
Common Babbler					

289	Alcippe poiocephala broucei	
	Family AEGITHINIDAE	
362	Aegithina tiphia tiphia	
366	Aegithina nigrolutea	
368	Chloropsis aurifrons aurifrons	
374	Chloropsis jerdoni	
	Family PYCNONOTIDAE	
~~399~~ 403	Pycnonotus cafer bengalensis	Bengal
410	Pycnonotus jocosus emeria	Bengal
411	Pycnonotus jocosus fuscicaudata	Southern
433	Pycnonotus luteolus	White
	Family CERTHIIDAE	
456	Salpornis spilonotus	Spotted
	Family TURDIDAE	
	sub-family ERITHACINAE	
~~484~~	~~Luscinia brunnea~~	
537	Luscinia svecica pallidogularis	E. Red-
532	Phoenicurus ochruros rufiventris	E.
558	Copsychus saularis saularis	
563	Copsychus malabaricus indicus	

Names | 1

Quaker Babbler

Common Iora

Marshall's Iora

Gold-fronted Chloropsis

Jerdon's Chloropsis

Red-vented Bulbul

Red-whiskered Bulbul

" " "

Crowned " "

Gray Creeper

Pied Chat

spotted Bluethroat

Indian Redstart

		Sub-family SAXICOLINAE
494		Saxicola caprata bicolor
495		" torquata indica
557		Saxicoloides fulicata cambaiensis
		Sub-family TURDINAE
577		Turdus ruficollis
587		Geokichla citrina citrina
608		Monticola solitarius pandoo
		Family MUSCICAPIDAE Sub-family MUSCICAPINAE
638		Muscicapa parva parva
647		~~Muso~~ " superciliaris superciliaris
649		" westermanni melanoleuca
657		" rubeculoides rubeculoides
660		" tickelliae tickelliae
665		" thalassina thalassina
675		" poonensis poonensis
679		Culicicapa ceylonensis ceylonensis
		Sub-family MONARCHINAE
688		Terpsiphone paradisi paradisi
692		Hypothymis azurea ~~azurea~~ sykesi

Sub-family RHIPIDURINAE

700	Rhipidura aureola aureola
705	" pectoralis

Family LANIIDAE

706	Lanius excubitor lahtora
710	" vittatus
712	" schach tricolor
714	" " erythronotus
716	" tephronotus tephronotus
719	" cristatus cristatus

Family CAMPEPHAGIDAE

724	Hemipus picatus picatus
729	Tephrodornis pondiceriana pondiceriana
733	Pericrocotus flammeus speciosus
738	" brevirostris
745	" peregrinus peregrinus
749	" erythropygius
756	Coracina melanoptera sykesi
758	" novaehollandiae macei

Family ARTAMIDAE

763	Artamus fuscus

Family DICRURIDAE

766	Dicrurus macrocercus peninsularis
775	" leucophaeus longicaudatus
777	" caerulescens caerulescens
789	" paradiseus grandis

Family SYLVIIDAE

795	Acrocephalus stentoreus brunnescens
799	" dumetorum
839	" aedon
825	Cisticola juncidis cursitans
827	Prinia hodgsoni hodgsoni
831	" buchanani
936	" socialis stewarti
937	" sylvatica sylvatica
940	" inornata inornata
852	Phylloscopus affinis
854	" collybitus tristis
860	" fuscatus fuscatus
870	" inornatus inornatus
845	" Cantator Cantator
813	Orthotomus sutorius sutorius
? 840	Hippolais rama
? 846	Sylvia hortensis jerdoni

Family ORIOLIDAE

953	Oriolus oriolus kundoo
954	" chinensis diffusus
958	" xanthornus xanthornus

Family STURNIDAE

~~952~~ ~~Gracula religiosa~~
982 Sturnus malabaricus malabaricus
991 " pagodarum
1064 " contra contra
996 Acridotheres tristis tristis
998 " ginginianus
998 " fuscus fuscus

Family PLOCEIDAE

Sub-family PLOCEINAE

1008 Ploceus philippinus philippinus
1012 " " benghalensis

Sub-family PASSERINAE

1096 Passer domesticus indicus
? 1094 Gymnorhis xanthocollis xanthocollis

Sub-family ESTRILDINAE

1021 Lonchura striata striata
1030 " malabarica
1031 " punctulata punctulata
1036 Estrilda amandava amandava

Family FRINGILLIDAE

Sub-family CARDUELINAE

1069 Carpodacus erythrinus roseatus

Sub-family EMBERIZINAE

1119 Emberiza schoeniclus
1139 Melophus lathami subcristata

FAMILY HIRUNDINIDAE

1150 Riparia concolor sintaungensis
1152 Hirundo rustica rustica
1157 " smithi filifera
1158 " fluvicola
1161 " daurica nepalensis
1162 " " erythropygia

Family MOTACILLIDAE

1166 Motacilla alba dukhunensis
1171 " " alboides
~~1172~~ " ~~maderaspatensis~~
1173 " " leucopsis
1172 " maderaspatensis
1174 " cinerea melanope
1175 " flava beema
1176 " " thunbergi
1179 " feldegg feldegg
1181 " citreola citreola
1182 " " calcarata
1183 Dendronanthus indicus
1186 Anthus hodgsoni hodgsoni
1191 " similis jerdoni
1194 " novae-seelandiae thermophilous
1195 " " rufulus