STRUCTURAL BOTANY

BY

HARENDRA NATH MITRA, M.A.

Professor of Botany, Bangabasy College, Scholar of
the University of Calcutta.

WITH A PREFACE BY

PRINCIPAL G. C. BOSE, M.A., M.R.A.S., F.H.A.S., &c.

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PREFACE.

The text-books on Botany which are in use in our schools and colleges are some of the very best of their kind, but they are all written from the European standpoint and deal with European plants. Indian students therefore find considerable difficulty in following them. A want has long been felt of a suitable text-book on Indian Botany written on modern lines, and dealing with Indian plants. Dr. Oliver's First-Book of Indian Botany is undoubtedly a valuable and handy *resume* of Indian Botany, but written about half a century ago it naturally falls short of the modern requirements of a text-book on the subject. The Madras Branch of the Christian Literature Society has recently brought out "A Botany for India by P. F. Fyson, B.A., F.L.S." of the Indian Educational Service, which though very elementary is sure to be of some help to Indian students where help is so badly wanted. But what the Indian student specially wants is a book illustrated with commonly occurring Indian plants and dealing with the special features of the plants of the country. With this end in view Professor H. N. Mitra has brought out his book and it is for the public to find out how far he has succeeded in his laudable efforts in meeting the long-felt want. Most of his examples have been taken from Bengal plants to which he has added Botanical names and wherever possible vernacular or Bengali names as well. In assigning Botanical names he has mostly followed Roxburgh's Flora Indica although the latest nomenclature of Indian plants adopted by Dr. Hooker and followed by Dr. Prain departs in many instances from Roxburgh's nomenclature, his reasons for this departure being that Dr. Hooker's Flora of British India and Dr. Prain's Bengal Plants are in the first place much too high priced for ordinary students and in the second place out of print, while Clarke's Edition of Roxburgh is very moderately priced and readily available. The addition of Bengali names will no doubt be helpful to our students where the names are those which are commonly adopted almost all over the country. But unfortunately some of these Bengali names are likely to mislead the students and land them into difficulties where they vary from district to district or even from village to village. Notwithstanding this drawback, I do think that for a beginner at least, these names will be of great value in identifying the plants and facilitating his study, and Professor Mitra has spared no pains in selecting them after fully consulting the invaluable collection of vernacular names left in the classical work of Roxburgh.

The book has been rushed through the Press, and a few misprints and errors have naturally crept in. I hope these will be corrected in the next edition.

CALCUTTA.
22 JULY 1912.

G. C. BOSE.

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STRUCTURAL BOTANY.

INTRODUCTION.

Nature can only be studied with the aid of experiments and observations. But a mere collocation of facts and phenomena promiscuously mixed up without any plan or method would enrich our knowledge as little as a blind memorising of events and dates of History would enable the student to enter into the spirit and teachings of the subject. On the contrary, our observations of natural phenomena as also the experiments that we make in order to elucidate some of her mysteries, in short, our knowledge of Nature must, in order to be comprehensive and self-consistent, be linked together by the chain of reasoning. Such a systematised knowledge with all its subject-matters arranged in an orderly plan is Science, and the science of the vegetable kingdom, or plants in general, is **Botany.**

Matter or material objects existing on the surface of the earth we can best divide into two great groups :—Living and Non-living. This division is characterised by the fact that the force dominating the one is absolutely wanting in the other. This force is one of those mysteries bound up with life which scientists, working still in the twilight of hypothesis, have tried to encompass by the term vital force. But whatever be the precise significance in which we use the term, it is clear to everybody that it is life which renders possible the existence of such matters as animals and plants. Deprived of this force, living bodies degenerate into a lifeless mass of matter in no way differing from stocks and stones. The independent existence of this vital force, however, has been denied by a large section of the modern scientists and correlation between this and other forces, working in nature, has been demonstrated. It will be enough, here, to point out to the beginner that there is a current of force underlying the whole living world—plants and animals alike—which has, up to the present moment, defied all attempts of scientists to analyse and comprehend.

It is not easy, though at first sight it might seem plain work, to draw a rigid line of demarcation between plants and animals. Undoubtedly the most obvious point of distinction is the power of locomotion. Not that plants can never move and animals have all the movement to themselves but that in by far the great majority of cases, the former move, if they can at all do so, within a very small range, whereas the latter have universally a much greater latitude. Ordinarily a bird driving through the air is at once known to be an animal, and a winged seed or fruit flying through the same medium is recognised as vegetable. But for the non-existence of one thing, we might as well call the winged structure an animal—for there is the instinct, the feeling recognisable in the latter which at once differentiates it from the former. This instinct, this feeling, this perception of the senses, culminating in the highest type of animals, man, in those half-understood powers of intellect and reasoning which it is his prerogative to enjoy, is in fact, a criterion, a test which we apply in distinguishing the two great classes of living matter. But very low down in the scale of organic life, both in plants and animals, this test becomes quite inapplicable. For there are organisms existing at the present day in deep sea and in fresh water, which owing to the extreme simplicity of their characters, have mocked the attempt of scientists to classify them either along with plants or animals. In some the animal and vegetable characters are quite inseparably blended together, so that, while some Botanists would leave them alone and disown them as plants, others rush in with all the enthusiasm and warmth of a discoverer, to see in them the primeval types of living matter that once formed the starting point of organic creation. Thus they attempt to bridge over the wide gulf between animals and plants.

For, a comparative study of the existing plants and animals as also of those that existed in the past ages, traces of which we find in fossil remains in the different strata of the earth's solid crust, has enabled scientists to draw a genetic line of descent through living organisms of successive ages and to come to the conclusion that the modern complex forms of living bodies have been derived from those that existed in the immediate past—that this complexity has been arrived at after a long series of changes—changes that have been going on ever since the inception of cosmic phenomena, unlocking the potential characters of things in harmony with their environment—time and space. As a matter of fact, no truth has been more throughly established than that which Palæ-ontology—as the science of fossils is called—has unveiled, revealing the fact that in times bygone, forms of life existed on the earth, which by their gradual modifications have been moulded through the long course of ages, into their present forms—that the structures of animals and plants have progressed from a more generalised to a more specialised character, and from simpler to more complex forms. We may well believe, here, in the law of harmony in Nature. Physical causes now on play on earth are, no doubt, dependent upon those that rule the solar system. Hence it will be evident, that forms of life that exist under the present conditions, on the earth, would be ill suited to inhabit it, thousands and tens of thousands of years hence, when the temperature, moisture, wind and other physical factors will be altogether changed. Consequently, the fact that in the infancy of organic evolution on the surface of the earth, changing through a progression of complexity as time—counted, no doubt, by the millions—went by, becomes intelligible.

This theory—**Theory of evolution,** as it is called, is based upon the theory of Natural Selection, of which Charles Darwin was the first scientific expounder and author. He called attention to the fact that the offspring never resemble the parent entirely—that a slight variation from the character of the stock is continuously going on—that this variation is dependent upon the environment of organisms and that in conforming to their changed surroundings, they are constantly maintaining a hard **"Struggle for existence,"** as a result of which the weaker are pushed to the wall and the stronger always thrive. The gradual solidification of the earth's crust has been the immidiate cause of differentiation, not only in the different strata of which it is composed, but also at different parts of the same. Thus, adaptability to environment being the sole factor in determining which will survive, complexities in structure arise in those organisms that do. Simpler organisms, naturally disappear in the long struggle for existence when there are new and better equipped forms to dispute the field with them. This is the grand moral of the **Survival of the fittest.**

The primary creatures that lie on the borderland of animals and plants have been called **Protista** by **Earnst Haeckel**, the great Naturalist. It will be quite out of place here to describe in detail all the classes into which the Protista are divided according to their shape, behaviour, and other characters, but a few of these may be safely noted here to give the student some idea of these peculiar organisms. They are composed essentially of a jelly-like mass of matter called *Protoplasm.* It is this Protoplasm that forms the basic principle of life in all plants and animals. In fact, the phenomena of life have been attributed to the peculiar property of *Irritability* of the Protoplasm. It is a thing which has the power inherent in it of receiving stimulus from the outside world and answering in response thereto. Vital force, if there be such a force, resides in this Protoplasm, and it is through its activity that the voluminous structure such as that of a plant or an animal is enabled to live. In short, it is the proximate cause of nutrition, of growth, of respiration, of movement, of reproduction, that is, of all sorts of phenomena exhibited by a living organism. It forms also the essential and vital part of those microscopically minute bodies called *cells* that form the ultimate units of which the bodies of plants and animals are composed. The diversities of forms exhibited by these cells are merely the physical expressions of the dynamic property of the Protoplasm, to which property, again, are due the development, union and aggregation of cells into what are called tissues. And it is the congenital union of different tissues in accordance with the laws determined by the Protoplasm that makes up the organic body.

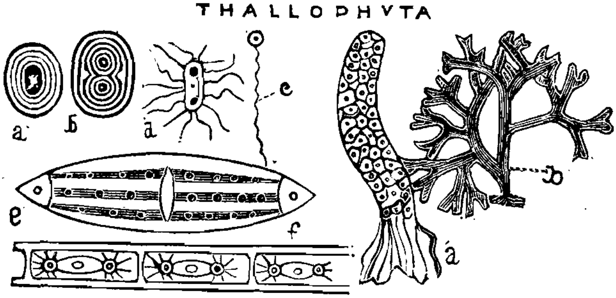
The cardinal point of difference between the animal and the vegetable cell is, that while the former consists exclusively of a naked mass of Protoplasm, the latter is, in the generality of cases, separable into two essentially different parts, namely, the *Protoplasm* and a cellular encasement imprisoning the latter, called *cellwall* Now, the enigmatical things, the Protista, are of various kinds. Some of them are invested within a cellwall and thus show a pronounced relationship with the vegetable cell ; others again are quite naked. But, naked or not naked, they all show a peculiar kind of movement quite unparalleled in the rest of the plant world. For while some of them get about creeping over obstacles in their path others rehabilitate the fish-like swimming movement in their body. Again, in their mode of taking food, they lean more towards the lower animals than towards plants. For while plants, in general, have little power of living upon organised food matters, and, in fact, with a few exceptions, they always live upon food synthetically prepared by themselves from the elements, many Protista, on the other hand, live like animals, entirely upon complex organic matter. Hæckel has demonstrated that like the colourless blood-cells of animals, Amœba, one of the protistal organisms, can receive and feed upon solid particles of colouring matter. Again, with regard to reproduction—that most universal and imperative function of all living structures, it is a patent fact that while all the higher plants and animals multiply in a sexual manner and sexuality is a regular phenomena even in those low forms that multiply chiefly asexully, by buds etc, the Protista propagate themselves exclusively in the non-sexual mode. There are neither male nor female protista.

Leaving aside for the present all these matters that lie on the speculative rather than on the practical side, we next enter upon the **Subdivisions** into which the vegetable world has been classified.

Taking a brief survey of the vegetation of the world we find that our ponds and lakes and other marshy bogs abound in a large variety of small plants. In most of these, however, the ordinary segments into which a plant is divided—the roots, stems, flowers etc. are not to be found. Some of them are mere bundles of inordinately long green threads, floating freely in the water, or attached to some submerged piece of stone. On bark of trees, on old unplastered brick walls, and on stony rocks again, we find very curious structures sometimes foliaceous or leafy, sometimes glued on to the support on which they rest, in the form of circular, elliptical, or irregular incrustations. Here, too, the vegetable nature of the living mass is indisputable, but then the plant as we call it is unsegmented. Such unsegmented plants naturally occupy the very lowest position in the hierarchy of the different classes into which the vegetable kingdom is divided, and are called Thallus-plants or **Thallophyta**—the term thallus denoting an unsegmented body. This group, Thallophyta, comprises the two large branches of *Algae* (Seaweeds, Fresh water algae etc.) and *Fungi* with the *Lichens*. The toad-stool, known in this country as *Banger-chata* (Frog's umbrella) and *shap-ky-chata* (serpent's umbrella), as well as the whitish deposit of mould found on putrifying cow-dung, cheese, and bread, on old moist boots and leather goods, are Fungi, while the thick and sometimes massive expansions found as incrustations on rocks, walls, bark of trees etc, fall under the Lichens.

The next subkingdom of the vegetable world, the Prothallus-plants, or **Prothallophyta,** includes the *Mosses* or *Bryophyta* and the *Ferns* or *Pteridophyta.* They are called Prothallus-plants, because every individual plant coming under this subkingdom exhibits two different generations of which one is called the *prothallium* or *Fore-growth* and the other, the *Cormus* which is an up-right shoot differentiated into stem

FIG. I. FIG. II.



Figures to show the gradual ascent in complexity of form.

Fig. I. a-e, unicellular plants. a, b, Glœocapsa ; c, nitrifying Bacteria ; d, Fermentation Bacteria ; e, Diatom.

f, Multicellular plant, a filamentous alga.

Fig. II. a, Multicellular plant, *Ulva Lactuca.* b, Thallus plant *Riccia fluitans.*

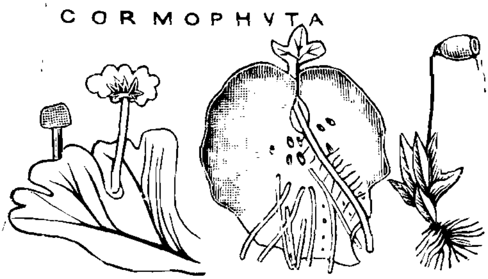
and leaf. The prothallium and the cormus manifest a regular alternation of generation, the prothallium producing the cormus, and the latter again giving rise to the prothallium, and in this way the life-cycle of each individual is encompassed. Here, the body of the plant is segmented into members, that is, stem and leaf, but the differentiation is not of a very high order. Yet, again, in Bryophyta this differentiation is so ill-defined that we can come by easy steps of complexity from the simplest Algae, through the transitional region of Mosses, to the highly segmented Pteridophyta.

Alike in Thallophyta and Mosses and Ferns, Flowers that form the distinguishing feature of the third subkingdom called Flowering-plants or **Phanerogamia** (from Gr: paneros = evident and gamos = marriage), are entirely wanting. Hence they are also called Flowerless-plants or **Cryptogamia** (from Gr: kruptos = hidden and gamos = marriage). It is only in the Phanerogamia that diversities of structure in the external segments of the plants are completely developed and manifested in endless varieties. This division comprises the majority of our land plants which are most fitted from their complex structure to carry on the multifarious functions that are necessitated under the existing conditions of the terrestrial surface.

Thus, regarded from the stand point of structural differentiation plants are either thallus-plants or cormus-plants, *i. e.* they fall either under Thallophyta or Cormophyta.

The lowest Thallophytic plants consist of a single cell which, alone in itself, performs all nutritive and reproductive functions. Other simpler forms occur, where cells are simply united into colonies. Long filaments with cells attached end to end, giving the appearance of beaded strings, may thus arise. All Thallophytic plants are either composed of single cells or filaments or other complex colonies which again may attain a further complexity by forming plates of cells. Higher in vegetable life, in the lowest Cormophytas (Bryophyta), complexity becomes outwardly manifested in the form of a shoot or cormus. But here, too, the body of the plant is composed of simple cells united into plates—the cells are still thin, delicate, soft and more or less round. Hence in contrast to the higher Cormophyta where cells are variously moulded, fused, modified and impregnated to form what are called tissues, the Thallophyta and the Bryophyta are together called **Cellular plants**. Tissues are formed by the

FIG. III. FIG. IV. FIG. V.



Figures shewing the gradual ascent in complexity.
Fig. III. Thallus and shoot of Marchantia.
Fig. IV. Prothallus and shoot of Fern.
Fig. V. Shoot of Moss ; a typical cormus.

congenital union of a group of cells following a common law of growth and development and subserving definite functions. The most complex tissues are those that form the *Vessels* or right canals or tubes resulting from partial or complete absorption of the transverse walls of a longitudinal row of cells. All plants above the Bryophyta possess true vessels and are, hence, designated **Vascular,** as opposed to the Cellular. Ascending, then, from the Thallophyta, we find that in Bryophyta, though the external segmentation is almost complete, the internal structure is still of a rudimentary character, being essentially cellular. In the axis of Moss-plants, however, we find a fore-shadowing of vessels that occur in plants higher up in the scale of complexity—for, there, some of the cells are greatly elongated, and though not fused to form right canals, serve, at least, an equivalent function? Alike again, in

Pteridophyta, called specifically the Vascular Cryptogams, and Phenerogams, the plant body is made up of three essentially different tissues,—the outermost layer of a rather tough and elastic structure, which can be easily peeled away, called the Epidermis; the innermost strand of hard cells and vessels, called the Conducting strand; and the intermediate soft, succulent and green portion, called the Cortex. Vascular plants have attained the highest step of structural complexity. For, it will be evident, that the differentiation of the three tissues is immediately dependent upon the functions they have to carry out. The Epidermis affords protection to the plant against external injury—its function is mainly protective. The soft Cortex is the actual vital field of the plant—it is here that food materials are manufactured, stored, transmitted and again drawn upon, by the whole living organism. The central hard and bony structure forms the main skeleton of the plant, and serves to maintain its upright position; and more than that, it is the channel through which ingredients of the plant-food are transmitted—it is their sole rout of transit.

As in all other plant-functions, so in reproduction, complexities arise as we rise higher in the scale. In Thallophyta, this function is carried on very simply. In the lowest among them, it is effected by a simple bipartition of the cell or the filament into two daughter-cells or filaments each of which, then repeats the life-history of the parent. Higher up in the same class, reproduction goes on by the union of two cells, almost alike, called *gametes*. Higher still in the plant world, the gametes become differentiated into male and female cells. Even in the Thallophyta, sexuality is very clearly defined, but the sexes themselves are of a very simple organisation. In the gradual ascent of structural complexity the sexual cells attain more and more complex and particularised forms till at last they come to be borne by that most complicated and specialised structure that characterise the Phanerogams,—the Flower. One consequence of reproduction taking place through the agency of flowers is that seeds are produced, as a result of fertilisation of the female by the male sex. Flowering plants are, therefore, seed-producing plants, and hence, are also called **Spermaphyta.** In one section of Phanerogams or Spermaphyta the seeds are developed within a cellular encasement called the *Ovary.* This section is known as **Angiosperms** or the covered-seeded plants. The other division of Phanerogams, the **Gymnosperms,** have their seeds naked *i. e.* without any investment to the female organ which matures into the seed.

The Angiosperms are divided into two great classes, namely the **Monocots** and the **Dicots.** These are abbreviated forms of the expressions Monocotyledonous plants and Dicotyledonous plants. The former have only one Cotyledon or seed-leaf, while in the latter there are two Cotyledons in the Embryo, or the initial plantlet that resides in the seed.

The Departments of Botany.—It is usual when we set out to study a science to divide it, for the sake of convenience, into separate departments related to each other rather closely, but each independently embracing a particular side of the problem. A good round knowledge of the plant kingdom can be best obtained if we start with the study of the individual plant—its external form, physical parts, its internal structure and the functions of each of these, and then proceed with the classification of the vegetable world with the help of the materials thus furnished. That is, we have first to start with the study of plants, each taken in itself, and then wind up with their study collectively. This latter part forms the great department called *Systematic* or *Descriptive Botany* and is based upon *Taxonomy* or the principles of classification. Under the first head come the twin departments of *Morphology* and *Physiology*. *Morphology* is concerned simply with the segmented parts of the plant body as its members and literally denotes the knowledge of forms (morphy = form and logos = knowledge).—*Physiology*, on the other hand, deals with these

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Thus Physiology and Morphology deal with the same subject-matters but only from different stand points. For as Physiology sees in the plant segments, organs subserving definite functions allotted to them according to a hypothetical law of division of labour, Morphology keeps them in view only as members irrespective of any function that they may be destined to carry out. But Physiology divorced from Morphology would be quite defunct, for one part, at least, of Morphology called *Internal* Morphology or Anatomy and Histology where we study the components and constituents of the plant body, as also their structure and disposition, is essentially bound up with the former, so much so, that an entirely one sided consideration of physiological questions apart from Anatomy and Histology would not only detract much from its value as a science but also make it delusive into the bargain. The other part of Morphology called *External* Morphology or simply Morphology, deals only with the members of the plant as externally differentiated into the Root, the Stem, and the Leaf, forming what are called the vegetative members, and the Flower, the Fruit and Seed, or the *reproductive* members.

Thus Morphology, Anatomy and Histology, Physiology, and Systematic Botany form the four most important departments of Botany regarded purely as a speculative science. But studied in its relation to the other sciences, it builds up other separate departments, as *Ecology* or the study of Morphology and Physiology from the stand point of adaptation to environment ; *Palæo-phytology* or the study of petrified remains of plants entombed in the rocky strata of the earth's crust in the past Geological ages, leading to the formulation of grand generalisations concerning Evolution and Descent ; *Economical Botany*, *Agricultural Botany*, *Geographical Botany*, etc. terms which explain their individual province.

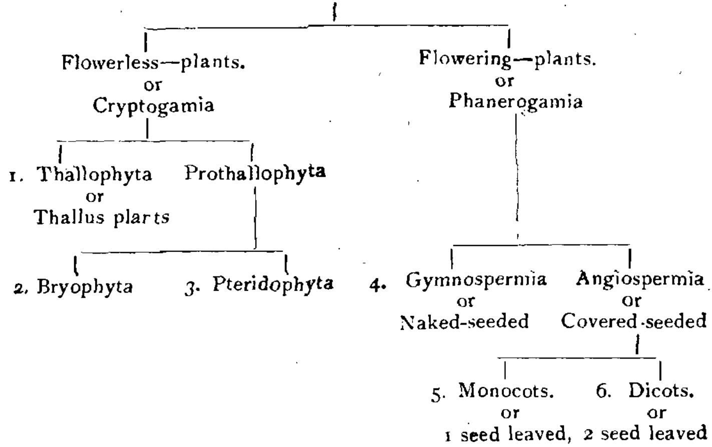
In this volume, Part I deals with the External Morphology, chiefly of Phanerogams ; Part II with the Internal Morphology or Anatomy and Histology of plants in general.

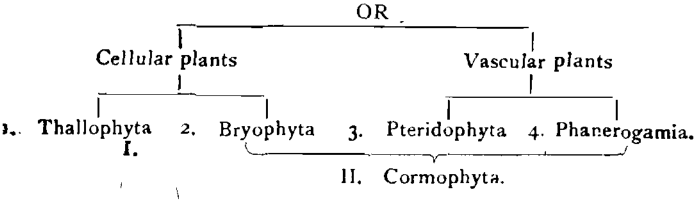
The subjoined table gives the distinguishing characters of the different classes of plants and will aid the student in remembering them.

	CLASSES.	DISTINGUISHING CHARACTERS.
Thallophyta.	1. Algæ.	Green thread-like filaments freely floating in fresh water or red or brown flat cellular structures inhabiting the Sea, with stem and leaf-like expansions which are really thalloid ; some freshwater algæ are unicellular and microscopic bodies.
	2. Fungi.	Unicellular or multicellular organisms with no stem and leaf but a thallus. Found as moulds on decaying animal and vegetable matters, sometimes thick and massive. Never green, generally colourles but coloured in a few.
	3. Lichens.	Incrustations (thalloid) on rocks, barks, etc ; yellowish or colourless.
	4. Mosses.	Slender stem and leaves—green—no true roots—living in shade, on old walls, stones etc., and in moist places. The simplest Cormophyta.
	5. Ptridophyta.	Shade and moisture loving plants, completely segmented into stem and leaves—main stem generally not branched (Ferns) or branched at the apex or in whorls (Equisetums). Leaves bearing a large number of minute globular bodies or spores. This group includes the Ferns, Lycopods, Equisetums and Sellaginalla.

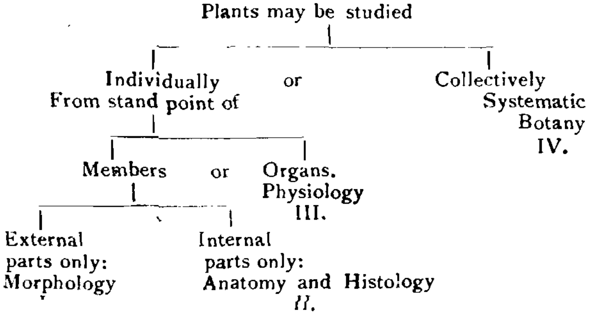
Gymnosperms.	6. **Conifers.**	Large stout trees with thin needle like leaves in dense clusters. Branching profuse, flowers very minute and very small and produced in profusion. Seeds naked.
	7. Cycads.	Palm-like trees with very large leaves and stout, thick and stunted stems, generally not branched. Flowers and seeds as in (6)
Angiosperms.	8. Monocots.	Unbranched trees or shrubs or small herbaceous plants with showy flowers in most cases. Members in floral whorls of three, Cotyledon one. Seeds within fruit. Ex. Palms. Grasses. Bamboo, Aroids etc. Leaves always parallel veined.
	9. Dicots.	The most conspicuous part of land flora—trees, shrubs or herbs with stem much branched. Leaves with a network of veins and small. Floral members, five or four in each whorl. Seeds within fruits. Cotyledons two. Ex. Mango, Guava, Litchi, Jack-fruit, Sal, Mahogany, Toon etc.

CLASSIFICATION OF PLANTS.





DEPARTMENTS OF BOTANY.



PART

MORPHOLOGY

EXTERNAL.

CHAPTER I.

The Root.

In Phanerogams the ripe seed contains the rudimentary plant, called the **Embryo**. The hard coat (testa) of the seed protects the embryo during the early stages of its existence, and food materials are stored usually along with it within the chamber of the seed. This nutritive material, known as albumen, forms generally the more prominent part of the seed-contents of Monocots, but in Dicots it is more frequently absorbed by the embryo, not unoften totally obliterated during this resting period of the initial plantlet. But as germination, that is, the awakening of the plant from its embryonal dormancy to a state of vegetative activity, starts, the testa is burst open, the embryo comes forth from its enclosure and eventually establishes its independent existence on the soil. And while most Monocot embryos remain but feebly differentiated, so that a naked-eye examination fails to detect anything more than a globular or tubular mass of tissue, lying by the side of a large albumen, Dicot embryos generally have their bodies segmented, even when they are within the seeds, into parts that correspond to the leaf and stem. Witness, for instance, the seed of the Mango, or the Pea, or the Tamarind. The embryo in these cases occupies the whole interior of the seeds. It is segmented into two large lobes, rather flat, but rounded on the outside and a little depressed on the inner surface, called the *cotyledons* or seed-leaves. (Fig. 1,*a*.) Between these, nestles the first bud of the plant, called *plumule* (Fig. 1,*c*) which, when traced downwards, is found to be organically united with a short, tapering, rod-like structure, from the apex of which roots arise later on. This part is known commonly as the *radicle* or the root-end of the embryo, but called more properly the *caulicle*, (diminutive of *caulis* = a stem). The axis of the embryo may be conveniently divided into two parts—the *hypocotyl* or the hypocotyledonary axis (Fig. 1,*d*), being that part which is between the radicle and the point of insertion of the cotyledons, and the *epicotyl* (Fig. 2, *e*), or the part above this point up to the plumule. On germination, the radicle protrudes, curves downwards vertically, avoids light and then penetrating the ground absorbs nourishment from the soil. Usually during these changes, the hypocotyl elongates, splits the seed-coat open, liberates the cotyledons from their dark bondage, and then growing vertically upwards enables them to open out in the air. The plumule, so long hemmed in, now grows vertically upwards and produces the new shoot.

FIG. 1. FIG. 2.

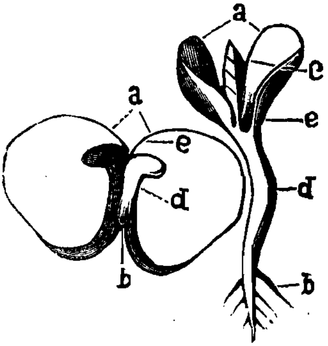


FIG. 3.

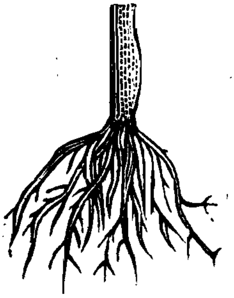


Fig. 1. Embryo of Pea cut open to show (*a*), the cotyledons; (*b*), the radicle; (*c*), the plumule and (*d*), the hypocotyl.

Fig. 2. Seedling of Bean (*a*), cotyledons; (*b*), the root: (*c*), the bud; (*d*), hypocotyl; and (*e*), the epicotyl.

Fig 3. Fibrous root of a Monocot.

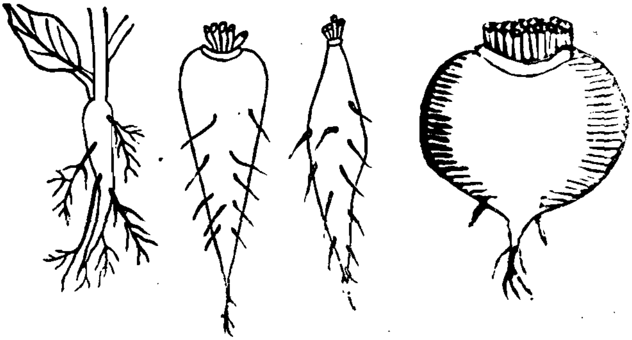
A fuller description of all the different ways in which seeds germinate will be found in a subsequent chapter. Enough, here, has been said to allow us to proceed with the morphology of

The Root.

It will be seen from the above that the downward prolongation of the radicle forms the root. The two most important functions that roots are required to carry out are, (1) the fixation of the whole plant in the soil, and (2) the absorption and transmission of nutriment from it. For this purpose, roots generally have to go deep into the soil or other substratum, but there are a few exceptional cases, where they remain simply suspended in the air. These functions, together with a few others of a sub-ordinate nature, coupled with the peculiar conditions of the substrata which plants are thrown upon to live in, necessitate the development of the root in various ways and forms. Thus we may distinguish between the Subterranean, Aerial, Parasitic, Climbing and Aquatic roots.

A. **Subterranean roots**—The direct downward prolongation of the radicular end of the axis of the embryo is called the *primary root.* It generally grows continuously in Dicots, and produces what are called *secondary* rootlets in acropetal succession, *i.e.*, the youngest nearest the apex, and the oldest, the furthest removed from it. Usually, however, the main or primary root develops more strongly than its secondary branches, and is then called a *Tap Root* (Fig 4). Such tap roots with their complex branch systems are characteristic of all Dicot trees and shrubs, and normally carry on the functions referred to above. In many herbs, however, they have to perform the additional function of storage of food materials prepared by the plants during the periods of active vegetation and they thus become modified accordingly. Three such, modifications of the tap root deserve special mention. These are :—

FIG. 4. FIG. 5. FIG. 6. FIG. 7.



Tap Root and its modifications—
Fig.4. : Tap Root with secondary branches ;
Fig. 5 : Conical ; Fig. 6 : Fusiform ;
Fig. 7 : Napiform.

1. *Conical*, (Fig. 5), when the tap root is wide at the base, and gradually tapers down at the lower extremity, as in our common Moola[1] *(Raphanus Sativus)*, Gajur (*Daucus Carota*) etc.

2. *Fusiform*, (Fig. 6), when it is swollen in the middle and gradually tapers towards the two ends, as in Punarnava[2] (*Boerhavia procumbens*), in Kat-bish or Mita,[3] (*Aconitum ferox*) etc.

3. *Napiform*, (Fig. 7), when it is much swollen at its upper part and tapers down suddenly to a somewhat thread-like structure, as in Beet Palung.

The above cases are examples of the modifications of the tap root when it is not branched. In many cases, however, the secondary rootlets grow more strongly than the primary

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[1] Sans. *Mooluka* ; Hind, *Moolea* ; Arab, *Fujl.* [2] Sans. *Shotughnee* Beng. *Swetpurnee.*

[3] Hind. *Sringi bish* ; Beng. *Mitha.*

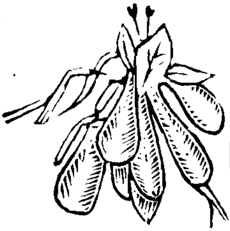
root, and they may again be thickened or rendered fleshy and succulent, or subdivided into a large number of tufted roots. Thus :—

1. *Fibrous roots* arise in tufts of long filiform structures from the radicular end of the axis, or from the lower surface of stems trailing on the ground, as in many Grasses. (Fig. 3)

2. *Fasciculate roots*: when some of the rootlets in the above case become thickened and fleshy by the deposit of reserve food-material, the root-system presents the appearance of a large number of tubercules, or enlargements, originating closely from a common point. A very good example is furnished by the Satamuli[4] (*Asparagus racemosa*), where the root system consists of a number of fusiform swollen tubers. The common Soosni-aloo (*Dioscorea fasciculata*) has also a similar root. Where the number of these fleshy rootlets is much reduced and the root consists of only one or two tubercules it is called

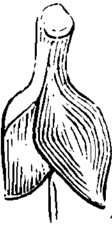
3. *Tubercular*, as in the Sakarkand-aloo—the red variety—(*Convolvulus Batatas*), Bhooi-kumra,[5] Dhol-somudra[6] (*Leea*

FIG. 8.



Fasciculate root of Satamuli.

FIG. 9.



Tubercular root of orchid.

FIG. 10.

Nodulose root.

FIG. 11.

Moniliform root.

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[4] Hind. *Satawar*. Tel. *Challa*. [5] Teling. *Matta-pal-tiga*. [6] Sans. *Sumoodruka*.

macrophylla), etc. In many Grasses, also, as in Mootha[7] *(Cyperus rotundus)* the fibrous roots form small tubercules of this nature. When the tubers are divided at their extremities into finger-like parts, they are called *palmate* tubers. Moreover, a root is called

4. *Nodulose*—when its branches enlarge into nodules towards the extremities ;

5. *Moniliform*—when it is alternately swollen and contracted, so as to present a necklace-like or beaded appearance.

Roots, when they do not originate from their normal place of origin *i.e.* the end of the radicle, are called ADVENTITIOUS roots. The primary root, as a rule, persists in most Dicots, but in many other cases, especially in Monocts, it soon perishes and then new roots spring from the lower part of the stem. In fact, plants may strike roots from any part of their surface,—and such roots are necessarily adventitious in their origin. Thus most Grasses trail over the ground for a considerable distance and regularly strike root from their lower surface. In the Cocoanut and other Palms, the lower part of the trunk is beset with a large number of adventitious roots that, arising from the stem, arch down and strike the ground, giving them the appearance of so many ropes tugging the plant on to the earth. In our Ketuky or Kea[8] (*Pandanus odoratissimus*) and the English Screw-pine, again, the trunk appears to be stilted up on long prop-like structures that are really adventitious roots. In our sacred Banyan trees, (Aswatha—*Ficus religiosa,* and the Bur or Baut—*Ficus Indica*), in proportion as the branches are developed the horizontally projecting boughs send down cylindrical roots which reach the ground, and becoming attached to it form pillars, supporting the whole leafy canopy. Moreover, it is a matter of common experience that cuttings from plants, planted in a moist

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[7] Sans. *Moosta, Moostuka.* Teling. *Shaka-tunga.*

[8] Sans. *Ketukv.* Hind. *Keura.* Teling. *Mugalik* or *Gozdoogoo.*

soil, send forth roots from their cut surfaces very easily and these are undoubtedly adventitious.

ANNUAL, BIENNIAL AND PERENNIAL ROOTS :—Quite a large number of plants live only through one season such, for example, as our Palung (*Beta bengalensis*), Panmouri[9] (*Anethum panmori*), Mustard (*Sinapis dichotoma*), Hatisoor[10] (*Heliotropium indicum*), and most Grasses. They come up in spring, unfold their vegetative body, and then die down after flowering and fruiting before the advent of the next spring, leaving to their seeds the charge of multiplying the species. The roots of such annuals are generally fibrous, and since for the short period of their existence, they do not require the storage of food in subterranean reservoirs, they are rarely tuberous or swollen. In biennial and perennial plants, it is quite otherwise. Biennials, or plants that have their term of life extended over two years or seasons, develop, during the first year, a very short stem and foliage leaves, and a strong thickened tap root (*e.g.* conical, fusiform or napiform) in which food for subsequent use is stored up during this period. In the second year, another erect shoot with leaves and flowers is developed and the fructification and the ripening of the seed go on at the expense of the food already reserved in the root, and then the whole plant together with the exhausted root dies down to the ground. In Kantikari (*Solanum jacquini*), Beet (*Beta Vulgaris*), Carrot (*Daucus Carota*), Moola, and in many plants having a tuberous root we get good examples of biennial roots. In perennials or plants that live from year to year, though their aerial parts annually die down, the roots when they serve for the reception of nutriment, are considerably thickened and modified. Thus the Sakarkund—alloo plant has a perennial tuberous root ; the Soosni-alloo plant (*Dioscorea fasciculata*), so much cultivated for its supply of starch, has a perennial fasciculated root system. The nodulose,

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[9] Sans. *Mudhurika*. [10] Sans. *Shreehustine*.

moniliform and the tuberous, are the different forms of such perennial roots.

B. **Aerial roots**. It will be noticed that the adventitious roots of the Ketuky, Palms, and Banyan trees are neither exclusively aerial, nor subterranean. But though the term aerial root embraces all such as are produced in the air, it particularly signifies those that, throughout life, remain unconnected with the ground. They are characteristics of the *Epiphytes* or air-plants—that is, those that grow upon the trunks of other plants without taking up any nutriment from their system. Necessarily, these roots have to absorb moisture and food from the cracks and crevices of the bark of the tree-trunks on which Epiphytes chance to live. Not unfrequently, however, the aerial roots of such Epiphytes resting on boughs of trees, hang in long ropes freely in the air from which they are enabled to absorb water, by the formation of a bibulous sheath called *velamen*, and gases, by the development of a green pigment in their superficial cells. A good example of an Epiphyte with its aerial roots is in *Vanda Roxburghi* known as Rasna in vernacular, and found wild on the common Mango tree. Vanda is an Orchid and most Epiphytes belong to the two families of Orchids and Bromelias, to which latter our Pine-apple belongs.

C. **Parasitic roots**. Another class of plants called *Parasites*, are known to live like the Epiphytes upon other plants but they are not mere platonic dwellers on them, but suck out from their tissue, at least, a part of the nourishment, by sending their roots that bore their way through to the interior of the latter which is hence called the host-plant. Thus, some parasites live wholly upon the *host* and do not consequently produce foliage. Others, again, produce foliage, only to a limited extent, and push their roots into the host to draw, at least, the supply of water they could otherwise nave got from the soil. The sucking roots, in the above cases, are called *haustoria*, and their peculiar nature enables them to form an organic connection between the host and the parasite. For example, the Algosy-lata[11] (*Cuscuta*), so very common in our hedges and trees, has its leafless, yellowish, tendrillar stem entwined in the leafy twigs, and wherever it comes in contact with the soft stem of the host, it produces processes which, dissolving the epidermis or skin of the latter, penetrate into it and unite with its conducting system of tissue. Manda[12] (*Loranthus bicolor*), another common parasite, is, on the other hand, provided with leaves. The root-parasite *Orobanche pendunculata* grows upon the roots of the Khus-khus plant. It is a very small plant which, as it springs from the root of the host and hence from the ground, simulates a nonparasitic plant. Rafflesia Arnoldi, a vegetable Titan of Sumatra, grows as a parasite upon the stem of a plant very near the ground. It has no leaf and no stem ; but the only evidence of the plant is given by the monster flowers—each measuring nine feet in circumference and weighing about sixteen pounds !

D. **Climbing roots.** The typical Climbing root is that which does not strike root in the ground, nor draws nourishment from the soil or atmosphere but merely serves as an organ for attaching the plant to supports—big plants or rocky surfaces or old walls.

The Guj-pippul[13] (*Pothos officinalis*), for example, has a perennial stem that creeps up to the top of large trees and thus takes a firm hold of the support with the innumerable roots which arise from the side of the stem next the support. *Hoya carnosa*, another climber on Palm trees, develops light-avoiding climbing roots which nestle in the substratum and uniting, adds to the security of the plant. Girdle-like clasping roots, tying plants on to the smooth surfaces of tall trees are commonly seen in Darjeeling, in the Himalayas and other hilly places. *Tecoma radicans*, an ornamental plant commonly

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[11] Teling, *Sitama-poorgooloo*, [12] Sans. *Vunda*, Teling. *Wadinika*.

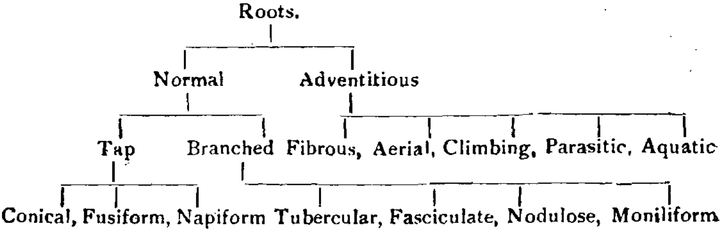
[13] Sans. *Kuri-pippulee*, *Kupi-vullee*, *Vushira* etc.

used to decorate portico-walls, clings to the latter by the formation of pale rootlets which appear as a fringe of threads seeking the creeks and crevices on the rough surface. These roots, also, are light-avoiding, and are formed as soon as the young stem with its burden of leaves, creeping over the wall, bends away from it owing to the weight it has to carry vertically upwards.

E. **Aquatic or floating roots** arise from the lower surface of floating stems. They are generally fibrous and to a slight extent twisted. In Pana or Takapana[14] (*Pistia*), commonly covering the surface of our ponds with a rich leafy verdure, such long, tapering, fibrous roots arise in clusters from the submerged stem of the plant.

The growing apex of the root is ordinarily protected by a cellular sheath called *Root-cap* (see p. 29). As the root has to push on one side hard grains of sand and other particles of earth, the root-cap is subjected to a great strain and is gradually brushed away; but it is always being supplemented and renewed by the growing tissue of the root just behind the cap. In aquatic roots and haustoria the root-caps are wanting. This is obviously connected with their function; for they do not require the protection afforded by the root-cap—its presence would, on the contrary, prevent the roots of parasites from penetrating into the tissue of the host.

The subjoined table gives a classified view of the different kinds of roots and may aid the student.



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[14] Sans. *Koombhica*. Teling. *Nuroo-boodhookee*.

CHAPTER II

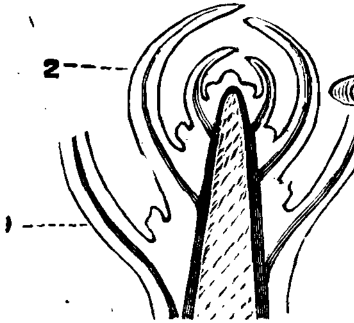
The Shoot.

Its origin.—It has already been seen that the plumule grows upwards and develops into the shoot. The shoot is essentially the ascending part of the axis, and, though, in many cases, it deviates from this vertical position, even becoming subterranean in some, this character forms one of its distinguishing features. For, as the root is the descending axis of the plant, its shoot forms the ascending axis. It may be instructive, here, to note the points of

Distinction between the shoot and the root:--In the first place, the completely developed shoot, which is usually differentiated into the stem and the leaf, grows continuously at its apex (the growing point, or *punctum vegetationis*), where it remains entirely unprotected by any other foreign tissue. In roots, however, the apex is always protected by a cellular mantle called the *root-cap*. For roots arise from within the tissue of plants—the primary from the radicle, the secondary from the primary, and the adventitious from the stem—and carrying, in their further progress of development and elongation, the torn piece of tissue of that part from which it springs, it retains it in the form of a sheath; this sheath protects its delicate growing point, as the root bores its way through the soil.

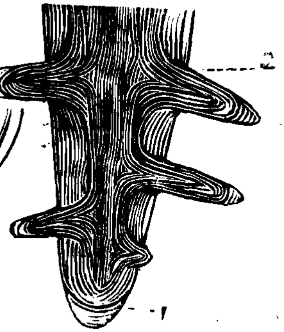
If a vertical median section through the growing point of a stem be magnified and examined, there can be observed a number of small conical bulgings on the two sides of what will appear to be an almost undifferentiated mass of a central tissue, which really represents the main axis of the stem. Lower down, these bulgings attain a larger size, the further removed they are from the apex, and become more and more elongated. These elongated structures thus coming out from the surface of the main axis, and each superposed on the one next above it, are the rudimentary leaves; and these, enveloping the more rudimentary ones and over-arching the growing point, form a rather compact structure, called the Bud. Buds are the potential shoots, and the plumule is the first bud of the plant. When a bud unfolds, it grows out into a leafy twig; and, as the leaves originate primarily as outgrowths from the parent shoot on its surface, they are said to have an *exogenous* origin. Roots, on the other hand, always arise *endogenously*, *i.e.* from within the tissue of the parent. In the diagram, fig. 13., the secondary rootlets are shown to originate

FIG. 12.



Apex of a Phanerogamic Shoot—showing the leaves overlapping, with the buds at the base of each. Development—exogenous.

FIG. 13.



Apex of a Phanerogamic Root—showing root-cap and the endogenous origin of the secondary lateral rootlets also provided with cap.

from within the main axis of the primary root, and the superficial tissue of the latter being eventually pierced through and torn away, forms the root cap. By referring to fig. 12, again, it will be observed that smaller protuberances also arise at the base or axil of the bigger bud leaves. These, when fully developed, show up to be shoots as well, and hence are also buds. Now, buds, whether arising from the axil of the leaves, or terminal, are normally produced by the shoot, while they are rarely, if ever, produced by roots. To sum up, the root differs from the shoot in the following points :—

1. The root is always protected by a root-cap ; the shoot, is entirely unprotected at the apex.

2. The root grows behind the root-cap and endogenously ; the shoot grows exogenously.

3. Buds and leaves are normally formed on the shoot ; they are never formed normally on the root.

4. The root is essentially the descending part of the axis, the shoot is the ascending.

5. The root is never green, except in a few cases (see Epiphytes) ; the shoot is normally green.

As has already been observed, shoots or leafy branches normally arise from buds, but sometimes abnormally from wounded plant-surfaces, or old tree-trunks. Such shoots are called *adventitious*, and always originate endogenously.

Buds generally produce an elongated shoot, which is outwardly differentiated into a central axis or stem and the leaves. The points from which leaves spring on the stem are called *Nodes*, and the space between two successive nodes is called an *Inter-node*. In the great majority of land plants *Inter-nodes* are rather well developed, but, in a few others the vertical growth of the stem is suppressed, at least, at certain points ; these dwarf shoots naturally leave little space for their leaves to remain otherwise than close together. Yet, again, in some water plants, *e.g.* the common Pana or Takapana[1] (*Pistia*) of our ponds, and in a few of our annual and

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[1] Sans. *Koombhica.* Teling. *Neeroo boodooked.*

biennial plants, *e.g.* Chandramoolika *(Kæmpferia Galanga)* Bhooi-champa *(Kæmpferia rotunda)* Sookh-Darshan *(Crinum asiaticum)* and the common Kutchoo or Kochu *(Colocasia antiquorum)*, this non-development of the internodes is carried so far as to produce no aerial vegetative stem at all, at least for some period, while a large number of leaves are spread out on the ground, originating apparently from the root. Such stemless plants are called *acaulescent* (*a*, privative, *caulis*—stem).

We shall next study the stem with regard to—

A. its shape ;

B. its position—whether upright or bent ;

C. its modifications and kinds.

A. **The general shape** of the stem is roundish, *i.e.* a transverse section through it presents a more or less circular outline. But it is

1. Triangular, in many Grasses; for example, in Kessoor *(Sicrpus kysoor)*, Mootha *(Cyperus rotundus)* etc., and in Tekata-shij (*Euphorbium antiquorum*).

2. Square, in the whole family of plants known as Labiatæ, to which our Toolsi (*Ocymum sanctum*) and the aromatic plant Podina (*Mentha viridis*), belong; in the fleshy succulent stems of Harjoora (*Cissus quadrangularis*); in the common medicinal Kalmegh[2] (*Justicia paniculata*) and Bakash (*Justicia adhatoda*); in the Gandha-bandhuli (*Oldenlándia paniculata*); in the young shoots of the well known Sephalika or Seuli[3] (*Nyctanthes arbor-tristis*) etc.

3. Hollow, in the internodes of many Grasses and Bamboo.

4. Flat, in many species of Cactus as in the Nag-phanee (*Cactus indica*) used as a fencing and in Coccoloba (Fig. 14).

5. Ribbed, in many plants of the Cucumber family, such as

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[2] Sans. *Maha-tita.* Teling. *Nella-vemgoo* ; *Kreat.*

[3] Sans. Hind. and Beng:—*Singahar, Nibari, Harsinghar, Sewli.*

Patol or Pulwul (*Trichosanthes diœca*) where it is five-ribbed, Turbooj,[4] Kumra[5] (Cucurbita), Sosha,[6] Makal[7] (Cucumis) etc.

6. Globular, or round, as in the African Melon-cactus.

FIG. 14.

FIG. 15.

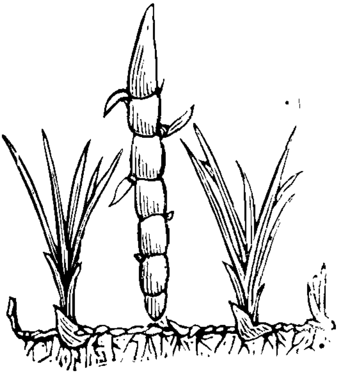

Fig. 14. Flattened stem of Coccoloba.
Fig. 15. Creeping Rhizome of Carex.

B. As regards position, the stem of big plants is generally erect, but three kinds of erect stems have received specific names. These are :—

1. *The Caudex.* It is the technical name applied to the unbranched stem of Palms. The whole surface of the caudex is marked with the circular scars of dead old leaves, which have been cast off, and is armed in some cases with scales—the remnant of former leaf-stalks.

2. *The Culm.* It is the closely-jointed stem peculiar to Grasses and Sedges. It also is unbranched and the lower part, quite free from leaves and hence smooth, as in the Bamboo and the Sugar-cane.

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[4] Hind and Beng. *Turmooj* or *Turbooj*

[5] Hind.-*Hanhora.* Teling. *Koorda-goomoodoo.*

[6] Hind. *Kheera.* [7] Teling. *Sheti-putsa,*

3. *The Scape.* It is a flowering stem without foliage, arising from the ground. In the acaulescent Chandra-mullica. (*Kampferia Galanga*), Bhooi-champa (*K. rotunda*) and Kutchoo, the flowers are borne on scapes which elevate them but little above the ground. But in Sookha-darshan (*Crinum asiaticum*), Rajanee-Gundha (*Polyanthes tuberosa*), in Onion (*Allium cepa*) the long scapes bear clusters of flowers above the ground on which are spread the radical leaves.

The indigenous plant Agave Americana (A. Cantula, Rox.), commonly growing in hedges and sandy places, is acaulescent during the early vegetative period, the whole plant being only a dense cluster of very large boat-shaped leaves. Gradually, however, a thick scape rises up in the air, and finally reaches a height of 25-35 feet, when it looks like a widely-branched mast of a ship. It is very commonly seen in out-of-the-way places in Behar and Upper India.

Three terms, Trees, Herbs and Shrubs, apart from the popular sense in which they are used, have acquired a Botanical significance. Thus :—

Trees are woody plants, with a clear trunk denuded of branches at their lower part, which attain a great height and live for a long period.

Shrubs are woody plants, with a rather profuse branch system arising from the main central axis at or near the ground, and are of a bushy nature. Their duration of life may be equal to that of trees, but is generally much less.

Herbs are plants which are not woody, not persistent, which do not live for a long time, are generally of a soft and succulent nature, and die down to the ground at least, annually or after flowering and fruiting. They are called annual, biennial, and perennial, according as their term of existence is limited to one, two, or many years, or seasons.

In general, the stem is erect and rigid, but many are not strong enough to maintain their upright form. Thus, stems may be :—

1. *Procumbent or Prostrate,* when they trail over the ground ;

2. *Decumbent*, when they tend to rise upwards at their free ends, after having trailed for some distance ;

3. *Climbing*, when they cling to neighbouring supports. Climbing plants make use of a variety of structures as organs for climbing. Thus there are

FIG. 16.

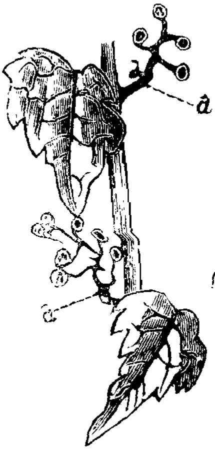

FIG. 17.

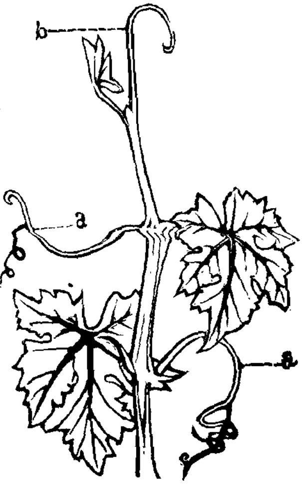

Fig. 16. Branches modified into tendrils (a) the discs adhering to stony, surfaces—of a species of Vine.

Fig. 17, Shoot of Grape-Vine : b, the main axis modified into a tendril which becomes displaced laterally (a, a) by the strong growth of axillary branches—thus producing a Sympodium.

(*a*) *Twiners* or *twining plants*, *i.e.* those which ascend by coiling their stems round supports afforded by the not too thick stocks and branches of neighbouring plants. Twiners are called *dextrorse*. when they make a clockwise movement *i.e.* from the left to the right as in many Dioscoreacæ[8] ; and *sinistrorse,* when the movement is anti-clockwise or from right to left, as in many Convolvulus[9] (Dood kalmi, Bhoomi-kumra), Bun-barbatty[10] (*Phaseolus alatus*), Shim[11] (*Dolichos*) plants, as well as in Eswar-mula[12] (*Aristolochia indica*), and in many others.

(*b*) *Hook climbers, i.e.* where the climbing organs are hook-like structures, as in the Kantali-champa (*Michelia champaca*).

(*c*) *Root climbers, i.e.* those which like the *Guj-pippul*[13] (see Climbing roots) and *Hoya carnosa*, climb by means of ærial roots and thus remain anchored on the supporting substratum.

(*d*) *Tendril climbers, i. e.* where a number of filiform delicate structures, capable of spontaneously coiling round supports, is formed, as in the common Gourd, Cucumber, the Jhumko-lota (Passion-flower plant—Passiflora) and many other plants belonging to the same families.

(*e*) *Leaf climbers,* (Fig. 86) or those where the leaf or specially some part of it is adapted to climbing. In Ulat-chandal[14] (*Gloriosa superba,* Fig. 73) and in the Bun-chandal[15] (*Flagellaria indica*) the midrib of the leaves becomes drawn out into the form of a tendril which tugs the plants on to supports. In the Mossoor (*Lathyrus Aphaca*) and Khesari (*L. sativus*), the leaf becomes tendrillar, while the stipules (see p.   ) are modified into leaf-like expansions.

C. Kinds and Modifications of the Stem or shoot. The main stem or axis of the plant that, having developed from the germinating seedling, remains erect and maintains its

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8. Beng. *Kam-aloo, Chupree-aloo, Soosni-aloo.* Teling. *Ava-tenga-tiga, katsji-kelengu.* 9. Beng. *Bhoomikumra,* Teling. *Mattapal-tiga* Beng. *Doodkalmi,* Sans. *Synonyma.* Teling. *Tella-tagada.* 10. Teling. *Kar-alsanda.* 11 Teling. *Chikurkai.* 12 *Ishermool* or Teling. *Isaro.* 13. ***Pothos Officinalis.*** 14. Sans. *Eesha-langula.* Hind. *Cariari.* 15. Hind. *Harcharrul* Teling. ***Poindee poctee.***

upright position, is called the primary axis or stem, as opposed to the secondary and other branches of higher orders. It is often more strongly developed than the lateral axes ; but it may also happen that, the primary shoot itself being arrested in its growth, secondary and other branches, that originate from it, develop more vigorously, and, ultimately supplanting it, make it quite nugatory. Hence, the non-development of the internodes, the too strong development of the branches, and other functional causes may operate to bring about modifications in the form of the shoot or the stem. It should be remembered, that the chief function of the stem is to drag along with it the green foliage which alone can prepare nourishment for the plant, provided the sun and the air and other environmental agencies are brought to bear their full influence upon it. But, as in the case of roots, so here too, functions may change and functions may multiply, and the same stem, which is busy with one function at one part, may be called upon to perform another at a distant part. Thus, there is rarely any plant in which the stem is developed uniformly from the base to the apex. In all ordinary cases, it is quite possible to distinguish, in the plant body, stories one above the other, each of which is modified in accordance with the function it has to perform.

Three such stories can be often distinguished in many plants ; namely the leaf-scale region, or the underground part of the stem bearing, as it does, scaly leaves ; the foliage region or the aerial vegetative shoot ; and the floral region, or that of the reproductive organs. It will be more convenient, however, to discuss the modifications and kinds of the stem as under :

First, the subterranean stem, and
Secondly, the aerial stem.

FIG. 18

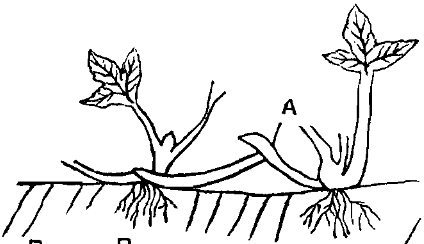

FIG. 19

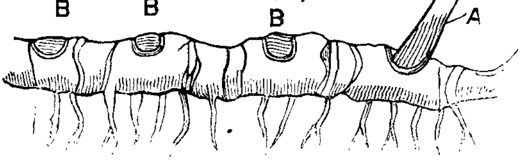

Fig. 18. A Stolon. A, the point of separation of the young plant (to the left) from the parent (right).

Fig 19. A fleshy Rhizome. B, the scars of former aerial shoots ; A, the present shoot ; to the right, the advancing growing tip.

I. **The Subterranean Modifications** of the stem or the shoot.

1. **The Rhizome** or Rootstock is a horizontally or obliquely growing perennial stem, that either trails on the surface of the ground, or more commonly lies buried in it, and sends out shoots from its upper and roots from its lower surface in contact with the ground, at definite points (nodes). That it is a stem is clearly borne out by the following considerations :—

(*a*). Its anatomical structure corresponds to that of the stem and not the root.

(*b*). Its apex is always naked and it grows exogenously.

(*c*). Its surface is covered with small scale leaves from the axils of which leafy shoots are thrown up periodically from the axillary buds.

(*d*). The nodes and internodes that are clearly marked out on its surface are never found on roots.

Grasses generally trail above or below the ground before they develop a vertical foliage shoot. The trailing scaly-stems of such Grasses are rhizomes (Fig. 15). Rhizomes are frequently very well developed in herbs, especially in those that are perennials. In them, though the aerial stems die down periodically, yet the main stem remains perfectly uninjured below the ground, storing, like a cellar, all the nourishment that will be required by the next leafy shoot to be sent up in the air. Thus, in contrast to the rhizomes of Grasses, which are thin and delicate, there are thick rhizomes as well. Examples of fleshy rhizomes are found in the Man-kutchoo (*Arum maculatum*), in the common Ginger and Turmeric, in Dulal-champa (*Hedychium coronarium*), in Banana etc. Generally in such fleshy rootstocks, and rarely in the thinner ones, there are found circular impressed scars on the upper surface, which represent the places from which aerial shoots, since dead, took their origin, and with their death, have left each a permanent seal on the still active stock growing horizontally at the apex. Fig. 19.

FIG. 20.

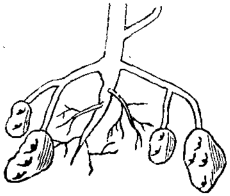

FIG. 21.

FIG. 22.

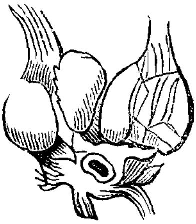

Fig. 20. Potato plant with Tubers.
Fig. 21. Onion Bulb with two axillary buds.
Fig. 22. Corm, a daughter corm developing from the parent.

2. **The Tuber.** It is an under-ground stem, which having been gorged with the deposition of food-materials, has become

globular at a certain part of the underground branch, the rest of which remains slender. In the Potato thin, filiform stolons (P. 42) are formed under-ground, and the extremity of such a stoloniferous branch becomes swollen into a fleshy mass—the tuber. What are called the *eyes* of the tuber are really axillary buds, hid in the axils of small scale-leaves originating from the nodes. These *eyes* or buds develop into new plants when the tuber is placed in the soil under proper conditions, at the expense of food-materials already stored in the thickened stem. The scale-leaves of the tuber with their axillary buds, fasten upon it the cauline character, and the absence of an advancing growing point, of the annular cicatrices, of the adventitious roots coming out from the lower surface, combined with its rather globular or fusiform shape, at once distinguishes it from the rhizome. The number of internodes involved, as can be told by noting the scales, may be many or only a few. In some species of the Lotus and Water Lilies, a single internode becomes thickened out into a tuber, but in Potato and in some Ginger-plants growing wild, several internodes are concerned. Fig. 20.

3. **The Corm.** Imagine a fleshy rhizome strongly condensed into a flat, rounded mass of tissue where the nodes are still less distinct than in the case of the tuber, and we come to the corm. It is a fleshy subterranean stem—rounded, solid, flat and depressed, from the upper surface of which shoots are given out, and from the lower, roots in filiform bunches are adventitiously developed, as in the case of the rhizome. In our Oal[16] (*Arum campanulatum*) and Kutchoo,[17] we get good examples. In these cases small daughter-corms are also found attached to the main body—they are formed from the small buds on the sides of the primary corm, and each of them is as true a corm as the parent from which it springs.

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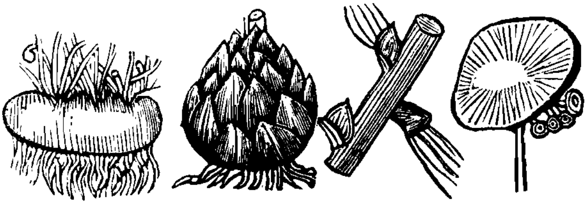
[16] Teling. *Manchi kunda.* Sans. *Kunda* or *kulla.*

[17] Teling. *Chama-kura.*

In Bish-kuchoo (*Calla*) the sheathing bases of a few foliag leaves enclose the corm with a membranous covering and thu the corm approaches

FIG. 23. FIG. 24. FIG. 25. FIG. 26.



Subterranean (Figs. 23, 24) and Aerial modifications of the shoot.

Fig. 23. Corm of Oal (Arum campanulatum .

Fig. 24. Scaly bulb of Lily.

Fig. 25. Bulbils from axil of leaves.

Fig. 26. Cladode of Lemna.

4. **The Bulb.** Imagine, again, the internodes of a rhizome so far reduced as to produce a flat circular plate of tissue from the upper surface of which scale-leaves arise in compact clusters. The stem becoming much too abbreviated to store food materials, the scale leaves afford room for the latter, and thus, become fleshy and thickened. In the common Onion and Garlic, for example, the abbreviated stem remains flat on the ground, and produces a cluster of fibrous roots from its lower, and a pack of fleshy leaves with axillary buds, on the upper surface. If, as in the above cases, the bulb be composed of leaves, with the inner ones disposed concentrically, and a few outer, completely investing the latter and remaining membranous and scaly, it is called a *tunicated* bulb, Fig. 21. But in many Lilies the bulbs are composed of fleshy leaves that merely overlap each other—such bulbs are called *scaly* bulbs, Fig. 24. In Saffron (Beng : Jafran—*Crocus sativus*) and in Rajani-Gandha the bulbs are tunicated.

II. Modifications and kinds of the aerial stem or shoot.

1. **The Sucker :**—it is a branch that, arising from the main stem under ground, ascends into the air after having trailed below the ground for a short distance, and giving out roots from the lower part of its trailing body establishes an independent connection with the ground. The Rose plant, for example, is a cluster of branches, all coming out from within a small circle of the soil. Now, the seedling could not normally have sent more than one shoot up in the air, and the explanation of so many stems arising from the ground, lies in the fact that the main axis of the plant is not sent vertically up in the air, but that it trails under the ground for some distance, sending up at the same time vertical branches from its nodes. It is common in many small woody plants.

FIG. 27. FIG. 28. FIG. 29.

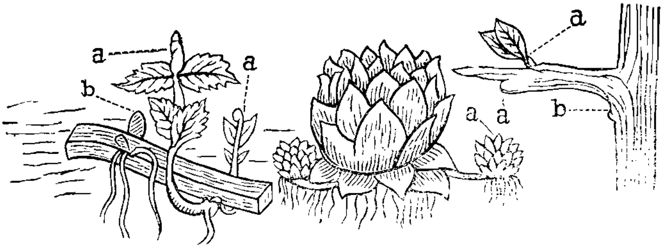


Fig. 27. Sucker of Mint ; *a*, the aerial shoots ; *b*, a bud.
Fig 28. Offset, Fig. 29. Thorn ; *a*, buds of which the upper one has unfolded and the lower has become abortive ; *b*, the scar left by the fall of the subtending leaf.

2. **The Stolon** is similar to the above, differing from it in the medium in which it arises. It is a branch which originates from the lower part of the main axis just above the ground, curves downwards towards the soil, trails over or burrows through it, and then, striking root, rises up again as an upright shoot. It eventually becomes independent and separated from the parent by the disorganisation of the part

of the bent stem that forms the conecting link. (Fig. 18, A.) Two kinds of stolons have received substantive names. These are :—

3. **The Runner.** It is a filiform slender branch, which touches the ground after arching over it and forms a bud at the tip where it strikes root, and then produces a new plant which, in its turn, sends out a similar filiform branch which again arches over, strikes root at the tip, and so the plant runs, as it were, on the ground by means of its branches. The best examples are in the Amrul-shak[18] (*Oxalis pussilla*) and in Thulkuri (*Hydrocotyle asiatica*), common creeping plants that delight in moist shady places.

FIG. 30.

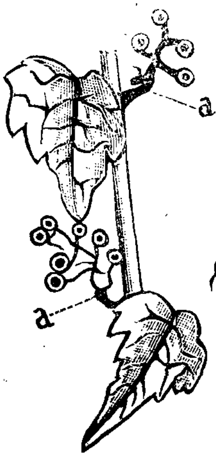


FIG. 31.

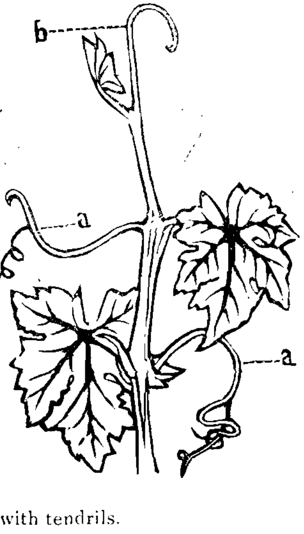


Fig. 30. Shoot of Ampelopsis with tendrils.

Fig. 31. Terminal shoot of Vitis vinifera (Grape vine) with the terminal tendrils which become displaced laterally on the sympodial axis.

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[18] Sans. *Amlulonica, chukrika.*

4. **The Offset.** It is a very short or condensed stolon and not unoften a sucker. Imagine a runner modified into a thick and succulent structure, with the running branches transformed into dwarfs of stunted growth, with a load of tufted leaves at the free end, and we get a good idea of the Offset. It is a short, prostrate, thickened branch which behaves exactly like a runner. Example :—Looniya or Noonia-shak [19] (*Potulaca meridiana*), a common pot-herb with rosettes of succulent leaves.

In the above four cases of modifications, the external characters of the shoot are preserved well enough, but there are others where all vestige of the outward semblance of the shoot or stem is lost. In these, the nodes, the leaves, and the branches, the presence of which on a plant-member points to its cauline nature, are not usually traceable.

5. **The Tendril.** It is a filiform, leafless stem or branch, capable of coiling round supports, and helping plants in climbing. It has been shewn already, how for this purpose plants call upon various members—root, shoot, leaf, etc,—so to become modified as to subserve this special function. Those of such climbing structures, that grow from the axils of leaves, are cauline and so must be taken as modified branches. In the Cucurbita or Cucumber family of plants and in the Jhumkolota [20], we get very fine examples of such axillary tendrils. But in some cases, the primary shoot itself becomes metamorphosed into a tendril, and when this happens, the tendrillar shoot is pushed on one side to take up a position on the stem opposite to the base of the leaves, from the axils of which buds develop into branches. These branches growing more strongly displace the tendrillar axis, grow erect instead of being slanting, continue the prolongation of the axis in the vertical direction, and thus give rise to a false axis (sympodium)

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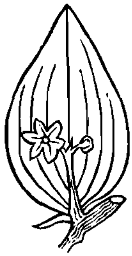
[19] Teling. *Pail kura.*

[20]. The Passion flower plant.

(see Fig. 31). That this is so is rendered intelligible from the fact that, the terminal part of the shoot just above the youngest leaf is a tendril. The best example of this case is in the Angoor (Grape-Vine—*Vitis Vinifera*).

6. **The Thorn** is a bud, whether terminal or axillary, which having become arrested in growth forms an indurated, hard, leafless structure, drawn out to an acute point. It may be branched or not branched, but in either case is homologous with the stem. Its stem-nature is recognised by referring to its internal structure or its position on the main axis and by the fact that, though terminal in some cases it bears lateral buds. In fig. 29, the thorn represents an axillary branch which has become hard and pointed at the apex but has also produced a leafy bud lower down (a). Examples, in the Bael or Billva[21] (*Aegle Marmelos*), Karamcha [22] (*Carissa Carandas*), Dalim [23] (*Punica granatum*) etc. Thorns characterise the flora of deserts where the joint tyranny of sun and wind renders it impossible for the stem to develop soft, delicate and green foliage.

FIG. 32. FIG. 33.



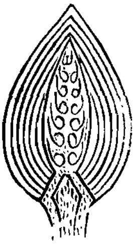


Fig. 32. Cladode of Ruscus with a flower in the centre of the flattened branch.

Fig. 33 Diagramatic Section through a Bud.

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[21] Sans *Bilva* ; Teling. *Maredoo* ; Tamil. *Willa marvum*,

[22] Sans. *Krishna-pakphula* ; Teling, *Waaka* ; Tamil. *Kalaaha*.

[23] Sans. *Darimbo* ; Hind. *Anar*, *Goolanar*.

Of all similar needle-like structures, i.e. spines, bristles, and thorns, only the latter are modified stems. Bristles are mere superficial outgrowths, while spines are modified leaves or parts of leaves.

7. Still another kind of metamorphosed stem is the **Cladode** or **Phylloclade**, where the stem, having become flattened, serves the purpose of foliage. In a few cases, only parts of the stem and branches become leaf-like in apearance, as in Ruscus (Butcher's Broom). In fig. 32 such a Cladode of Ruscus is shewn. It is only a branch modified into the form of a leaf. Its stem-character is evidenced by the presence of small flowers in the centre of the leafy expansion. In Lemna and Pistia (Pana), on the otherhand, the main part of the shoot is reduced to a flat, green, floating, leaf-like structure ; and from the lower surface of this a delicate, filiform stem is supended in the water (see Fig 26). Again, in Asparagus (Satamuli) the branches are green needle-like phylloclades. Massive leaf-like expansions of the stem form the peculiar feature of many plants which have their natural habitat in deserts, or in hot and dry situations ; such, for examples, are many Cactuses (*Cactus indica*, the Nag-phanee of Bengal), Coccoloba (Fig. 14) and Euphorbias (Tekata-shij). In the latter, the axis and branches of the plant present the appearance of so many winged columns, triangular in section, and are armed with double spines at the protuberances of the angles. In Nag-phanee, the plant-body is composed of a proliferously jointed mass of flattened branches, from the surface of which arise numbers of spines and thorns in clusters.

Buds.

The Bud, as has already been observed, is a condensed or rather undeveloped shoot. At the apex of the main axis and of all the branches, the stem terminates in a cluster of small leaves which envelop the young bud and protect it. (Fig. 33). These leaves are scaly, membranous and generally provided with hairs which secrete a resinous or gummy matter. These scales or cataphyllary leaves as they are called, are particularly noticeable in the buds of temperate and cold climates where the rigour of winter has to be warded off. Buds thus protected by leathery or hairy scales are called *scaly*, in contrast to the ordinary *naked* buds of mild tropical countries where the rainfall is evenly distributed, and of herbaceous plants which do not pass through the winter. Where, however, the tropical heat is very great, similar protective expediencies are found covering the bud.

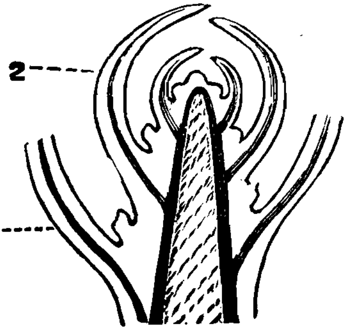
The young bud is composed of (Fig. 34):—

1. The soft, undifferentiated growing point of the stem ;
2. The rudimentary leaves overlapping one another and over-arching the main tip ;
3. The rudimentary buds at the axils of the lower bud-leaves.

The bud which lies at the apex of the shoot is a *terminal* bud ; the terminations of branches or the rudimentary shoots that arise in the axils of leaves are called *lateral buds*. The position of lateral buds is closely related to that of leaves ; for though in many Ferns, buds arise immediately below and by the side of leaves, in Phanerogams, as a rule, they are developed normally in the axils of leaves. Typically buds are formed in the axil of every leaf, exceptions being the leaves of flowers and those of Gymnosperms.

There are many plants in which the terminal buds of the year's growth regularly die; in many others, on the contrary, the buds of the first year's growth remain quite undeveloped even during a number of years without losing their vitality, and then, suddenly unfold into leafy twigs after the lapse of a considerable number of years. These are termed *dormant buds*. Often, at the base of large trees, and originating from the main trunk, quite a large number of leafy shoots can be seen growing luxuriantly up, in the vertical direction, giving the hard and rough tree-trunk a very gay and pleasant appearance. These are undoubtedly the fully-developed dormant buds. Dormant buds are liable to be too readily mistaken for *adventitious buds*, for both apparently originate from anomalous places on the stem-surface. But buds are called adventitious, when they appear contrary to the usual order, at indefinite points, unconnected with the axils of leaves and may be endogenous in origin. They appear readily in detached leaves of Bryophyllum (Pathur-kuchi) and some Begonias, particularly in the incisions of the margin.

(FIG. 34).



Two specially metamorphosed buds—*Bulbils* and *Gemmae*, play a very important part in the reproduction of plants in which they occur. They are stem-buds which detach themselves from the parent and can give rise to new individuals. Like seeds, they are always well supplied with nutritive materials. Bulbils occur frequently in some Monocots, particularly in *Dioscoreaceæ* and Liliaceæ. *Globba bulbifera* (Condapooshpa), a common pretty herbaceous plant of Bengal and Madras, has a large number of such bulbils in the axils of leaves, situated a little below the true floral region of the stem. Gemmae occur only in some Bryophyta *e.g.* in the Hepaticeæ.

Branching.

The three most important parts into which a Cormophyte is differentiated or segmented are the root, the stem and the leaf, to one or other of which all other plant-parts may be referred. The various members and organs of a plant may be reduced to these types. New and dissimilar members may arise from

FIG. 35. FIG. 36, FIG. 37.

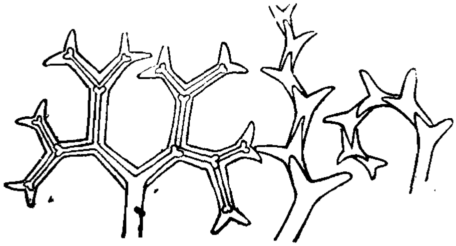


Fig. 35-37 Dichotomous branching.

Fig. 35. Bifurcate system or the normal dichotomous branching ; the lateral branches are developed in a forked manner.

Fig. 36 Diagram of Scorpioid dichotomy : the left branch of the first fork only branches again and then the right one of the second fork and so on.

Fig. 37. Diagram of Helicoid dichotomy ; the successive branches branch again only on one side i.e. on the left.

either the root, the stem or the leaf, but similar members always arise normally by the process called *Branching*. Thus roots may produce roots, shoots may give rise to other shoots and so on. It will be evident that in the building up of a plant-body branching plays an essential part—and it is only with the normal mode of branching that we are concerned here, adventitious branching being of a nature too ill-defined to require a strict scientific consideration.

All branching is really only terminal ; for branches first arise at the terminal part of an axis. There are three important modes in which branch-systems may arise :—

1. **Dichotomous,** in which there is a cessation of growth at the apex which becomes split up into two parts—two new apices, which continue the growth at the two new directions. (See figs. 35-37). The member (or stem) which bears the branches is called the *podium* and each of these new branches may become the base or foot of a new dichotomy. When the two lateral members of this branch-system grow with equal vigour, the branching is distinctly *bifurcate*, It occurs only in Thallophyta. More generally, however, one of the two branches grows more strongly and at the expense of the other, and when this happens the bifurcate character is apparently lost. (See figs. 36, 37). In this way a sympodium (*syn*, with, *podos*, a foot) results, when the successive branching members, owing to their comparatively stronger growth, become almost straight and displace the weaker and unbranched members as lateral appendages. Fig. 37 represents diagrammatically the simplest form of a dichotomous branch system where the branching members are all on one side of the main axis—it may straighten itself and simulate an elongated shoot. Owing to its essentially coiled nature it is called *Helicoid Dichotomy*. When the members branch alternately to the right and left of successive dichotomies, as in fig. 36, it is called *Scorpioid* or *Cincinnal dichotomy*. It is

he characteristic mode of branching in most Pteridophyta, *.g.* Selaginellas and Lycopods.

FIG. 38.

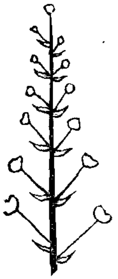
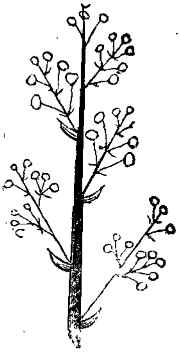


FIG. 39.



Racemose or Monopodial Branching.

Fig. 38. Diagram of a monopodial branching ; the main axis of the plant grows continuously at the top and the secondary branches are thrown out in acropetal succession.

Fig. 39. Diagram of the same with the branches again branched ; all the branches follow the same law of development.

2. **Racemose,** in which the main axis grows continuously t the apex while lateral structures of a like kind are produced beneath it in acropetal succession, from the lateral or axillary uds. The main stem is called a *Monopodium* because it is the ommon foot or base of all the other lateral branches. In uch a system, every lateral branch may again branch in the ame manner, and thus give rise to secondary monopodiums. *It is seen very clearly in the stem of Pines and other Conifers,* s also in the majority of Phanerogamic plants.

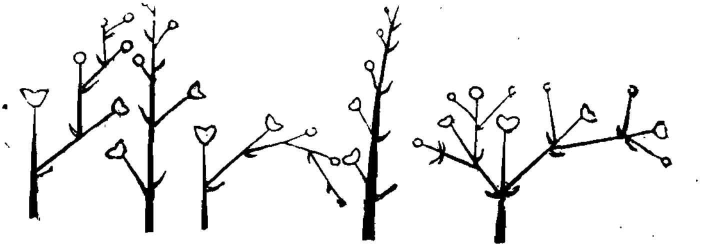
3. **Cymose,** in which the vertical elongation of the main xis is arrested soon after the development of the lateral branches of the first order. These then grow more vigorously han the parent stem and produce branches in more profusion, r in the same manner as the parent. The branch system is

called a *Cyme*, of which there are two principal forms, according as a false-axis (Pseud-axis) or Sympodium is formed or not :—

(*a*). When two, three, or more lateral shoots arise beneath the growing point of the main axis, which develop in different directions more strongly than the parent axis, the growth of which soon ceases, an apparent Dichotomy or Trichotomy or Polytomy results. When there are two lateral branches in such a cymose system it is called a *Dichasium* ; when many, a *Polychasium*. Fig. 44 gives the diagram of a dichasial cyme.

(*b*). When, as shown in diagrams, (Figs. 40-43), one lateral shoot always develops with geater vigour than the parent, a sympodium results. A symopodial system when growing strongly appears like a primary shoot with lateral branches, the

FIG. 40 FIG. 41 FIG. 42 FIG. 43 FIG. 44.



Diagrams of Cymose Branching.

Fig. 40 Scorpioid Sympodium; the branches are developed on alternate sides of the axes, the 1st branch being to the right, the second arising from it to the left and so on.

Fig. 41, The same after it has straightened. The lateral branches are really the terminal part of the different axes in Fig. 40.

Fig. 42, Helcoid Sympodium ; branches developed all on one side.

Fig. 43. The same after straightening. In Figs. 41 and 43, observe the position of the branches—opposite to and not in the axil of the leaves. This is the criterion of a Sympodium.

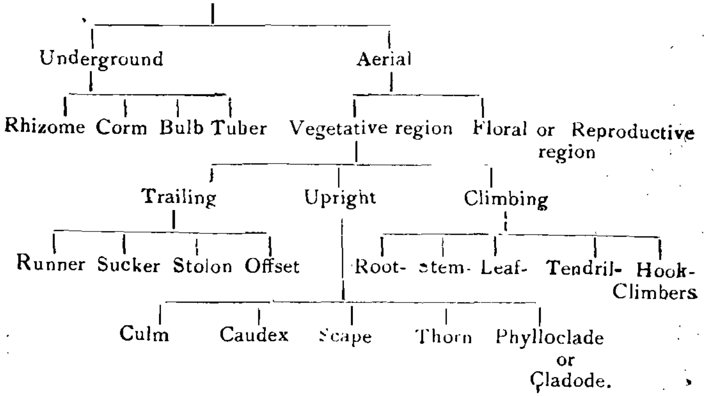
Fig. 44. A Dichasial Cyme. This is not Sympodium.

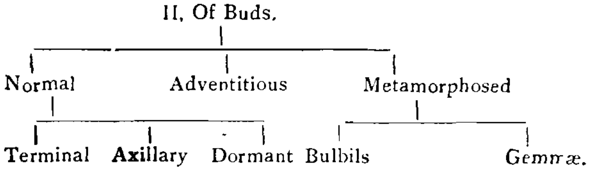
true character of which becomes difficult to be understood in the case of stout thick stems with no leaves on their surface ; but where, on the other hand, the stem is young and the leaves proper to it are present, the sympodial character becomes clear beyond doubt, from the fact, that each branch is situated opposite the leaf on the common axis, whereas, the normal position of branches, on a monopodial axis, is in the axils of leaves. This happens on account of the stronger development of the portions of the shoots below their lateral branches, the terminal parts of which consequently become bent almost transversely to the false axis, and thus displaced, appear to be axillary branches. A branch system is called a *Helicoid Cyme* when the lateral axes always develop and branch only on one and the same side, figs.42-43 ; if they develop alternately on both sides as in figs. 40-41, it is a *Scorpioid Cyme.* In both cases, however, the axis is a sympodium.

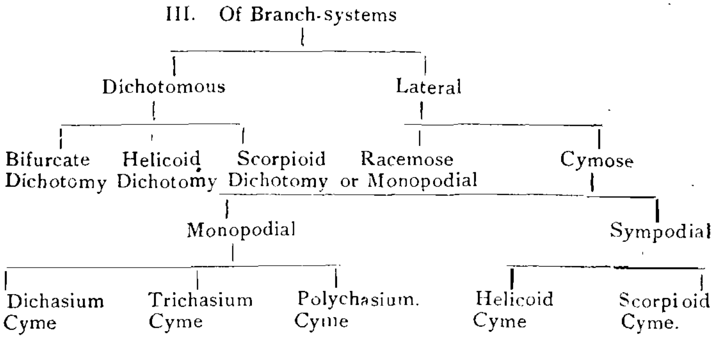
Cymosé sympodial branching occurs more frequently in the floral than in the vegetative region of Phanerogams, and will be again taken up for illustrations in the description of the Inflorescence.

Classifications

I. Of Stem.







SUMMARY AND EXPLANATION OF TERMS.

1.	*Adventitious.*	That which has come as a stranger; applied to all plant structures which do not arise from their proper place of origin.
2.	*Exogenous*	Growing on and originating from the exterior or surface.
3.	*Endogenous.*	Originating from within, and increasing by internal growth.
4.	*Rhizome.*	A perennial underground stem, producing leafy stems or flower-stems from year to year; a Root-stock. Ex. Banana, Ginger, Nymphæa (Shalook) etc.
5.	*Corm.*	A bulb-like fleshy stem, or base of a stem; a solid bulb. Ex. Oal and other Aroids.
6.	*Bulb.*	A subterranean leaf-bud with fleshy leaves as scales or coats, (tunicated and scaly). It differs from Corm in not being solid. Ex: Onion, Garlic, Saffron etc.

7.	*Bulbils.*	Diminutive of Bulb. Metamorphosed aerial buds, produced at the axil of foliage leaves, which do not produce branches but multiply and propagate the plant. Ex. Globba bulbifera and many Lilies.
8.	*Tuber.*	A thickened and short roundish subterranean branch beset with buds or eyes. Ex. Potato.
9.	*Runner.*	A prostrate filiform branch or stem which rarely becomes erect, but trails over the ground and strikes root from the lower surface of its trailing body. Ex. Oxalis (Amrool),Takapana,(Pistia), many Grasses etc.
0.	*Offset.*	A short, thick, trailing lateral shoot with a rosette of leaves at the extremity. Ex. Portulaca (Nuni-shak).
1.	*Sucker.*	A shoot originating underground as a branch and sent up in the air.
2.	*Stolon.*	An aerial branch which is disposed to root independently and to form a separate individual.
3.	*Culm.*	The peculiar jointed stem of Bamboo, and Grain-plants. It is usually hollow.
4.	*Caudex.*	The peculiar unbranched trunk of Palms.
5.	*Scape.*	A flowering shoot arising from the ground. It is connected with plants that are acaulescent and have radical leaves.
6.	*Tendril.*	A slender, leafless portion of a plant, which attaches it to supports and helps it to climb. Tendrils may be a modified stem, as in Grape-vine ; an axillary branch, as in Passion flower ; sitpules, as in Smilax (Topchini) ; on the end or a leaf, as in Pea.
7.	*Thorn.*	A branch transformed into a hard and sharp-pointed projection.
.	*Spine.*	A leaf or part of a leaf transformed into a sharp-pointed projection.
.	*Phyllocladium.*	A flattened stem or branch which resembles a leaf and performs the respiratory

	and assimilatory functions of leaves. Ex.: Coccoloba, Cactus (Phani-mansa) etc.
20. *Cladode.*	A branch especially modified into a leaf-like expansion, as in Ruscus.
21. *Dichotomous.*	Literally, cut into two ; applied to branching when the terminal growing point is divided into 2 parts, each growing in a new and transversely oblique direction.
22. *Trichotomous,* *Polychotomous.*	Have similar meanings.
23. *Monopodium,* *Monopodial.*	Having a continuous and central vegetative axis ; opposed to,
24. *Sympodium.*	A stem or branch resembling a simple axis but made up of superposed and fused branches, as in Grape-vine.

CHAPTER III.

The Leaf.

A leaf, as we understand by the term, is a flattened, green structure borne on the stem. But the Botanical conception of the term embraces a number of forms, some of which are not at all green, and a few widely differing in shape, texture and place of origin from those of the ordinary green leaves. Leaves, as has already been observed in the previous chapter, are laterally developed members which spring in acropetal succession from the outer layers of tissue below the growing point of the stem. It is on this particular point about their origin that all leaves are correlated. And it must be observed that, the variety of functions carried out for the economy of the plant, and the consequent division of labour, necessitate the metamorphosis of the leaves in each plant body. The term *Phyllome* has been applied to all leaf-structures, irrespective of form, or texture, or colour; and such of these that become green are specifically called leaves. Thus, for instance, the scale-leaves of the Onion are thick and fleshy and never green—they only act as reservoirs for reserve food materials; the membranous and chaff-like small scale-leaves of the Tuber act only as protective organs; the big hood-like covering—yellowish, dry and tough—that is found thrown over the clusters of flowers of Palms, is as much a leaf as are the former, and the separate members that make up the structure of flowers claim no less their morphological relationship with ordinary foliage leaves. The same morphological structure, the phyllome, then, has shaped itself out into variety of forms so that it may be better adapted to work out various offices. And taking the green leaves as the type of such structures, we may call the other phyllome structures, the METAMORPHOSED leaves.

To the green leaves, particularly, has been assigned the task of preparing food-materials for the nourishment of the plant. These are the actual laboratories where crude materials from the media in which plants have to live, namely, the soil and the atmosphere, are brought together to be worked up into complex organic compounds fit for the nourishment of the plant. But in the flower, leaves are modified to subserve the function of repoduction. We shall see later on (Part II) that the green colour of the foliage is essentially bound up with the manufacture of nutritive materials, and that it is developed only in parts of plants exposed to the influence of white light. Consequently phyllomes, that are not concerned with the nutritive function, are never green. Thus, the scale or cataphyllary leaves that clothe the surface of under-ground stems, as also the reproductive leaves of the flower, are never green. Yet, again, another class of leaves, the seed-leaves or cotyledons, are charged with one or more of the following functions :—

1. The storage of nutriment.
2. The work of dissolving and transmitting nutriment deposited in the seed.
3. That of preparing nutriment like ordinary foliage leaves.
4. That of protecting the seedling or the plumule.

And their texture and colour depend upon the function or functions they may be required to carry out. Thus, from the stand-point of functions, Phyllomes may be classified into :—

1. Foliage organs—found on aerial stem and branches: function being manufacture of food ;
2. Floral organs—found in the floral region of the plant: function being reproduction ;
3. Cataphyllary organs—found on subterranean stems: function being mainly protective ; and
4. Cotyledonary leaves—found in seedlings: functions, noted before.

'In this chapter we study only the phyllomes that fall under the first heading, that is, foliage leaves and their modifications.

Foliage leaves, again, have received qualifying terms, regard being had to their place of origin.

1. *Radical* leaves are those that appear to proceed from the roots i.e., from under the ground, but they really originate from the underground stem, as in all acaulescent plants. They are common in many herbaceous Monocots.

2. *Cauline* leaves are those that arise from the main axis or stem of the plant.

3. *Ramal* leaves are those found on the secondary branches or on those of higher orders.

The Duration of leaves :—Unlike the stem, which in the case of trees and shrubs, persists for an indefinite period, leaves have quite a transient existence. In most cases, in our country, they live only through one season, *i.e.* through the spring and summer, and, just before the advent of the next spring, they are cast off, and then the whole tree presents a dull and yellow appearance, quite denuded of its green leaves. Such leaves are called *deciduous*; on the other hand, those that are shed soon after their appearance and do not care to live even through one season, are called *fugacious*. In other cases, notably in Pines (Deodars) and Firs, the leaves are *persistent*, that is, they remain quite green and are not shed even during the second or third season, and then they fall away but not until other green leaves are formed to take their place. Plants having leaves of such prolonged duration are called *ever-greens*, for they never appear otherwise than green and never bear the dried mass of shrivelled up yellow, old leaves. The Indian Shimul-cotton[1] tree (*Bombax heptaphylla*), for instance, remains for the greater part of the year, quite leafless. The leaves of this plant may be called fugacious, when their duration is in question.

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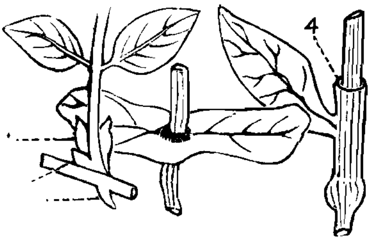
[1] Sans. *Salmale.* Teling *Boogna.*

The parts of the Leaf :—If we examine the leaf of a common plant, say Aswatha (*Ficus religiosa*), we find that in its longitudinal axis, or what is technically called the *Phyllopodium*, it is segmented into two parts—one, the lower, is the leaf-stalk, called *Mesopodium* or *Petiole,* and the other, the plate-like, outspread, green portion, called the *Epipodium* or *Lamina.* In the case in point, the base of the petiole is quite simple, but in many other cases, it is widened, grooved, or provided with a membranous border, so that, the stem is then surrounded by it like a sheath. In still other cases, the *Hypopodium,* as the base of the petiole is called, is more than sheathing ; it is winged. Such wing-like appendages in the form of two lobes, arising one on each side of the petiole and remaining green throughout the life of the leaf and falling away generally with it, are called *Stipules.* Leaves provided with stipules are called *stipulate,* as opposed to *exstipulate,* or those not bearing stipules. Leaves in which the epipodium or lamina, mesopodium or petiole and hypopodium or the sheathing or stipulate leaf base, are plainly developed, are on the whole less frequently met with than those in which one or other of such parts is absent. When the petiole is present, the leaf is called *petiolate* ; when not, it is *sessile.*

FIG. 45. FIG. 46. FIG. 47. FIG. 48.



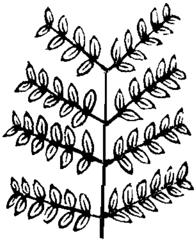


Fig. 45. Leaf of Rose with adnate stipules (1), (2), axillary bud.
Fig. 46. Connate leaves, with fused stipules
Fig. 47. Leaf of Polygonum, Ochreate stipule, 4, Ochrea ;
Fig. 48. A Bipinnate leaf.

1. **The Stipules** are morphologically the lateral branches of leaves, arising at the very point of insertion. They found more particularly in Dicots, while in all Gymnosperms and in almost all Monocots they are absent. They are called :—

(*a*) *Free* or *Ununited*, as in Juva[2] (*Hibiscus Rosa-sniensis*), Krishna-chura[3] (*Poinciana pulcherrima*), in Kantali champa (*Michelia champaca*) where the large convolute stipules protect the young leaf-buds, in Kantal (the Jack fruit—*Artocarpus integrifolia*), in the India-rubber plant (*Ficus elastica*) etc. The compound leaves of the Shirish[4] (*Mimosa Sirissa*) tree are provided with two such stipules at the base of the common petiole, and besides two at the base of each pair of leaflets. The diminutive terms *petiolule* and *stipels* are applied to the leaf-stalk and stipules respectively of these leaflets.

(*b*) *Foliaceous*, when they are large wing-like and leafy in form and function, as in Musoor (*Lathyrus Aphaca*) and Khesari (*Lathyrus sativus*).

(*c*) *Interpetiolar*, when the stipules of opposite leaves cohering form two structures, each between two leaves on either side, as in Gandharaj (*Gardenia florida*), Manject (*Rubia tinctoria*) and other plants belonging to the family Rubiacae, and in the Nux-vomica. plant (*Strychnos Nux-vomica*).

(*d*) *Connate*, when they are more or less united ; as in the sheathing bud-scales of the India-rubber plant.

(*e*) *Ochreate*, when they unite to form a sheath round the stem just above the node, as in Pan-murich (*Polygonum flaccidum*) and other plants belonging to the family Polygonaceæ.

(*f*) *Axillary*, when they fuse by their inner margins and

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[2] Sans. *Java*. Vern. *Jaba, Oroo* ; *Shoe-flower* of the English.

[3] Sans. *Krishna-chura*; Tam. *Komri*. [4] Sans. *Serisha*, Teling. *Durshuna*.

form a single body which appears to arise from the axil of the leaf.

FIG. 50.

FIG. 49.

FIG. 51.

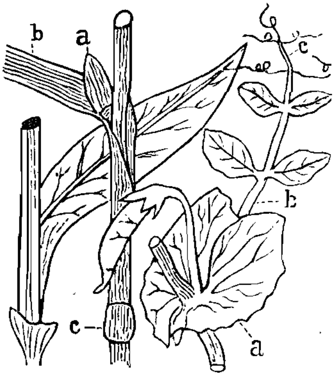

Fig. 49. Decurrent leaf.

Fig. 50. Stem and leaf of Grass. *a*, the ligule ; *b*, the leaf ; *c*, the node. Note the ligulate leaf has a sheathing base which completely encircles the stem above the node *c*.

Fig. 51. Leaf and foliaceous stipules (*a*) of the Pea. The leaf (*b*) is partially modified into tendrils *(c)*.

(*g*) *Adnate*, when they become congenitally united with the base of the petiole making it winged in appearance, as in the Rose. Fig. 45. 1.

(*h*) *Tendrillar*, when, as in Topchini[5] (*Smilax china*), they become transformed into long thread-like tendrils.

2. **The Petiole** and the leaf-base (Hypopodium). While stipules are developed almost only in Dicots, all Monocots, on the other hand, have their leaf-base enlarged into a sheathing expansion. But in Grasses, a membranous structure arises as an outgrowth from the inner side of the sheathing leaf at the point from which the lamina bends away from the stem—it is called a *Ligule*. (Fig 50.a). The petiole is a comparatively unessential

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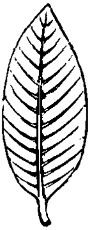
[5] Sans, *Kumari*.

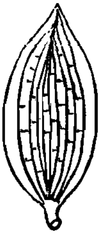
part of the leaf. In Pines and other Conifers it is entirely wanting, while in many Dicots the total non-development of the mesopodium makes the lamina sit directly on the stem ; in many such cases, the green tissue of the lamina completely encircles the stem like a collar, so that it might be thought that the stem had grown perforating the leaf—such a leaf is called *Perfoliate* (see Fig. 70). If two or more of such sessile leaves arise from the same node, they may be fused into a bowl or cup-shaped structure, and then it looks as though the stem has been thrust through the fused leaf-system which is, hence, called *Connate*. If, on the other hand, the epipodium-tissue of a sessile leaf be continued down the stem in the shape of two bands or wings, it is called *Decurrent*. (Fig. 49).

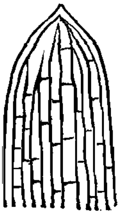
3. **The Lamina or Epipodium** is typically flattened in form, expanded, and generally symmetrical. It is the main part of the leaf, so far as its function is concerned. Preparation of food materials goes on exclusively in it, all other parts having but little physiological importance. Connected with this function, is the distribution of the thread-like strands that traverse the whole leaf and appear to radiate from the petiole or the stem. These strands are the essential tissues through which water and other food-materials are carried to and distributed in the soft tissues of the lamina. They are called Veins in morphology, and the mode of their distribution in the celluar tissue of the epipodium is called *Venation*. As in many other cases, so here too, the two great classes of plants, Monocots and Dicots show a well-marked difference. If we examine the leaf blade of a Grass or a Bamboo, we find that the veins all run parallel. In the Banana or the Canna plant (Monocots), there is a single strong midrib, dividing the leaf into two symmetrical halves, but the veins that originate from this midrib all run parallel throughout their course. In the large-leaved Gymnosperms, for instance, in the Palm-like Cycads, as also in all Palms, the veins are all *parallel*. Thus, parallel venation is the rule in Monocots and some Gymnosperms.

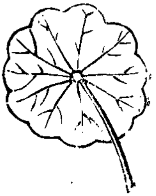
On the otherhand, Dicot leaves, as those of the Aswatha or Bur (or Bat), have their veins ramifying in all conceivable directions, producing an anastomosing network of fine meshes. This mode of distribution is called *reticulate.*

FIG. 52. FIG. 53. FIG. 54. FIG. 55. FIG. 56.









Figs. 52-54. Diagrams to illustrate Parallel Venation.
Fig. 52. Pinnate venation. (Unicostate).
Fig. 53. Convergent multicostate parallel venation.
Fig. 54. Typical parallel venation.
Fig. 55, 56. Reticulate venation. 55 Pinnate type.
56. Palmate type. Fig. 55. Simple lanceolate leaf.
Fig. 56. Peltate Orbicular leaf of *Nasturtium* with margin Crenate.

Kinds of Parallel Venation :—

1. When, as in the case of the Banana or Canna, there is a single midrib from which the secondary branches run in parallel lines to the margin, the venation is called *unicostate* or *costal nerved.* (costæ = ribs).

2. When there is no such midrib, but all the veins run from the base, it is called *multi-costate* or *basal-nerved* ; in Grasses, the Bamboo, Paddy plants etc. such veins all converge towards the apex : the venation is *convergent multicostate.*

3. But when, in a multicostate venation, the veins radiate from the base towards the spreading end of a leaf, as in Palms, typically in Fan-Palms, the venation is called *divergent multicostate* or *Flabellinerved.*

It should be observed that, in all the above cases, the primary ribs or the strong veins are only parallel—between two strands of which the ultimate veinlets anastomose more or less, though not so very well as in the

Kinds of Reticulate venation :—In these the primary strands or *Ribs* give rise to secondary and less strong veins and these undergo ultimate subdivisions, called veinlets. All these ramifications of the Rib or Ribs form a net work of fine meshes or *reticulations*.

1. When there is a single midrib, dividing the lamina into two almost symmetrical halves and on its right and left are arranged the secondary veins, in the manner of the plume on the shaft of a feather, the venation is *Pinnately*,—or *Feather-veined* or *Penni-nerved*. This is the most common type in those Dicot leaves that are decidedly longer than broad. In some cases, as in the common Sunflower, two or occasionally more lower veins become much stronger, and behave exactly like the main midrib. Such leaves are called *triple* or *quintuple-nerved* or *ribbed*, according as the number of such veins is three or five.

2. *Palmately*—, *Digitately*—, or *Radiately—veined* or *Palminerved* leaves are those where instead of a single strong midrib, three, five, seven, or more ribs, all equally strong, radiate from the tip of the petiole, each with a system of veins, ramifying and filling up the interspaces of the lamina. This kind of venation is called *Palmate* or *Digitate*, because the ribs appear to radiate like the fingers of the palm fully stretched-out. It is naturally connected with broad leaves or those where the base forms a wide and prominent part. Common examples are in the garden Nasturtium, Cucumber, Water-Lily (Padma), Castor-oil plants etc.

Of the two kinds of reticulate venation the first is of the unicostate and the second of the multicostate type. It should be noted that venation, like branching, may be referred to two primary types : Racemose and Cymose. The unicostate venation, whether parallel or reticulate corresponds to the racemose system ; the multicostate to the cymose. In the latter, the median rib represents the enfeebled parent axis and the other ribs growing as strongly as, if not more than, the parent, represent the daughter-axes of the branch system.

FIG. 57. FIG. 58. FIG. 59. FIG. 60. FIG. 61.

Fig. 57. Pedate leaf.
Fig. 58. Asymmetrical leaf of Begonia.
Fig. 59—61. From simple to compound leaf.
Fig. 59. Three-cleft or trifid simple leaf.
Fig. 60. Three-parted or tripartite simple leaf.
Fig. 61. Three-divided or trisected compound leaf.

Simple and Compound Leaves :—Leaves, as we have seen, are longitudinally segmented into the petiole and lamina, but the latter may also be segmented laterally. Lateral segmentation consists either of rudimentary branching as in indented, toothed or sinuate leaves (see margins), or of actual branching as in pinnate, deeply-lobed or compound leaves (see lobation). But when the lamina is altogether unsegmented, that is, the cellular tissue completely fills up the spaces between the ribs and veins, it is called *entire*. Usually however, it is not completely developed and small irregularities or cuttings on the margin, and frequently large incisions run between the chief veins or ribs, as in the Papaw[6] (*Carica papaya*), or Kantikari (*Solanum jacquini*) leaves. But so long as the segmentation, or non-development of the epipodium between the branches of the main midrib or the separate diverging ribs, is not complete,

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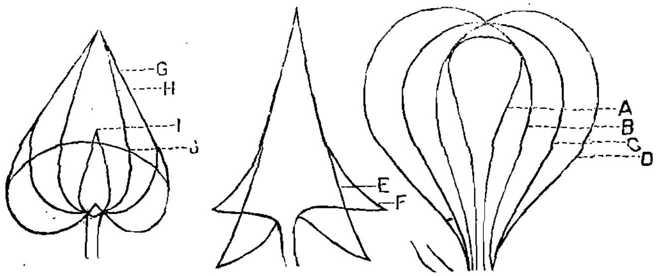
[6] Beng. *Pepey*. Hind. *Papita*.

the lamina, and for the matter of that the leaf, is regarded as *simple*. And leaves are termed *compound*, when the individual lateral lobes of the lamina are completely separated at the base, the separation being due to the total non-development of the epipodium-tissue at that part. The simplest leaf is *Entire*, as in the Aswatha, Bat, or Jack fruit (Kantal) tree. In the Cucumber or Papaw plant the lamina is lobed, but still simple. But in Tamarind, Asoka (*Jonesia asoka*), or Bilva,[7] (Bael—*Aegle Marmelos*), the leaf is compound and the separate leaflets resemble, in many respects, the simple leaf.

Outline of the Lamina :—with regard to the superficial aspect presented by the leaf, the following terms are in use :—

FIG. 62. FIG. 63. FIG. 64.



Diagrams to illustrate the leaf-outline.

1. *Subulate*—a narrow, hard leaf which gradually tapers from base to apex, ending in a sharp point. Fig 62. I.

3. *Acicular*—a sharp, pointed, elongated leaf which is distinctly, flatter than the above, i.e. with distinct edges. Fig. 66.

3. *Linear*—a narrow elongated leaf, with edges running parallel, of about the same breadth throughout, and not tapering, as in many Grasses and Isupgool[8] (*Plantago Ispaghula*). Fig. 65.

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[7] Teling. *Maredoo*. Tam. *Willa-marvum*.

[8] *Ispagool* the Hind ; and Persian name.

4. *Lanceolate* or lance-shaped,—an elongated leaf with edges gradually diverging from the base and then again drawn to a tapering point from about the middle—being thus tapering both towards base and apex, as in Ata (Custard Apple),[9] Devadaroo, (*Uvaria longifolia*). Fig. 62. H.

5. *Oblong*—a very widely linear leaf, as in Fig. 67.

6. *Oval* or *Elliptical—i.e.* like an ellipse ; a very wide leaf of the lanceolate type, as in the common garden plant Gool-Firinghi (*Vinca rosea*). Fig. 68.

7. *Ovate*—when the outline is like the section of a hen's egg lengthwise *i. e.* rounded off towards the base and gradually pointed at the apex as in the Bat (or Bur—*Ficus Indica*) Fig. 62. G.

8. *Orbicular* or *Rotund*—when nearly circular, as in Padma,[10] Kool[11] (Byar—*Zizyphus jujuba*). Fig. 56.

9. *Cordate*—or *Heart-shaped*—any wide leaf with the basal portion growing out in the form of two lobes on the two sides of the petiole, leaving a notch on each side, as in Kalmilata, the common Gourd and other plants belonging to the respective families (*Convolvulaceæ* and *Cucurbitaceæ*). Fig. 62.G.

10. *Reniform or Kidney shaped*—a cordate leaf rounded at the top, and broader than long, as in (Fig. 62. J), Thulkuri (*Hydrocotyle asiatica.* Fig.78), Harjoora, (*Cissus quadrangularis*). Paniphal [12] (Singhara—*Trapa bispinosa*)

11. *Auriculate*,—a leaf having a pair of small and blunt projections like *ears* at the base ; i.e. a cordate leaf having ears pointing downwards insted of lobes. Fig. 69.

12. *Sagittate*,—The same as above, but the projections are pointed, so that the leaf appears like an arrow, as in (Fig. 63.E.) Kat (*Sagittaria sagittifolia*) a common water plant.

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[9] *Anona Squamosa* the Bot. name.

[10] Sans. *Shetambuge*, *Poondureeka*, *Kokunád*, Pers. *Nilufu.*

[11] Hind. *Bayer.* Teling. *Rengha.*

[12] Sans. *Julukuntuka.*

13. *Hastate,*—when such projections point outwards instead of downwards, as in Fig 63. F.

14. *Peltate,*—when a round leaf, at least one with a wide base, becomes attached to the petiole by the lower surface instead of at the base, as in (Fig. 56) the Padma, Kanak-champa[13] (*Ptersopermum acerifolium*), in the garden Nasturtium etc.

FIG. 65,66. FIG. 67,68. FIG. 69. FIG. 70.

Apart from outline, a few other characters have given substantive names to leaves. Thus :—

15. *Amplexicaul* or stem clasping—when the winged leaf-base completely clasps round the stem ; *Semi-amplexicaul*, when it does so only partially. Ex : Poppy (the opium poppy—*Papaver somniferum*), the Mustard (*Sinapis dichotoma*), Sheal-kanta (*Argemone mexicana*) etc.

16. *Perfoliate* leaves are sessile leaves with the basal part growing round the stem which thus appears to pass directly through the leaves, as in *Uvularia perfoliata*. Fig. 70.

17. *Connate* leaves arise by the fusion of the membranous bases of two sessile leaves standing opposite and at the same node of the stem. Fig. 46.

18. *Decurrent* leaves are those in which the leaf-membrane runs down the stem, as wings or ribs for some distance, Fig. 49.

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[13] Sans. *Kurnikara.*

19. *Ligulate* leaves are those provided with a ligule. Fig 50. It is characteristic of the Grasses.

20. *A Cuneate* leaf is wedge-shaped; a *Lunate* leaf is crescent-shaped.

As to the Extremity or tip of the leaf the following terms are used in description:—

1. *Cuspidate,*—*i.e.* tipped with a sharp and rigid point. Fig. 71.A.

FIG. 71.

Diagrams to illustrate the apex of leaves.

2. *Mucronate*—*i.e.* tipped with a small and narrow point, not sharp and rigid, *e.g.* Rungun[14] (*Ixora coccinea*), Kookoorchura[15] (*Ixora pavetta*). Fig. 71.B.

3. *Acute*—*i.e.* ending in a small angle without tapering. Fig. 71.D.

4. *Acuminate*—,*i.e.* an acute tip gradually drawn out to a long fine point as in Aswatha. Fig. 71.C.

5. *Obtuse*—*i.e.* ending in a rather blunt extremity. Fig. 71.E.

6. *Truncate*—*i.e.* ending in a flat transverse line. Fig. 71 F.

7. *Retuse*—*i.e.* with an obtuse end slightly depressed in the middle, over the termination of the midrib Fig. 71.G.

8. *Emarginate*—*i.e.* with a more decidedly prominent notch in the middle of an obtuse end as in Kanchan[16] (*Bauhinia*) Fig. 71.H.

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[14] Sans. *Ruktuka, Bundhooka.* [15] Teling. *Nooni-papoota*

[16] Hind. *Cuchunar.*

9. *Obcordate—i.e.* inversely cordate, with two lobes on the sides of a rather deep depression as in Amrul-shak[17] (*oxalis*). Figs. 71.I.

10. *Tendrillar—i.e.* with the apex prolonged into a tendril as in Ulat-chandal[18] (*Gloriosa superba*). Fig. 73.

The Margin of the Leaf. Three stages mark the transition from the simple leaf with an *entire* margin to the compound leaf. These are :—

1. Dentations—when there are marginal incisions not entering deeply into the lamina.
2. Lobations—when the marginal incisions penetrate deeply into the lamina, generally between the ribs or veins.
3. Segmentations—When they run right into the main midrib or the petiole, giving rise to a compound leaf.

Dentations :—

FIG. 72.

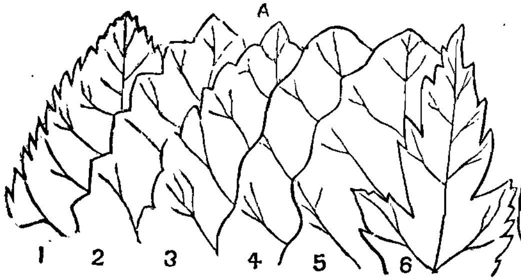

FIG. 73.

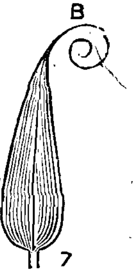

Fig. 72. Diagrams to illustrate the margin of leaves.

Fig. 73. Leaf of Gloriosa with the apex transformed into a tendril.

1. The margin is *serrate* (Fig. 72.1) when there are small and sharp teeth like those of a saw directed upwards, as in the Bhumi-Nim [19] (*Gratiola serrata*).

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[17] Sans. *Amluloonica, Chukrika.* [18] Hind. *Cariari..*

[19] *Peetsjanga-puspam.*

2. If the sharp processes are in their turn serrated once or twice, the margin is called *biserrate* or *triserrate* accordingly. If the teeth of a serrated leaf be very minute it is called *serrulate* as in the cordate leaf of Harjoora (*Cissus quadrangularis*).

2. The margin is *dentate* (Fig. 72.2) when the teeth are more prominent and do not point upwards. It is *bi-dentate* when each of the processes bear secondary teeth of the like type.

3. It is *crenate* (Fig. 72.3) when the processes are rounded and not sharp, as in the reniform leaf of Thulkuri (Fig. 78) (*Hydrocotyle asiatica*).

4. It is *repand* or *undulate* (Fig. 72.4), when the margin is a wavy line bending slightly inwards and outwards, as in Kanakchampa (*Ptersopermum*) and Devadaroo (*Uvaria*).

5. It is *spinous*, when there is a number of pointed processes resembling prickles, as in Kantikary (*Solanum jacquini*), Sheal-kanta (*Argemone mexicana*) *etc.*

6. It is *sinuate* (Fig. 72.5), when the margin is widely wavy in its outline, as in Toon [20] (*Cedrela Toona*) and in many Crotons.

7. It is *incised*, (Fig. 72.6) when there are deeper cuttings running into the lamina. These when still deeper, run into the

Lobations.

1. When the incisions extend not more than half way down the lamina and the parts thus isolated are rounded, the leaf is *lobed*.

2. When in the above case the parts are pointed, the leaf is *cleft*.

3. When the incisions run almost, but not quite to the midrib or petiole, the leaf is *parted*.

4. When the incisions extend right into the midrib or base of the lamina, the leaf is *divided* or *compound*.

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[20] Sans. Hind. *Lood* ; *Toon*.

When these lobes are in their turn divided, the ultimate portions are called *lobules* and the separated portions of a divided or compound leaf are called *leaflets*.

Lobations and segmentations are typically of two kinds—pinnate and palmate. When the venation is pinnate, the leaf is pinnately-lobed, cleft, or parted; when palmate, it is palmately-lobed, cleft, or parted. Thus, we have the terms, *pinnatifid*, *pinnatipartite*, *pinnatisect* and *palmatifid*, *palmatipartite*, and *palmatisect* corresponding to the two types of venation and the depth of the incisions.

With reference to the **incisions in the margin** of the leaf, there are a few more terms descriptive of the simple leaf :—

1. *Lyrate*—when in an unicostate leaf with pinnate venation the incisions being confined to the lower half of the lamina, give rise to smaller lobes with a large rounded terminal lobe, the leaf is lyrate. Fig. 74.

FIG. 74. FIG. 75. FIG. 76. FIG. 77.

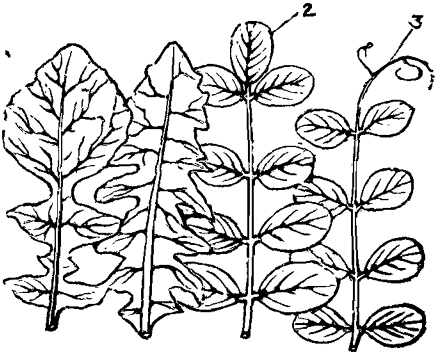

Fig. 74. Lyrate leaf. Fig. 75. Runcinate leaf. Fig. 76. **Imparipinnate leaf.** Fig. 77. Cirrhiferously pinnate leaf.

2. *Runcinate*—when, as in the above case, the lower part of the lamina is pinnatifid, and the terminal segment is pointed instead of lobed, the leaf is runcinate. Fig. 75.

3. *Pedate*—when in a multicostate leaf with cymose branching of the ribs, there are deep incisions which give rise to a large central lobe with smaller ones flanking it on the two sides, the leaf is *pedate*. Fig. 57. It is only a variety of the palmate; the only peculiarity here is that the venation proceeds on the cymose type. The median rib represents the main axis, the lateral ones, the cymose branch system. It is called pedate because there is a fanciful resemblance to the claw of a bird.

Compound leaves :—a compound leaf is very often mistaken for a branch with its leaf-system. The following points, however, establish the nature of such structures beyond doubt.

1. Buds and branches arise normally from the axils of leaves and not of branches. Hence a supposed branch with a leaf-system subtending another branch, is really a compound leaf.

2. Stipules or an expanded sheath may be present at the base of a leaf but never of a branch.

3. The apparent leaves—really leaflets, of the compound leaf, do not bear axillary buds while leaves have them normally.

4. There is no apical or terminal bud in the compound leaf, while it is normally present in the branch.

Forms of Compound Leaves.

It has already been said that the segments of a compound leaf are its leaflets. These may be either sessile or stalked. They are subject to the same modifications as to their margins, apex, outline etc. as the blade of simple leaf. Again, as they are homologous with the lobes of a simple leaf, they may be arranged on the petiole or rather its prolongation called Rachis, either in the pinnate or palmate form. Thus Compound leaves may be either pinnately or palmately compound, according as the ideal simple leaf to which they may be referred, is penni-nerved or palmi-nerved.

Pinnately Compound Leaves.

1. A *Paripinnate leaf* is one where the number of leaflets is even and the same on the two sides of the rachis (midrib) without an odd terminal leaflet, as in the Tamarind, Krisnachura[21] (*Poinciana pulcherrima*), Kal-Kashinda (*Cassia Sophora*), Soondali[22] (*C. Fistula*) and many plants of the family *Leguminosæ*.

2. An *Impari-pinnate* leaf is one where there is an unpaired terminal leaflet, as in Nim[23] (*Melia azadiracta*).

3. A *Lyrately pinnate* leaf is one where the terminal leaflet, as in the above case, is large and quite out of proportion to the other leaflets. It arises from the complete segmentation of the lamina of a lyrate leaf.

Fig. 78.

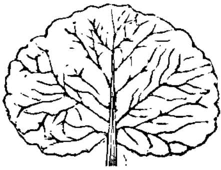

Fig. 79.

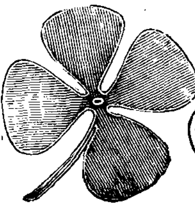

Fig. 80.

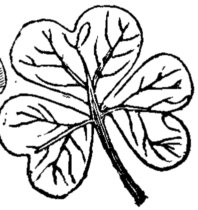

Fig 78. Reniform leaf of *Hydrocotyle* with margins Crenate.
Fig. 79. Quadrifoliate leaf of *Marsilea*
Fig 80. Ternate leaf of *Oxalis* with Obcordate leaflets.

4. An *Interruptedly-pinnate* leaf is one where there is a decided inequality of size among the leaflets, that is, where large and small leaflets alternate with each other.

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[21] Sans. *Krishno-choora* , Tam. *Komari*.

[22] Sans. *Suvurnuka*, Hind. *Umultuss*. Teling. *Rela*.

[23] Sans. *Nimba*. Teling. *Vepa*. Tam. *Vepam*.

5. *Cirrhiferously-pinnate* leaf is one where the terminal leaflet, as in case 2, is transformed into a tendril, as in the common Pea. Figs. 51, 77.

6. A pinnately compound leaf is called *Bipinnate*, *Tripinnate etc.* when they are further compounded. Thus Bipinnate leaves are formed when the main petiole bears secondary petiolules with distinct leaflets pinnately arranged. Tripinnate leaves are those having three series of secondary petiolules on which the leaflets are arranged in the pinnate manner as in Shajina (*Moringa pterygosperma*) Bipinnate leaves occur in many plants of the families Mimosæ. (*M. arabica*—the gum arabic plant—Babla in Bengali), Caesalpinia etc. In the well-known Lajja-baty-lala[24] (*Mimosa pudica*) the leaves are *digitately pinnate.*

7. *Decompound* leaves are those that are cut into numerous compound divisions, as in *Panax fragrans* (Gootee-soona, the Ver: name in Sylhet). The term, however, is applied to all leaves that are more than once compounded..

Palmately Compound Leaves.

1. *Digitate* is the general term applied to all such compound leaves, but it is more particularly applied to those having 5, 7 or more leaflets, as in Simul (the cotton—*Bombax heptaphylla*). Digitate leaves have no primary distinction into sorts, as in the case of pinnately compound leaves. But corresponding to the number of leaflets the following terms are in use :

2. *Binate* or *bifoliate*, if there are two leaflets ;

3. *Ternate or trifoliate* (Fig. 80.) if three, *Quadrifoliate*, (Fig. 79), if four, and so on.

4. A *Biternate* leaf is one which is twice compounded, each partial petiole bearing three leaves of the ternate type.

These terms, it will be observed are merely descriptive and become still more so when accompanied by the adjectives,

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[24] Verm. Lajuk.

pinnately or palmately. Thus a palmately multi-foliate leaf is really a digitate compound leaf with a large number of leaflets. A pinately quadrifoliate leaf may be a paripinnate compound leaf, etc.

In *Marsilea* (Shooshny Shak) the leaves are palmately quadrifoliate or quatern, as it is called. The leaflets are broad, truncate and entire. Fig. 79. In *Oxalis pusilla* (Amrul-Shak) the leaves are ternate and the separate leaflets are obcordate. Fig. 80.

Fig. 81. Fig 82. Fig. 83.

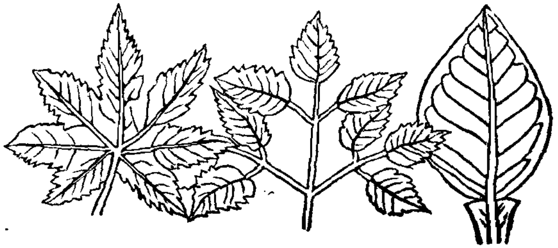


Fig. 81. Palmatifid Simple leaf of Castor-oil plant (*Ricinus*)
Fig. 82. Biternate Compound leaf.
Fig. 83. Unifoliate Compound leaf of Orange.

Some Special kinds of Leaves.

1. In the whole family of plants known as Begonias (*B. lacinata*—Beng. Hooirjoo), most of which are succulent ornamental pot-herbs, the leaves are peculiarly unsymmetrical; the obliquity of the leaves is due to a much greater development of one lateral half of the lamina. Fig. 58.

2. In the Orange and Lemon plants, each leaf has a distinct articulation at the point of junction between the petiole and the lamina. The petiole, again, is winged, so that the whole leaf appears to be sessile; but the presence of the articulation points to the compound nature of the leaf—for it is only in compound leaves that articulations of this kind are formed. Such leaves are hence called *Unifoliate* compound leaves. Fig. 83.

Hind. *Gool Shubbo*.

3. Again, there are leaves that are not segmented into parts, *i. e.*, lamina and petiole. For example, in the Onion and many Lilies, the leaves are hollow tubes or flat plates. In Pines (Deodar), they are subulate or like rigid and acute triangular needles. In many Conifers, they are cylindrical or rod-shaped. In Cedars, the whole plant-surface is covered with countless, minute, scaly leaves overlapping one another. In many other cases, again, particularly in many water and bog-plants, for instance, Vallisneria—plants commonly growing in ponds as submerged species and remarkable for the way in which they bring out their female flowers on the surface of water by long spirally-coiled stalks, the leaves are *ensiform* or sword-shaped with no distinction between, petiole and blade. Similar is the case in many radical leaves of acaulescent plants, e. g. in Rajanee-gundha (*Polyanthes tuberosa.*)

4. *Equitant Leaves*, unlike the ordinary leaves which open out almost horizontally in the air, are vertical and folded along the median, so that the upper or inner surface is concealed within the fold. They are called *Equitant*, as they are formed in clusters with the outer ones folding over and enveloping the inner, at their base. In outline they are ensiform, and are characteristic of the Iris family.

Metamorphosis of Leaves.

1. Leaves adapted to Floating. In many water-plants, the leaf-stalks are swollen into bladder-like structures which render them buoyant and enable them to float freely on the surface of ponds and fresh water lakes. Thus, in Water Chestnut (*Trapa bispinosa—Pan-phal*),though the plant is held fast to the muddy soil under water by roots, the rosettes of leaves on the surface of water are provided with inflated floats attached in large numbers to the petiole. In many species of *Pontederia* (Neelotpol), the leaf-stalks are large, spongy, fistular or bladder-like,—characters that are calculated to increase the buoyancy

of the plants ; and in fact they are driven by the wind on the still surface of ponds and lakes like ships. *Jussieua repens* (Kesara-dam), another common indigenous plant, floats by vesicles that encircle the petioles of the alternate ovate leaves.

Fig. 84.

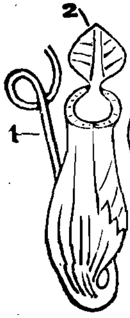


Fig. 85.

Fig. 86.

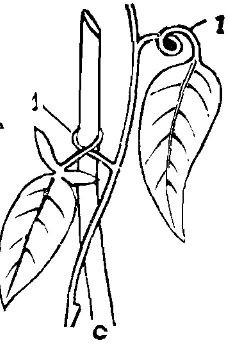


Fig. 84. Pitcher of Nepenthes ; a, the pitcher ; 1, the tendrillar petiole ; 2, the lid.

Fig. 85. Leaves of Dionea ; b, the base of leaves ; 1, an entrapped fly within a folded leaf.

Fig. 86. Petiole-climber of Solanum jasminoides. c, the support ; 1, the twining petiole.

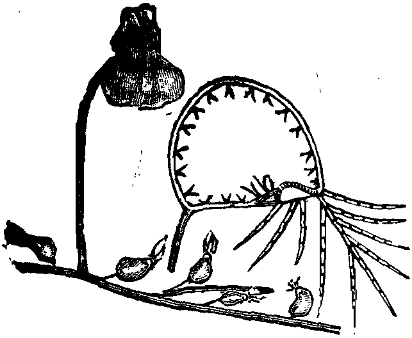
2. LEAVES ADAPTED TO CLIMBING. Some hint has already been given as to how leaves may function as climbing organs. Thus, in Smilax the stipules are tendrillar ; in Solanum jasminoides (Fig. 86.), the petiole makes a turn or two around a support ; in the Garden Pea, the upper pairs of leaflets of the compound pinnate leaf (Fig. 51) become transformed into tendrils which twine round supports. In Papilionaceae, a family of plants to which the Peas, Beans and other pulses belong, a metamorphosis of the whole lamina or some part of it, into tendrils is a comparatively frequent occurrence. For instance, in *Lathyrus sativus* (Khesari), the leaf is cirrhiferously pinnate, there being two pairs of leaflets and a terminal ten-

drillar portion. But in another plant of the same genus *Lathyrus Aphaca* (Mussoor-chana) the whole leaf is reduced to a tendril, and the function of the leaf blade is assumed by the stipules. These examples indicate the steps of the gradually modifying processes which have brought about a complete reduction of the leaf ; but there are other and still more remarkable cases where a progressive metamorphosis has led to very peculiar structures, as in

3. LEAVES ADAPTED TO ENSNARE AND CAPTURE INSECTS and to utilise animal matter. These are peculiar to what are called **Carnivorous** or **Insectivorous plants,** that is, those in which the most important vegetative process is the digestion and absorption of organic compounds from captured animals. Such plants may be conveniently divided into three classes, viz, those which develop chambers to admit of the entrance but not the escape of small animals ; those wherein the leaves are peculiarly sensitive to the contact of animals—insects in particular, the stimulus given by the contact being the cause of very quick movements whereby the prey is imprisoned till it dies of suffocation ; and thirdly, those where leaves are converted into lime-twigs and insects creeping over, stick to them and are ultimately digested.

To the first class belong the Pitcher plants (Fig. 84. Nepenthes : N.distillatoria, N. robusta etc,) Bladder-worts or Utricularias (Fig. 87), Sarracenias (Fig. 89) Darlingtonias and other allied plants provided with death-traps in the form of pitfalls. Usually there is also present a lid over the orifice of each cavity, which while preventing rain-drops from falling in, does not hinder the entrance of animals. These lids, as also the rim of the pitchers, are often brightly coloured and serve to attract insects which are further enticed by the exudation of honey, as bright drops, or as a glistening layer, over the month of the opening. Below this nectarial layer there is a zone of extraordinarily smooth, sharp, conical and attractive cells, all pointing downwords, and offering a very slippery path below, but resisting, with bristling bayonets, the attempt of any doomed insect to retrace its steps. Generally insects and other small animals, whether with or without wings, visiting the treacherous place, slip down the smooth surface and are drowned in the liquid

Fig. 87. Fig 88. Fig. 89.



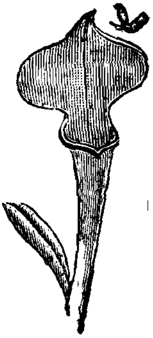


Fig. 87. Floating stem, vesicles and flower of *Utricularia.*

Fig. 88. Section through the bladder ; the dark cross-lines in the nterior are the secreting glands.

Fig. 89. Pitcher of *Sarracenia* ; a fly in the course of its visit.

ecretion present in the hollow of the pitcher ; a digestive erment then dissolves the soft parts of the carcass. Goebel, has pointed out that, the pitcher of the Nepenthes (Fig. 84) s a modification of the leaf blade, the lid is the still untransormed leaf, and the tendrillar part, a modification of the petiole. The submerged leaves of Utricularia (*U. stellaris*—Bara Jhanjhi) are similarly metamorphosed into bladderike cavities, the entrance to which is fitted with a small valve which opens inwards but closes the orifice when pushed rom within. (Figs. 87-88). The Utricularias are rootless plants and live suspended in water. The tuft of hairs produced from near the opening of the bladder lead insects, water-mites, water-fleas etc which come to seek protection against the pursuit of other water animals, into the closed bladder and thus seal their fate. Dying of suffocation or starvation, they are then absorbed by the digestive glands formed on the inner surface of the bladder as shown in fig. 88.

The second section of insectivorous plants includes those wherein the leaf is modified into organs of seizure and digestion of small animals, the retention of which is effected in very various ways of movements. A genus of plants known as *Pinguicula*, living in damp soil, moorlands, etc and found commonly on the mountain ranges of Mexico, is particularly interesting. The oblong or ovate leaves of these plants, rest their under surfaces on the wet earth and expose their upper faces to the sky and rain. A large number of glands is distributed on this surface which is rendered sticky by the secretion of a mucilage from them. When small insects alight on a leaf of *Pinguicula*, they remain almost glued on to the sticky secretion; their struggles to extricate themselves make them still more entangled and stimulate the leaf to roll its margins inwards. During this curling movement the insects are enclosed, and perishing, become dissolved and digested, after which the leaves are again unrolled.

The rolling and unrolling of the leaf margin of the Pinguicula is not so very conspicuous a phenomenon as to commonly attract the attention; for the movement is slow enough to be passed by without notice. But in the American Venus' Fly-Trap *(Dionæa muscipula)* shown in fig 85, the movement of the leaf, in its attempt of netting and capturing the prey, is surprisingly quick, being effected in less than thirty seconds. As shown in the drawing (Fig 85) the leaves are two-lobed and the midrib acts as a hinge. There are three pairs of stiff, sharp and sensitive hairs or spines pointing obliquely upwards from the surface of the lobes. In addition to these a large number of glands is scattered over it. The plant consists of a flowering scape in the centre, representing the stem, and quite a large number of the peculiar leaves spread on the ground in rosettes.

As soon as the upper surface of the lobed lamina is affected by animal-contact, the lobes hitherto outspread snap together, and the sharp marginal teeth being interlocked firmly adpress the lamina on to the body of the prey, which is then digested by the liquid secreting from the glands. It is interesting to note that the greatest and fastest movement takes place when any of the sharp, superficial hairs are touched,—they being the carrier of the stimulus given by the unwary insect.

FIG. 90.

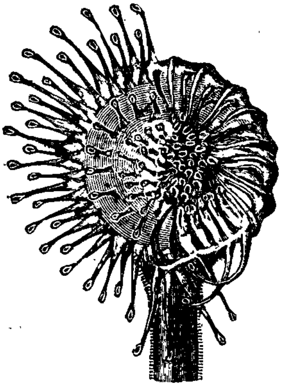
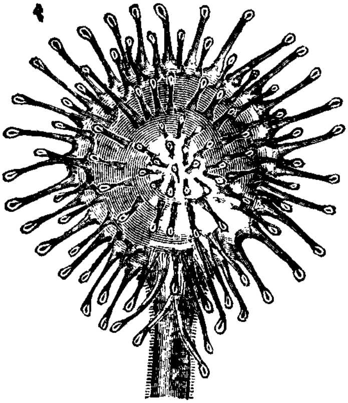


FIG. 91.



Leaves of *Drosera rotundifolia* with the tentacles.

Another blood-thirsty plant allied to Dionæa is the wa plant *Aldrovanda vesiculosa*, where the leaves are extremely alike in form and function to those of the former. But in the Sun-dew *(Drosera rotundifolia)* the metamorphosis of the leaf as a fly-catcher is singularly striking. As shown in fig. 91 the lamina is roundish and bears a large number of delicate wine-red filaments, globular at their extremities and each supporting a glistening droplet of fluid-secretion. These filaments or tentacles, as they are called, are really the capturing organs and appear as pins of assorted sizes stuck to the cushion of the leaf. The secretion from the glands or heads of the tentacles is very sticky and shines like dew-drops in clear air. The moment a small insect, allured by the honey-like drops, touches a tentacle or alights in the centre of the leaf, there flows out a copious secretion of acid juice—sticky and chocking—which besmearing the wings and legs of the prey renders all its attempts to escape quite futile. The thread-like tentacles, thus stimulated to movement by the continued kicking or flapping of the insect, close upon it (see Fig. 90) and dissolving and digesting and finishing its bloody repast open out again after a couple of days. Similar phenomena are observed when raw pieces of meat or egg-albumen are placed on the leaf—the movement in such cases being a little slow, taking from 20-30 minutes for the complete folding of all the filaments.

To the third class of insectivorous plants belong the *Drosophyllum*—plants indigenous to Portugal and Morocco. The leaves here are long, whip-like, drawn out at the upper part to a fine thread, slightly channelled on one side and studded with a very large number of small bead-like stalked glands, the secretions from which stand out as bright and shiny globules. Besides these, there is also a large number of sessile glands on the whole surface of the linear leaf. These glands, however, do not secrete unless they are stimulated by the contact of animals. Insects creeping over the leaves become besmeared and suffocated by the sticky juices of the stalked glands and eventually becoming overwhelmed, have to stop any further progress in their doomed excursion, and then sink and die of the burden. The sessile glands now come into play, secrete an acid juice copiously, dissolve the tender and digestable parts of the booty, and then absorb the rich food thus prepared.

It is not, however, on animals entirely that the so called insectivorous plants have to live. Like all other green plants they can prepare their own food from inorganic nature; but when fed with insects they become stronger, flower more freely, and produce fruits and seeds in profusion. Their habitat however has called upon them to have recourse to contrivances for getting nutritious food ; for most of them live in swamps or other localities destitute of Nitrogen, and this element so essential to living bodies, they take from captured insects and other small animals. Indeed, some of them have been known to have softened their gluttonous hunger for animals when grown in an otherwise rich soil.

Classifications.

I. Kinds of leaves.

- Seed-leaves or Cotyledons.
  - One, in Monocots
  - Two, in Dicots
- Scale-leaves or Cataphyllary leaves
  - Underground Scaly leaves
  - Aerial budscales
- Foliage leaves
  - Simple
    - Pinnate
    - Palmate
  - Compound
    - Pinnately compound
    - Palmately compound or Digitate.
- Floral leaves

II. Venation of Leaves

- Parallel
  - Unicostate
  - Multicostate
    - Convergent
    - Divergent.
- Reticulate.
  - Pinnately
  - Palmately

—veined.

The following Schedule will give the Student a comprehensive idea of the way in which leaves are to be studied.

A.

	Am (Mangifera Indica).	Krishna Chura (Poinciana pulcherrima).	Java-(Hibiscus Rosa-sinansis)	Dhan. (Oryza Sativa).	Padma (Nelumbium Speciosum).	Cocoanut Palm (Cocos nucifera).	Kutchoo (Colocasia antiquorum).
Position and stipulation	Alternate, exstipulate	Alternate, stipulate	Alternate, stipulate	Alternate, exstipulate	Radical exstipulate, floating	Alternate, exstipulate	Alternate, exstipulate, Radical.
Insertion	Petioled	Petioled	Petioled	Sessile and sheathing, ligulate	Petioled, peltate	Sessile and sheathing	Sheathing, peltate.
Division	Simple entire	Compound, bipinnate	Simple	Simple	Simple	Compound, pinnate	Simple.
Outlines	Lanceolate	Elliptical leaflets	Ovate, Acute	Linear	Orbicular, or broad-oval	Linear leaflets	Ovate, broadly cordate.
Margins	Waved	Entire	Serrate	Entire	Entire	Entire	Repand or wavy.
Veins	Feather-ribbed	Penni-nerved	Three-ribbed-Ribs feather-viened	Parallel, Straight	Palmi-nerved	Unicostate, parallel	Multicostate, parallel.
Apex	Acute	Blunt or Obtuse	Acute	Acute	Emarginate	Acuminate	Arrow-headed.

2. Alternate, scattered or spiral arrangement :—where the leaves stand one at each node.

The Alternate arrangement is so called because the leaves originate singly from the nodes, not all on the same side of the stem, but one on this side, the next higher on that and so on. It is also called spiral, because an imaginary line passing in succession through the bases of the leaves at different heights, form a spiral on the stem. We may regard the shoot as a cone, with big leaves towards the base, and the younger ones opening out in acropetal succession higher up and, the youngest at the apex. The genetic spiral as the imaginary line refered to, is called, will when projected in a horizontal plane form a helix or coil as shown in Figs.96-99. The position of the leaves on the stem may be best shown on this projection as thick lines. Examined carefully, such a figure will reveal a very characteristic geometrical law. It will be seen that, the *angle of divergence*, as the angle subtended by two successive leaves at the centre of an imaginary circle passing through them, is called, is always constant. The explanation that this angular divergence of the leaves is constant in

FIG. 92.

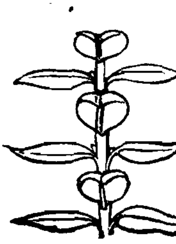


FIG. 93.

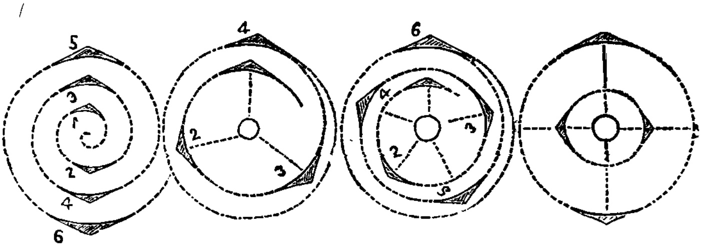
FIG. 94.

FIG. 95.

Fig. 92. Opposite decussate leaves.
Fig. 93. Alternate leaves.
Fig 94. A verticil or whorl of 10 leaves.
Fig. 95. A fascicle.

each particular plant lies in the fact that the leaves are always symmetrically arranged on the axis. For the leafy stem can be well imagined as made up of stories, each of which displays the same number, position, and distribution of the leaves, and agrees entirely with the adjoining stories on these points. If the number of leaves on such a story, or better the spiral line going only once round the stem, so that its horizontal projection is an almost closed circle, be two, the Phyllotaxis is called

FIG. 96. FIG. 97. FIG. 98. FIG. 99.



Projectional diagrams of Phyllotaxis.
Fig. 96 One-half Alternate or spiral Phyllotaxis.
Fig. 97. One-third spiral arrangement.
Fig. 98. Two-fifths Phyllotaxis.
Fig. 99. Opposite Decussate Phyllotaxis.

Distichous or two-ranked. It characterises the leaf-arrangement of all Grasses and many other Monocots. The leaves are exactly on opposite sides of the stem though not on the same level. It will be seen, that the 3rd leaf stands just above the first, in a vertical row with the 5th, 7th, 9th etc., that the 2nd leaf similarly stands in the same vertical line with the 4th, 6th, 8th etc. It is not possible to draw any other similar vertical lines on the stem, for all the leaves fall on one or other of the two already mentioned. Hence, these lines called *Orthostichies* tell us immediately the nature of the phyllotaxis of the plant in question. The phyllotaxis may be represented by the fraction ½ which points out the angular divergence, *i.e.* $\frac{1}{2}$ of 360° = 180°. This figure also tells us that there are two (denominator) leaves in one (numerator) closed spiral coil. The next kind of alternate arrangement is where there are three such Orthostichies and is called

Tristichous or three-ranked. It is less common, but can be observed in the Sedges,—Monocotyledonous herbs allied to Grasses. As will be understood, here there are three vertical Orthostichies—the leaves 1st, 4th, 7th etc being on one; the 2nd, 5th, 8th etc, on a second; and the 3rd, 6th, 9th etc., on a third line. The angular divergence is $\frac{1}{3}$ of the circumference or $\frac{1}{3}$ of 360° = 120°. The phyllotaxis may be called $\frac{1}{3}$ *i.e.* with three leaves in one closed spiral coil. The next one

Pentastichous or five-ranked or Quincuncial, is by far the most common, as in Aswatha, Garden Crotons etc. Here the spiral line, starting from the first leaf, takes two turns round the stem before it comes to a leaf vertically above the first; and it stops at the 6th leaf-base to complete the first story. In the *first* encircling coil the genetic spiral does not arrive at a leaf which is just above that from which it started,—thus, there are 5 leaves in *two turns* of the spiral, and consequently, five Orthostichies. The angular distance between the Orthostichies is $\frac{1}{5}$ of 360° or 72°, while the angular divergence of the leaves is $\frac{1}{5}$ of 2ce 360.° = 144°. The Phyllotaxis is $\frac{2}{5}$.

Still another kind of Phyllotaxis, specially characteristic of the Rose family, is the **Octostichous** or eight-ranked or $\frac{3}{8}$ arrangement. In it the genetic spiral makes three revolutions round the stem and when it stops at the point required, it touches the ninth leaf-base. It is far less common but is found also in the Plantago.

If we now arrange the primary forms of spiral phyllotaxis, we find that the fractions $\frac{1}{2}, \frac{1}{3}, \frac{2}{5}, \frac{3}{8}$ represent a series of which the sum of any two successive numerators makes up the numerator of the following and likewise that of the denominators. We find also that the numerator of one is the same as the denominator of the next but one preceding fraction. Extending the series according to the law thus indicated, we arrive at the fractions $\frac{5}{13}$, $\frac{8}{21}$, $\frac{13}{34}$ etc. as possible higher phyllotaxis. As a matter of fact these have been actually verified, though they are not very common.

The **Verticillate Whorled or Cyclic** arrangement. Here the leaves stand in whorls of two, three, four, five, etc., at each node. A particular case of this arrangement is the *Opposite*, where the number of leaves is only two, so that the circumference of the stem is divided longitudinally into two equal parts by the median plane common to the two leaves. Usually, however, opposite leaves form what is called a *Decussation*, when two successive whorls have their leaves arranged in the form of a cross. Such opposite and decussate pairs of leaves are characteristic of the Toolsy family (Labiatæ) of plants, in the Indian Jasmines (Kumud, Jui, Mallika, Bel, Chameli etc), in Acanthaceæ (Bakash—*Justicia*), in Apocynaceæ, Asclepiadaceæ, Oleaceæ etc.

The members of each whorl consisting of 2, 3, 4, 5, or more leaves, may either stand just in vertical lines with those next above or below them or may fall between the spaces left between those of the successive whorls. The first happens only in rare cases while the second arrangement (Decussation) is by far the most common. For example, the decussating pairs of whorls of the Toolsy and Jasmine familes form four orthostichies—the first whorl consisting of two leaves which stand just below those of the 3rd, 5th etc., whorls forms 2 orthostichies and these together with the 2 of the 2nd whorl make up 4 orthostichies in the total. In some cases the successive whorls are not directly placed between the intervals of those just below or above them, but a little turned to one side, so that the third whorl does not entirely coincide with the first as regards orthostichies but may anomalously do so with a pair higher up, This has been explained by the supposition that the spiral is the only arrangement, that by the non-development of internodes the spiral arrangement becomes partially condensed into the whorl. Thus if we suppose the internode between the first and second leaves of the distichous arrangement not developed, and similarly that between the 3rd and 4th, we get the opposite arrangement of the verticillate type. In the anomalous case referred to above the successive whorls might be arranged in a spiral manner with regard to each other.

II Arrangement of the leaves in the bud.

While Phyllotaxis explains the law of the arrangement of the leaf on the stem, Vernation and Aestivation explain that which underlies the different modes in which leaves are disposed in the bud. Naturally, as the space in the bud is only limited, the leaves composing it must be packed in the way most efficient to economise space. Vernation, or Præfoliation as it is also called, deals with the way in which leaves are coiled folded or otherwise packed *per se* and may be considered under two heads :—

1. Where the leaves are folded ;
2. Where they are rolled.

1. As to folding, a leaf is called—

(1). *Reclinate or Inflexed.*—When the upper half of the leaf is folded on the lower or the lamina on the petiole, as in the Tulip.-tree.

(2). *Conduplicate.*—When the lamina is folded along the midrb, as in Magnolia. Fig. 100.1.

(3). *Plicate or Plaited.*—When the lamina is folded several times like a fan along the several ribs, as in Fan Palms. Fig. 100.6.

2. As to rolling, a leaf is called

(4). *Circinate.*—When the lamina is rolled from apex downwards to the base, as in all Ferns. Fig. 100. 5.

(5). *Convolute.*—When the rolling is lateral *i. e.* from one margin to another, as in Banana. Fig. 100. 2.

(6). *Involute.*—When the lamina rolls up from each margin towards the midrib, the lower surface only being exposed. As in the Water Lily. Fig. 100. 3.

FIG. 100.

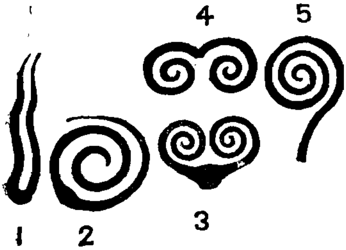
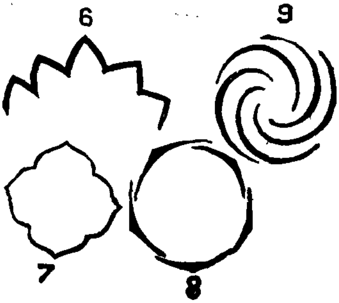


FIG. 101.



(7). *Revolute.*—When the lamina rolls up from each margin as in (6) but with the upper surface external *i, e.* the rolling is backwards. Fig. 100. 4.

(8). *Corrugate or Crumpled.*—When, as in the floral leaves (Petals) of the Poppy, the leaf is irregularly crumpled.

So far as regards the individual leaves of the bud. Aestivation, on the other hand, deals with the arrangement of the leaves in the bud, *inter se.* The relative position of the different leaves composing the bud is here the subject. It can conveniently be divided into two parts :—

1. Cases where the leaves do not overlap, *i.e.* their margins remain free.

2. Cases where the leaves overlap each other.

First Case. (*a*) When the margins of the leaves do not come into contact the Aestivation is called *Open or Indeterminate.* It is not very common but is formed in the flower buds of Mignonette and in the whole family of plants known as Reseda.

(*b*) Where the leaf margins just meet without overlapping, it is called *valvate.* Fig. 101.7 Here the leaves are necessarily placed at the same level on the axis, in a circle. It is found in the flower-buds of the Grape vine, in many Mimosæ (Acacia,—the gum-plant; Lajjabaty-lata etc.) in the whole family of plants, called Asclepiadaceæ (Akanda, Anantmul etc.) in the sepals of Java flower (Hibiscus) etc.

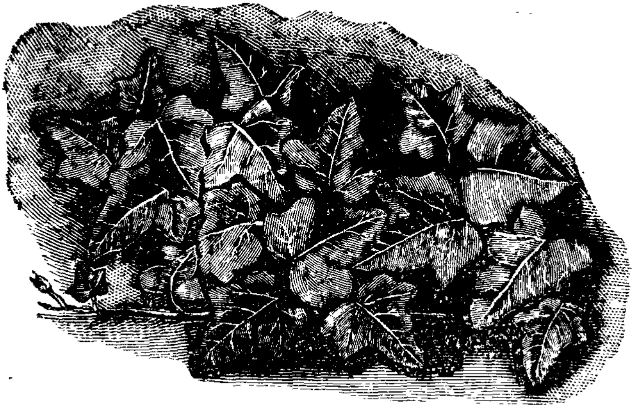
Second Case. (*c*) When the leaves, being placed at different levels on the stem, merely overlap by their margins, the Aestivation is *Imbricate.* It is by far the most common form.

(*d*) Where the leaves of an imbricate Aestivation become decidedly overlapping, so that the leaves appear to be twisted round the axis, it is called *convolute* or *contorted* or *spiral.* Fig. 101. 9.

Significance of Phyllotaxis.—If a large number of plants be examined with a view to studying the phyllotaxis, the significance of the different kinds of leaf-arrangement becomes apparent. As a general rule, it is found that the number of Orthostichies becomes smaller as the leaf blades become broader. If, as is generally the case in all Monocots, the leaves are large the phyllotaxis is never higher than $\frac{1}{2}$ or $\frac{1}{3}$. Broad cordate leaves of twiners and climbers follow this phyllotaxis. As the leaves become more and more narrow as lanceolate, linear, acicular etc, higher phyllotaxis are met with. Kerner mentions cases of Salix (Willow) with circular, elliptical, oval and narrow linear leaves; in these it can be plainly seen that the number of Orthostichies increases in proportion as the leaves become narrower. If should be observed that the arrangement of the leaves on the stem is connected with their function. Ass unlight is one of vital requirements of the leaves they are so arranged as to economise the largest amount of sunlight. Broad or cordate leaves if arranged in clusters would far more readily throw some of them in the shade than when they are kept widely though moderately apart. Again, narrow linear leaves growing at great distances on the stem will fall short of the strict economy which plants have necessarily to practise—for a large amount of sunlight available to the plant is then lost to it. If the leaves of the story which is rather low be separated by short distances, then, following this principle of economy, they will be small or narrow, for otherwise they would wholly throw in the shade other adjoining leaves just below ; if the stories happen to be high, the leaves may be large or broad but always so adapted as to utilise the greatest amount of sunlight without hindering the function of other leaves.

Leaf-Mosaic.—Inorder to be better adapted to catch the greatest amount of sunlight, leaves, as we have seen, become variously modified in shape ; but this adaptation to environment becomes very clearly manifested in what are called leaf-mosaics. The leaves of many plants growing in the shade of forests or under the leafy canopy of large trees are, *inter se*, so modified in shape and size as to fit in squarely in the notches or lobes or spaces left between the leaves, just as different coloured stones are fitted and set in a variegated marbled flooring. In the drawing (fig. 102) the relative position of the leaves of a species of Ivy carpeting the floor of forests is shown ; it will be noticed that the 5 lobed leaves have undergone manifold torsions and displacements, inorder that they may fit into one another and produce an almost continuous leafy surface. In the common Mirabilis Jalapa (Krishna-Kali) of our gardens a similar leaf arrangement can be observed. The dense foliage of this plant brings out in relief the contrast between the leaves of different sizes

FIG. 102.



Leaf Mosaic : Ivy growing on the shade of a forest.

that remain side by side, as if leagued in a combined confideracy to snatch up as much light as they possibly can. The ordinary leaves are broad-ovate or slightly cordate ; but a number of smaller leaves with no very strict and definite outline are found to occupy the spaces left between the above. This inequality of size in adjoining leaves of the same plant is particularly noticeable in many shrubby plants living in shady situations. The common Java (Hibiscus Rosa-Sinensis), for instance, produces a heavy cluster of leaves at the head ; but interspersed among these may be found a large number of leaves showing very fine shades of gradation from the ordinary broad-cordate leaf to one much smaller and having a very simple outline and margin. The gaps left between the larger leaves are generally filled and plugged with those that are small.

CHAPTER V.

Inflorescence or Anthotaxy.

When the vegetative organs of a plant are completely developed and almost everything in the way of nutrition has been done, the time comes for it to work out the next most important function—that of reproduction. The reproductive organs, in the case of Phanerogams, are developed on specially modified shoots called flowers, and the floral region of the plant as distinguished from the vegetative is called the *Inflorescence*. The term denotes the arrangement of the flowers on the axis, specially with regard to their relative position. And as the disposition of the foliage organs on the stem is denoted by the term Phyllotaxy, that of the floral organs is similarly called the Anthotaxy (Gr. *Anthos* = flower, *taxis* = order) or Inflorescence.

If, as it happens in a comparatively few cases, the primary axis of the plant terminates in a flower, it is called an *uniaxial* plant; usually, however, flowers originate only after the complete development of a complex branch system, that is after the formation of the secondary, tertiary and other branches of higher orders. Such plants are called *biaxial*, *triaxial* or *polyaxial* according to the degree of branching.

In many cases, instead of a terminal flower, or a solitary axial flower which is the simplest case of an inflorescence, the reproductive region of the plant undergoes modifications not only with regard to the leaves but also as to the mode of branching and the aggregation of a number of flowers on a common axis. In fact, it is to a collection of flowers borne on an axis with its branch system that the term inflorescence is properly applied in Botany.

In or near the inflorescence the leaves subtending the floral buds or the floral branches are modified into BRACTS (Figs. 103, 105-110.). In most cases these are like ordinary foliage leaves with but little modifications, but in others, they are developed as special organs subserving functions connected with reproduction. As a rule flowers originate normally from the axils of bracts and such flowers are called *bracteate* ; when the bracts are absent, the flowers are *ebracteate*. It will be shown later on that the flower is a modified shoot, and as such, it is normally subtended by a structure which is morphologically homologous with the leaf. Bracts, however have to carry on a variety of functions, and accordingly, their shape and texture and colour vary very much.

Kinds of Bracts :—

1. In the Kutchoo (*Colocasia antiquorum*) there is a large yellowish leaf enveloping a fleshy axis on which is clustered a large number of sessile flowers. In Palms also, the whole inflorescence is enclosed within a large leaf-like structure ; similar too, is the inflorescence of the male flowers of the Ketuky or Kea (*Pandanus Odorotissimus*). Such enclosing bracts, sometimes green, more often coloured, are called *Spathes*. Fig. 103. In the Banana plant the number of such spathes in the inflorescence is very great, and all of them are deeply coloured being scarlet on the inner surface.

2. In the Sunflower (Surjamukhy—*Helianthus annuus*), and all plants of the Marigold (Genda) family, the large number of minute flowers is surrounded at the base by a spiral collection of rather small green leaf like structures. So, too, the inflorescence of the Carrot (Gajur—*Daucus Carota*) is surrounded at the base by a rosette of such green leaf-like bracts. Such a whorl of bracts is called an *Involucre*.

3. The individual flowers that make up the inflorescence of the Sunflower and Marigold family, are subtended by diminutive chaff-like bracts, on the fleshy receptacle. These are called *Paleæ* (*sing* : *palet*).

FIG. 103.

FIG. 104.

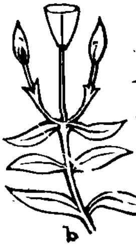


FIG. 105.

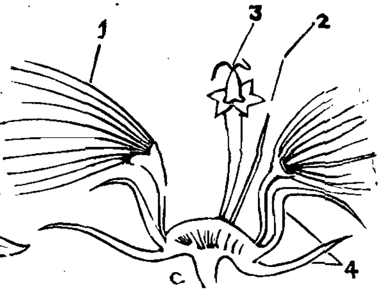


Fig. 103. Spathe (cut open) and Spadix of *Colocasia*; the circular dots represent the flowers.

Fig. 104. A Typical Dichasial Cyme with the terminal (central) flower opening before the lateral flowers.

Fig. 105. Inflorescence of Compositæ (cut vertically), c, the convex receptacle of the Capitulum. 1, the Ray-flowers ; 2, the scaly bract -Paleæ ; 3, the Disc-flower.

4. Such chaff-like dry bracts characterise also the flowers of Grasses and Sedges, and are then called *Glumes.*

The varied nature of bracts is consistent with the variety of functions that they have to perform. Being in the transitional region between the foliage and the floral, their functions have necessarily not been limited to one kind. When the transition is not too sudden and the bract is foliaceous, as in the inflorescence of the Bakash (*Justicia*) plant, it has to carry out the ordinary work of the leaves; when it becomes much reduced in form and texture and loses the green colour of the foliage, its function becomes mainly protective and sometimes it aids the dispersion of fruits and seeds. Not unfrequently, however, it rivals the high colouring of flowers and then its chief function is to invite insects and bees to effect pollination of the flower. Yet, again, in a few cases, two or more of these functions are combined: thus, the spathe not only affords protection but also allures insects by secreting a sweet juice around the base of the flower-stalk; (the secretion is called Nectar and the reservoirs for the reception of the juice are called Nectaries). An example of

5. *Petaloid bracts*, as they are called from their high colouring, is in *Bougainvillea spectabilis*, a thorny climbing shrub used as an ornamental plant on our gates. The inflorescence consists of three rose-red leaf-like bracts bearing three tubular flowers. The whole cluster is apt to be mistaken for a single flower by the beginner. *Euphorbia splendens* and *E. Bojeri*, two ornamental garden plants naturalised in this country, have each a bright scarlet pair of connate bracts immediately under the flowers which taken in themselves are only an insignificant part of the showy structure. Again, in Lalpata (*Poinsettia pulcherrima*), another garden plant much favoured for its showy flowers that are really bracts, the latter are very large and vermilion-coloured while the flowers are small and colourless or have only a greenish tint.

The following terms used with reference to the inflorescence, may, with advantage, be defined here.

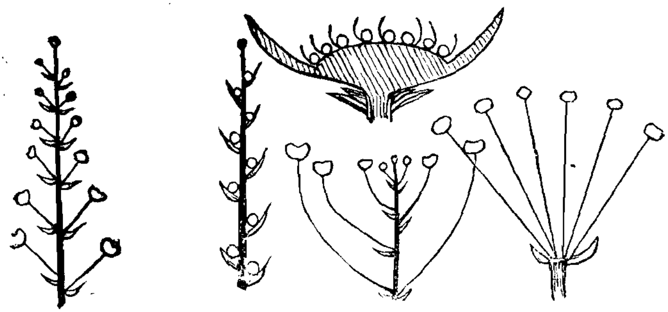
1. *Peduncle* is the general term descriptive of a flower-stalk, or a stem which bears a flower or a cluster of flowers instead of foliage leaves. It is the axis of an inflorescence, and as such, is distinguished from the

2. *Pedicel*, or the stalk of each individual flower, forming an unit of the inflorescence.

3. *Scape* is a peduncle rising from the gound; it may bear a single flower as in Water Lotus or an infloresance as in Rajani-gandha *(Polyanthes tuberosa)*. It is a typical reproductive stem with no leaves on it, and is found normally in plants which have no aerial stem bearing foliage leaves but instead have got subteranean stem and radical leaves.

4. *Rachis* is the main axis of inflorescence; it is the continuation of the stem or peduncle through an elongated flower-system; when it becomes short or flattened or globular it is called Receptacle or Head, as in the Sunflower.

FIG. 106. FIG. 107. FIG. 108, 109. FIG. 110.



Diagrams of Racemose inflorescence.
Fig. 106. Raceme. Fig. 107. Spike. Fig. 108. Capitulum.
Fig. 109. Corymb. Fig. 110. Umbel.
Note that the lower flowers open first.

Kinds of Inflorescence. The inflorescence is a modified branch or shoot and as such it mainly follows the laws of branch systems. If the main axis, the rachis or the peduncle, does not terminate in a flower at once but bears a number of lateral branches which develop in acropetal succession, so that, the youngest is nearest the apex and the oldest is the furthest removed, it forms a monopodial and racemose branch system. If then, the lateral axes produce flowers in the same order of succession, so that, they gradually open from the base towards the tip of the main axis, the inflorescence is MONOPODIAL, RACEMOSE, ACROPETAL OR INDEFINITE. It is called INDEFINITE, not because the main axis has an unlimited vertical growth, which it can never have in the reproductive region, but because owing to the acropetal development the growth of the lateral branches is arrested by the formation of flowers at the apex long before it is so with the main axis. The lowest flower buds are the first to open and hence are the oldest, and since the expansion proceeds regularly from below upwards, the inflorescence is also called ASCENDING or ACROPETAL; likewise it is CENTRIPETAL, because when the flower stalks run up to a common level (Fig. 109.)the unfolding of the flowers proceeds from the circumference to the centre. In contrast to this is the Cymose or Definite inflorescence. Here, the main axis as also the lateral branches terminates in a flower which opens first and before the opening of the flowers lower down the axis. In the Cymose type the main axis always becomes outstripped in growth by the secondary axes (Figs. 112.-116.), and these in their turn by the tertiary, and so on. It is called *Definite*, because the growth of the main axis is arrested before that of the lateral axes, by the development of a terminal flower. It will be seen referring to Fig. 116. that the expansions of the flowers proceed down the axis when it is elongated and from the centre to the circumference or *Centrifugally* when the axis is flattened. The simplest case is that of a solitary flower borne upon a peduncle. In some inflorescences of the Cymose type, the axis becomes a sympodium by the one-sided suppression of the branches and bracts as shown schematically in Figs. 112-115. DEFINITE, CYMOSE, CENTRIFUGAL and DESCENDING are almost synonymous terms, so far as regards this inflorescence is concerned.

The Racemose or Indefinite type :—

Primary axis producing a number of lateral branches in acropetal succession, and capable of a stronger development than the lateral axes :—

I. Simple: Lateral axes unbranched:—

A. PRIMARY AXIS ELONGATED :—

1. **The Raceme** :—Flowers stalked (Fig. 106). Ex :—In Mustard (*Sinapis dichotoma*), Bun-bur-buttee (*Phaseolus alatus*), Ghantaruv[1] (*Crotolaria sericea*), Kooch or Ratti (*Abrus precatorius*), Shun[2] (*Crotolaria juncia*), Palas[3] (*Butea frondosa*), the

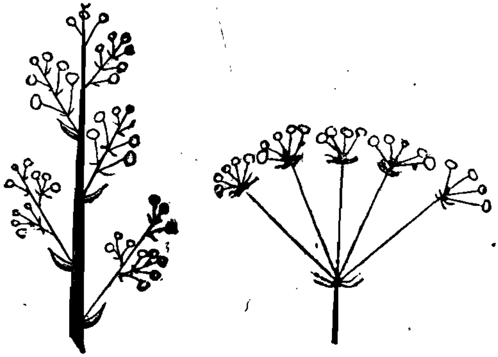
---

[1] Beng. *Peevooli.* [2] Teling. *Chanamoo, Thunjhun.* [3] Teling *Maduga.*

Tamarind (*Tamarindus indica*), Chitra (*Plumbago zeylanica*), Kantikari (*Solanum jacquini*) etc. It is the characteristic inflorescence of many families of plants, *e.g.*, Cruciferæ (Mustard), Capparidaceæ (Hurhuriya—*Gynandropsis pentaphylla*), Scrophulariaceæ (Bhumi-nim——*Gratiola serrata*), Papilionaceæ (Pea, Bean etc.), Ranunculaceæ (Aconite), Orchidaceæ etc.

2. **The Spike** :—Flowers sessile, axis slender. Fig. 107. Ex :—In the common medicinal Bakash, Isupgool (*Plantago Ispaghula*), Dulal-champa, Bhoi-champa (scapes), many Grasses etc. It is common in the Palms, Sedges, in the families Acanthaceæ (Bakash, Kanta-Kalika—*Ruellia longifolia*), Musacæ (Banana) etc.

Fig. 111. A. Fig. 111. B.



Diagrams of Compound Racemose inflorescence.
Fig. 111, A. Compound or Paniculate Raceme.
Fig. 111. B. Compound Umbel with involucres and involucels.

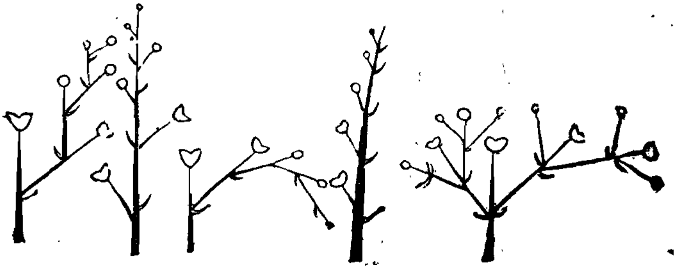
3. **The Spadix** :—Flowers sessile on a fleshy axis—usually spathaceous. Figs. 103, 118. Ex :—In the common Kutchoo, Banana, many Palms, Guj-pippul etc. In Ketuky or Kea the inflorescence is a male spike within a spathe. In the medicinal aromatic Bauch plant (*Acorus calamus)* the spadix is not provided with a bract or spathe. It characterises the family Aroideæ (Kutchoo).

4. **The Catkin or Ament** is a pendent spike which falls off in one piece after flowering or fruiting. It is usually unisexual. Such a deciduous, spicate inflorescence of male flowers is characteristic of the Barua or Puni-juma tree and its family (Salix).

5. **The Corymb** :—It is a raceme in which the lower stalks are elongated so as to bring all the flowers to about the same level. Fig. 109. Ex :—In Euphorbias, Jatropha, Rubiaceae etc.

B. PRIMARY AXIS NOT ELONGATED but growing horizontally, or irregularly so as to form a receptacle or Head.

FIG. 112. FIG. 113. FIG. 114. FIG. 115. FIG. 116.



Diagrams of Cymose inflorescence.
Fig. 112—115. Uniparous Cyme.
Fig 116. Biparous Cyme or Dichasium.
Fig. 112—13. Scorpioid Uniparous Cyme.
Fig. 114—15. Helicoid Uniparous Cyme.

6. **The Capitulum or Head** :—Rachis globular or conical or hollowed out in the form of a cup: Flowers sessile: Ex :—in the Sunflower (Surjamukhi) and Marigold family, the rachis is hollow; in the Kadamba or Kadam (*Anthocephalus cadamba*), it is spherical and solid. The Capitulum forms a distinguishing feature of the family of plants known as Compositæ, to which the Sunflower, Marigold, Koksim (*Vernonia cinerea*), Kusum (*Carthamus tinctorius*), etc., belong. Figs. 108, 105.

7. **The simple Umbel** :—Rachis extremely abbreviated.

Flowers long pedicelled and appear to spring from the apex of the peduncle, as in Fig. 110. The stalked flowers are called rays of the umbel, as they resemble the rays of an umbrella, whence the name of the inflorescence. Ex:—In Mudar (Akanda—*Calotropis gigantea*), Crinum (Shukha-darshan), etc.

8. **Hypanthodium**:—This is an extreme case of a hollowed receptacle and is the distinguishing feature of the Fig. (*Ficus Carica*), and Banyan (Bat or Bür—*Ficus Indica*) tree tribe (*Ficus.*) The diagram (Fig. 120.) represents a vertical section through the inflorescence. The minute flowers are packed closely on the inner surface of the succulent hollow receptacle the top or opening of which is almost closed by minute scales.

FIG. 117.

FIG. 118.

FIG. 119.

Fig. 117. Raceme of *Rununclaceæ*.
Fig. 118. Spadix of *Arum*.
Fig. 119. Helicoid cyme of *Digitalis*.

II. Compound: Lateral axes branched.

Any of the simple types of inflorescence referred to above may be compounded *i.e.*, the Raceme may bear branches which, in their turn, are Racemes or Spikes; Umbels may be aggregated together to form a compound Umbel, Capitula may be aggregated on an elongated axis to give the semblance of a simple Raceme and so on. In descriptive Botany the terms Capitulate raceme, Spicate raceme, Spicate capitulum etc., are much used to describe such compound inflorescence. But a typical compound inflorescene of the racemose type is found where the secondary axes develop branches in the same order as that in which the latter are formed on the main axis.

Panicle is the term applied to a compound inflorescence where the main axis is elongated, the secondary axes are branched, and the ultimate branches are in themselves racemes or spikes. Where the lateral axes of a raceme at once become spikes it is called a Compound spike as in Wheat (*Triticum vulgare*), Ryee, etc. Good examples of Panicles are in the Teak (the well-known Timber plant—*Tectona grandis*), the Mango tree, Khetpapra or Khetra Papra (*Oldenlandia biflora*) Gandha-Bandhuli (*Oldenlandia alata*) and in many Grasses as in the Khus-Khus plant (*Andropogon muricatus*), Ikshu—sugar cane plant (*Saccharum officinarum*) etc.

Compound Umbels, *i.e.* where the rays of a simple umbel themselves bear secondary umbels with a whorl of bracts called involucels at the base of the latter, as shown in Fig. 111. B. form the characteristic inflorescence of the family of plants known as Umbelliferæ (Carrot, Anise, Fennel, Asafœteda plant). It is far more common than the simple umbel. The secondary umbels are called *umbellules.*

Compound Corymbs, *i.e.* a corymbose inflorescence with the lateral peduncles bearing corymbs, are found in many plants of the Family Rubiaceæ. Thus the inflorescence of the Rungan and the Kukurchura (*Ixora*) consists of crowded, or paniculate, or otherwise condensed compound corymbs.

The Cymose or Definite type :—

Primary axis terminating in a flower and branching beneath this flower; lateral axes terminating in flowers and branching like the parent axis—the development of each shoot being stronger than that of the parent from which it springs.

FIG. 120.

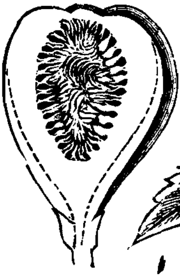


FIG. 121.

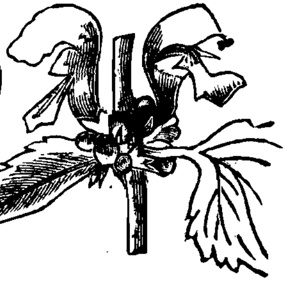


Fig. 120. Hypanthodium of the Fig (*Ficus Carica*) showing the fleshy and hollow receptacle with minute sessile flowers on the inner surface.

Fig. 121. Verticillaster in the axils of two opposite leafy bracts.

Cyme is the general name given to such a system of inflorescence, and the simplest cyme is that where the main axis terminates in a flower and the bracts lower down the axis throw up flowers from the buds potentially existing at their axils in centrifugal succession. (See Fig. 104.).

I. Cymose Inflorescence with a Monopodial axis.

Under this class fall all those flower-clusters of the definite type where a sympodium or false-axis is not formed. Two or more lateral axes are developed beneath each flower ; these in their turn repeat the same order of development.

1. **The Dichasium** :—Lateral axes in pairs, and on two sides of the primary. It appears to be composed of bifurcations, specially when the older terminal flowers of the primary and secondary axes, have fallen off. In many Caryophyllaceæ (the Pink family), this sort of inflorescence is common. In

Karavi (*Nerium odorum*), Gualy-lota (*Cissus Pedata*), Malaty (*Echites caryophyllata*) etc, as also in many Euphorbias, we get good examples of the Dichasial Cyme.

2. **The Polychasium** :—Lateral axes more than two, coming out beneath the terminal flower of the main axis. When an indefinite number of such lateral axes originate, and overtopping the primary axis, grow in an irregular complex manner, it is called an ANTHELA. It is common in the families Scirpus (Keysoor) and Cyperus (Mootha).

3. **The Cymose Umbel** :—In this form a whorl of three or more lateral axes arises from the primary axis, from each of which, again, another similar whorl is developed and in this way the branching proceeds. The system of branches resembles a true Umbel in form, but differs from it in being developed centrifugally. In *Jatropha multifidy*, the Coral plant, such an umbelliferous Cymose inflorescence is formed.

4. **The Verticillaster** (Fig. 121) is a condensed Cyme in which the flowers are almost, if not completely sessile. It characterises the large family of plants known as Labiatæ, (Toolsy—*Ocymum* ; Lavendar etc). In the axils of the opposite leaves of these plants, the flowering buds are opened out, without the formation of a peduncle, into the form of a cluster of flowers. Two such clusters seated in the axils of the opposite leaves, give the appearance of a complete whorl of flowers encircling the stem and form the Verticillaster. In Lal-Bichuty (*Bœhmeria interrupta*), Lal-Kudum (*Urtica globulifera*) and other plants belonging to the family Urticaceæ, the flowers are arranged like those of a Verticillaster but may not have any subtending leaf and generally are more compact. Such a compact and dense cluster of flowers formed by the condensation of a Cyme is called a Glomerule.

II. Cymose Inflorescence with a Sympodial axis.

Here each axis which terminates in a flower bears only one lateral axis below it. A false-axis or sympodium results from the stronger growth and superposition of the basal portions of the consecutive branches; the flower stalks being displaced, appear as lateral members. It may simulate a Raceme or Spike, but its true nature is revealed by the position of the bract leaves which always lie opposite to the flower-stalks on the main axis. It is also called Uniparous Cyme for this one-sided development of the branches.

1. When the constituent axes of the branch-system lie on the same side, whether right or left, it is called a **Helicoid Cyme.** Fig. 119. There is a regular suppression of the axes that are collateral to those that are developed. Examples are found in the Borago family. Hatisoor (*Heliotropium indicum*), for instance, has sessile flowers arranged in double rows on the conxex side of a coiled axis. *Borago indica* (Chota-

FIG. 122.

FIG. 123.

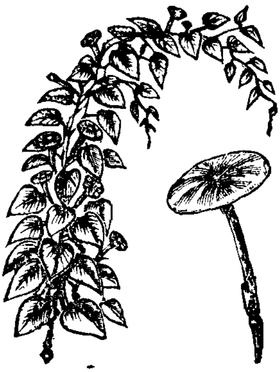


Fig. 122. Cyme of Phlox Drummondii.
Fig. 123. Cyme of Iphomæa Bona-nox (Kulmi-lota); three-flowered peduncles; to the right a single flower.

kalpa), another allied plant common over most part of India, has a similar inflorescence with only one flowered peduncles.

2. When the constituent axes arise successively on the right and left of the preceding axes, it is called **Scorpioid cyme.** Fig. 113. Here the branches are not uniformly suppressed as in the above case, all on one side but alternately on the two sides. The fundamental form is sinuons or like the moving body of scorpion, as it is a helix or coil in the above case; but a stronger growth makes the sinuous structure almost straight, thus producing a sympodium. Instances occur in the Sun-dew (*Drosera rotundifolia*) family already referred to under insectivorous plants. It is difficult to distinguish it from the true Receme, particularly when the bracts also are suppressed.

Summary and Definitions.

1. Inflorescence :—Mode of disposition of flowers.

2. Bract :—The modified leaf of a flower-cluster.

3. Peduncle :—The axis of a flower-cluster or of a solitary flower.

4. Pedicel :—An ultimate flower-stalk; the stalk of a single flower of an Inflorescence.

5. Rachis :—The main axis of an Inflorescence; literally means the back-bone.

6. Bracteate :—Having Bracts.

7. Ebracteate :—Not provided with Bracts.

8. Involucre :—A circle of small leafy bracts subtending a flower cluster (Capitulum or Umbel).

9. Involucel :—The inner involucre of an Umbellet.

10. Paleæ :—Chaff-like bracts; found on the receptacle of the Capitulum.

11. Spathe :—A very large sheathing bract; found in Spadix, Catkin or Spike.

12. Glumes :—The chaff-like bracts of the inflorescence of Grasses.

13. Raceme :—An elongated flower-cluster of the indeterminate type with many one-flowered lateral pedicels which develop and open the flowers acropetally.

14. Spike :—A flower-cluster of the indefinite type in which sessile flowers are arranged on an unbranched elongated axis.

15. Corymb :—A flat-topped inflorescence of the indefinite type with long pedicelled flowers opening centripetally.

16. Umbel :—A flower-cluster of the indeterminate type with the pedicels springing apparently from one and the same point.

17. Head or Capitulum :—An inflorecsence of the indefinite type having a cluster of sessile flowers on a very short or flattened axis.

18. Spadix :—A spike with a fleshy axis.

19. Catkin :—A deciduous unisexual spike.

20. Panicle :—An irregular compound inflorescence produced by the branching of lateral axes in any elongated form of simple inflorescence.

21.Cyme:—An inflorescence of the definite or centrifugal type.

22. Biparous Cyme :—A Cyme of two branches below each branching axis.

23. Multiparous Cyme :—A Cyme producing several branches from each axis.

24. Uniparous Cyme :—A sympodial Cyme having only one axis.

25. Helicoid Cyme :—An uniparous Cyme with flowers all on one side.

26. Scorpioid Cyme :—An uniparous Cyme with two-ranked flowers arranged on alternate sides of the axis.

Classifications.

Inflorescence
- Pure—all of one type.
  - I. Racemose.
  - II. Cymose
- Mixed—of two types combined.

I. Recemose Inf :—
- Simple
  - Axis elongated.
    - Flowers—stalked
      - 1. Raceme.
      - 2. Corymb
    - Flowers—sessile
      - 3. Spike.
      - 4 Spadix
  - Axis short.
    - Flowers—stalked
      - 5. Umbel
    - Flowers—sessile
      - 6. Head or Capitulum.
- Compound
  - Homogenously compound.
    - 1. Compound Raceme
    - 2. Compound Corymb
    - 3. Compound Umbel
    - 4. Compound Spike
    - 5. Compound Head
  - Heterogenously compound.
    - 6. Recemose Heads
    - 7. Spiked Umbels
    - 8. Spiked Heads
    - 9. Panicled Spikes
    - 10. Panicles

II. Cymose Inf :—
- Monopodial
  - Dichasium. or 1. Biparous Cyme
  - Polychasium or 2. Multiparous Cyme.
- Sympodial or Uniparous Cyme.
  - Fls. one ranked on rachis 3. Helicoid. Cyme.
  - Fls. two ranked on rachis Scorpioid. Cyme.

CHAPTER VI.

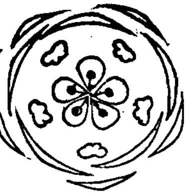
The Flower.

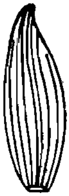
Its nature. It has already been stated that in the reproductive region of the plant the axis or the shoot is transformed into the inflorescence. Buds that appear in the axil of the bract-leaves do not open out in the form of foliage shoots but repoductive shoots. But the floral buds are morphologically homologous with the foliage buds, though physiologically their functions are quite different. Flowers, hence are regarded as modified shoots, the leaves in which develop in special forms to carry on the essential function of reproduction. For the same purpose, also, the floral leaves or at least some of them, become so far metamorphosed as to leave no trace of the leaf-character externally visible, and particularly defined is this metamorphosis in the essential organs of the flowers. The reproductive bodies themselves are called Spores—micro-spores or the male organs, and macro-spores the female—and are formed in chambers called Sporangia. The reproductive leaves of the flower are singularised from the other floral leaves owing to their bearing these sporangia and are hence called Sporophyls. And as there are two kinds of spores,—micro—the male, and macro the female—sporangia and sporophyls are in their turn designated micro—or macro—(with these as prefixes) according as they bear the male or the female sexual organs.

Its parts. Besides the two essential organs for reproduction or sporophyls, there are usually present in a normal and typical flower other structures which, though not directly concerned with reproduction, subserve functions which are *rather subordinate,* but operate with the same end in view.

Thus, the component parts of a flower may be placed under two different categories each having a set of functions peculiar to it, namely, the *axis* and the *appendages*. The floral axis generally remains undeveloped so far as the lengthening of the internodes is concerned, and is called the TORUS or the RECEPTACLE. The appendages borne upon this axis and

FIG. 124. FIG. 125. FIG. 126. FIGS. 127,128. Fig. 129.





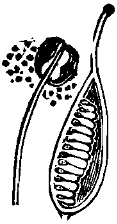


Fig. 124. A typical Dicotyledonous Flower. In the centre the carpels.

Fig. 125. Ground plan of the same—of a pentamerous flower.

Fig. 126. A petal. 127. A Stamen with Anthers bursting—the dots are pollen grains.

Fig. 128. A Carpel cut through showing the Ovary with many ovules, the Style, and the Stigma.

Fig. 129. Ovary cut transversely to show the chamber.

disposed in general accordance with the laws of phyllotaxis are very early differentiated in the bud into an outer series of leaf-like expansions, occupying the lower part of the axis and forming the protective envelope of floral leaves, and an inner series of delicate thin and elongated structures, crowded on the upper or terminal part of the torus, forming the essential organs of the flower. The floral leaves collectively are called the PERIANTH; the essential organs, the SPOROPHYLS. The perianth, again, is usually divisible into two parts—the outermost whorl of green segments called SEPALS, forming the CALYX, and the inner whorl of coloured leaves or PETALS constituting the COROLLA. Of the sporophyls those that bear the male sexual organs are individually called the STAMENS and collectively the ANDRŒCIUM ; and those that bear the female, are similarly called the CARPELS and collectively the GYNŒCIUM or PISTIL.

Thus the parts of a typical flower arranged in a table are :—

1. Floral axis or Torus.
2. Appendages

(*a*)	Floral envelope or Perianth	External whorl—Calyx ; its leaves are sepals. Second whorl—Corolla ; its segments are petals.
(*b*)	Reproductive organs or Sporophyls	Male sexual organs or Andrœcium ; its parts Stamens. Female sexual organs or Gynœcium ; its parts Carpels.

The male Sporophyls or Stamen consists of a long and slender stalk called the FILAMENT, and a swollen portion borne upon it at the apex called the ANTHER. The Anther is really a collection of microsporangia called pollen-sacs, and consists of two, more usually four, chambers in which the male reproductive Spores, the pollen grains, are formed.

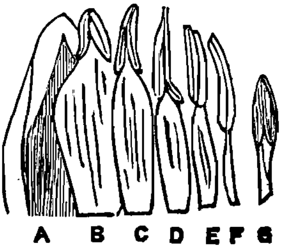
The Gynœcium, or the collection of macrosporophyls, that is, reproductive leaves bearing female spores, usually forms a single body by the congenital union of its constiuent carpels. In such cases it is composed of three parts, namely, a hollow inferior part seated on the torus, called the OVARY, a terminal part rendered sticky by secretions, called STIGMA and a filiform stalk connecting the two, called STYLE. In the interior, the ovary develops generative surfaces called PLACENTAS from which the *macrosporangia*, the OVULES, originate. The gynœcium, again, may consist of separate carpels each of which may then be differentiated into an Ovary bearing Ovules, the Style and the Stigma.

Before going into the description of the floral parts further in detail it will be instructive to give here the evidences that have been brought forward to prove that **the Flower is a Modified Shoot.**

1. *As to position* :—Flowers generally occupy the place of ordinary leaf buds, i. e. axils of leaves which may be modified into bracts.

2. *As to phyllotaxis* :—The disposition of floral organs on the receptacle follows the same law of distribution as that of the leaves on branches. The parts of the flower, particularly the sepals and petals, are either in whorls or in spirals ; as in the case of leaves, their order of development is strictly acropetal i. e. as a rule, the sepals are formed before the petals, petals before stamens and these in their turn develop before the carpels. Yet, again, they follow the general rule of alternation, that is, the sepals alternate with the petals, the petals with stamens etc. If lines be drawn as radii from the centre of a flower, it will be

Fig. 130. Fig. 131.



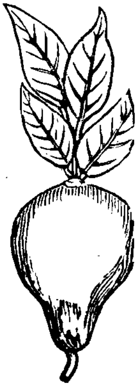


Fig. 130. Floral leaves of Water Lily—showing the gradual transition from Petals to Stamens (F, G)

Fig. 131 A monstrous Pear showing the prolongation of the thalamus into a leafy shoot.

found, that the sepals and stamens are in one line, likewise the petals and carpels. This however takes place in the typical ideal flower where, as explained, the stamens are *antisepàlous* and the carpels *antipetalous*.

3. *As to transitional forms* :- The change from the leaf to the carpel is indeed very wide. Generally the successive changes from foliage leaves to bract, and from bracts to the perianth segments, and thence again to the essential organs, are quite abrupt. But, in certain cases, the transition is very gradual and shows the real morphological nature of the flower. Thus for instance, in Water Lilies (Padma, Shalook, etc) it is found that the outermost set of the series of whorls that may be taken as the Calyx is composed of parts or Sepals that are quite leaf like. Those next above become partly coloured, usually on the inside, and then gradually by very slow changes, pass into the coloured Petals. The Petals, again, do not form strictly defined whorls ; for they also pass very gradually into the Stamens the outer most whorl of which are petaline in texture with small Anthers at the top. These facts clearly prove that the Stamen is a metamorphosed Petal and that the latter is a metamorphosed leaf, that in short, the flower is a metamorphosed shoot. Similar petaline stamens can be seen in our garden plant Sarvajaya (*Canna Indica*). Again, in many cases the calyx becomes highly coloured so that it vies with the corolla and may usurp its function. An example of highly coloured petaline bracts has already been given in page 102.

4. *As to monstrous and proliferous growths* :—By long cultivation many flowers have undergone a *retrogression* in the formation of its reproductive organs. In the *Double Rose* of our gardens the usual place of the stamens, and sometimes of the carpels also, is taken up by additional whorls of petals, or those that are mere degenerated carpellary or staminal leaves. In some European Apple trees the petals form minute green sepals and the outer stamens are converted into carpels.

Even in some of our garden Poppies, there are occasionally found some small stalked pistils taking the place of some of the stamens.

Prolifications, i. e. abnormal growths in the shape of flower within a flower, a shoot growing at the top of a fruit are not quite uncommon. Dr. Masters has mentioned a case of flower coming out of the axil of a Stamen in a species of Water Lily (Nymphæa Lotus). Such cases point clearly to the fact that the floral parts being metamorphosed leaves, the apex of the Torus or Receptacle may grow out through the flower in the form of a vegetative shoot or that axillary buds from the base of staminal leaves may, as in the above case, be developed.

The Floral Phyllotaxis :—Adopting the doctrine that floral organs are modified leaves, it is easy to understand that parts of the flower are symmetrically placed round the axis ; and that this is due to phyllotaxis. In many flowers, notably in those of Nymphæa (Shalook) and Nelumbium (Padma) the floral members are clearly arranged spirally on the Receptacle ; such flowers are called *acyclic*. Again, in those containing a a large number of members the ordinary $\frac{2}{5}$ and $\frac{3}{8}$ phyllotaxis of the shoot, also occur. But in most flowers the members are arranged in whorls, and consistent with the whorled phyllotaxis of foliage, they are always found to alternate, *i.e.* the whorl of petals always stands above the intervals of the whorl of sepals and below that of the Stamens. This arrangement in the case of floral organs is called *cyclic* and is by far the most common. Consequently the members of successive whorls will be equal in number and such a flower is called *Isomerous*. In a cyclic and isomerous flower the Stamens are antisepalous and the Carpels antipetalous.

The number of members in the different whorls though showing every stage of variation, is always typically three in a Monocot, and five in a Dicot ; but the number of whorls present in a complete flower, that is one containing all the four floral organs, is typically five ; one each for Calyx, Corolla, and Gynœcium and two for the Andrœcium. This is expressed when we say that flowers are *tri-merous penta-cyclic* in Monocots and *penta-merous penta-cyclic* in Dicots. As in Phyllotaxis, so here,the arrangements of the floral leaves can be best represented by means of diagrams where the successive cycles or whorls are projected on a horizontal plane. Thus in the diagrams (Figs. 124, 125) the Calyx lies externally ; and the Gynœcium being the uppermost series of organs lies most internally.

Floral Diagrams.—The relative position and arrangement of the parts of flower may be best shown in diagrammatical drawings called Floral Diagrams. These represent vertical and transverse sections of the flower, and will, when properly drawn, show the number, the form, size, æstivation,

FIG. 132.

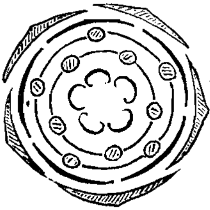


FIG. 133.

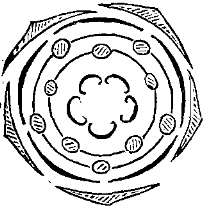
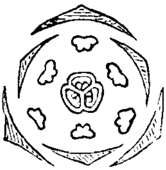


FIG. 134.



Figs. 132, 133. Pentamerous Pentacyclic Flowers. (Dicots)

Fig. 132. Diagram of Typical Flower with Obdiplostemonous Stamens.

Fig. 133. The same with Diplostemonous Stamens.

Fig. 134. Typical Floral Diagram of Monocot—Trimerous pentacyclic. Diplostemonous Stamens.

cohesion etc, of its parts. As will be seen from the following figures, the trimerous character of the Monocot flower is kept up all through the number of whorls ; but, as a rule, in Dicots the number of carpels is much smaller. As a rule, also, the Monocot Andrœcium consists of two whorls of three stamens ; and in Dicots the Andrœcium rarely conforms to the typical two whorled character. The typical Androecium of two alternating whorls standing in front of the Calyx and Corolla respectively is called *Diplostemonous* ; when they do not alternate with the Calyx and Corolla regularly, *i.e.*, when the first or outer whorl is opposite the Corolla and the second or inner whorl opposite the Calyx, the arrangement is called *obdiplostemonous*. Where, however, it is formed of a single complete whorl, the Androecium is *Haplostemonous*.

Modifications of the Floral Structure.—

The Typical Angiospermous flower is—

(*a*). Trimerous in Monocots ;
Pentamerous in Dicots ;
(*b*). Pentacyclic ;
(*c*). Isomerous ; and
(*d*). Diplostemonous.

But the *symmetry* or *regularity* of a flower may be lost through various modifications in the floral members. A *regular* flower can be divided by *any* vertical section into two similar halves—that is, where one is the exact reflection of the other. The terms used in describing flowers with regard to the symmetry are,—

1. **Actinomorphic** flower is regular in the above sense ; it is also called *radially symmetrical* for the different halves produced by any longitudinal section are all alike.

2. **Zygomorphic** flower can be divided into two similar halves by only one vertical section. It is also called *Monosymmetrical* for there can be only one *plane of symmetry*, as the dividing plane is called. Unequal or dissimilar halves are produced when it is divided by other planes.

3. **Asymmetrical** flowers are those which cannot be divided into similar halves by any plane whatever ; as, for example in Canna (Sarvajaya ; *Teling* :—Kristma-tamara).

The various causes that have led to the countless diverse modifications of the flower may be arranged under the following heads :—

1. *Abbreviation* of the floral axis.
2. *Cohesion* of parts of a whorl.
3. *Adhesion* of parts of different whorls.
4. *Suppression* of members of a whorl.
5. *Multiplication* of members of a whorl.
6. *Displacement* of parts of whorls.
7. *Enations* or outgrowths.
8. *Metamorphosis* of floral parts.

Amplifications and examples of these will be found in the following chapters and floral diagrams.

FIG. 135.

FIG. 136.

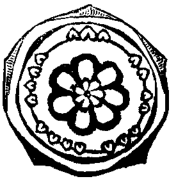
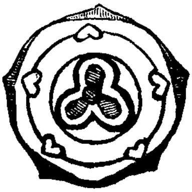


FIG. 137.



Floral Diagrams of Dicots :—

Fig. 135. Diagram of Poppy flower. Perianth Dimerous, consisting of two sepals and four petals ; stamens and carpels—a large number (multiplication).

Fig. 136. Diagram of Orange : Stamens in 5 bundles, (Multiplication or Splitting).

Fig. 137. Diagram of Celosia (cockscomb) : Perianth of 5 leaves in one whorl, the other whorl being suppressed : Stamens, one whorl of 5. Gynœcium of 3 coherent carpels (suppression or reduction and cohesion).

FIG. 138.

FIG. 139.

FIG. 140.

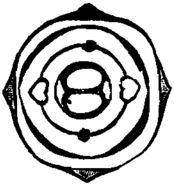


FIG. 141.

Floral Diagrams of Dicot Flowers.

Fig. 138. Diagram of *Cucumber:* Perianth—two whorls of calyx

and corolla; pentamerous. Andrœcium suppressed. Gynœcium, of three carpels (Cohesion). (Of the female flower).

Fig. 139. Diagram of *Sunflower* (Compositæ): Perianth—calyx almost suppressed; represented by the dots; corolla pentamerous. Andrœcium pentamerous, haplostemonous, Gynœcium Dimerous, of two carpels (cohesion and reduction).

Fig. 140. Diagram of the *Jasmines* (Oleaceæ): Perianth tetramerous. Andrœcium Dimerous (2 suppressed—shown by the dots). Gynœcium—dimerous, of two carpels (cohesion and reduction).

Fig. 141. Diagram of *Manjeet* (Rubiaceæ): Perianth—Calyx almost suppressed (only 4 notches, shown by the dots); corolla tetramerous. Andræcium tetramerous, haplostemonous. Gynœcium Dimerous (Reduction and cohesion).

FIG. 142.

FIG. 143.

FIG. 144.

FIG. 145.

Diagrams of Monocot Flowers.

Fig. 142. Trimerous pentacyclic flower of *Scirpus*; Andrœcium haplostemonous. Perianth reduced. Inner whorl of stamens suppressed.

Fig. 143. Diagram of *Canna*. Trimerous pentacyclic. Andrœcium—the 3 outer suppressed; the two inner modified into petals; only one fertile.

Fig. 144. Diagram of *Alpinia* (Poonang champa or Tara). Andrœcium suppressed (the outer whorl of three) and modified (two of the inner whorl): only one fertile.

Fig. 145. Diagram of *Banana* (Musaceæ): with the exception of a suppressed stamen (marked ×) the structure is typically trimerous pentacyclic.

CHAPTER VII.

The Floral Members.

The Floral Axis properly called the **Torus** or **Receptacle** but usually the **Thalamus** is the extremity of the floral stem, on which the floral organs grow in the same manner as leaves on the stem. The simplest form of the Thalamus is the conical, the internodes between the successive whorls of floral organs being but very poorly developed. Except in Conifers and Cycads where it is sometimes greatly elongated, in most flowers the internodes are rarely distinguishable on the abbreviated floral axis. In Magnolia, Michelia (Champak); Strawberry and a few other cases, the elongated or conical form of the Thalamus is maintained. But it is deeply concave or bowl-shaped in the Rose (Fig. 135), Myrtle and other plants belonging to the families Rosaceæ, Myrtaceæ (Jams :—Eugenia Jambolana, Jamrool :—*E. Alba*), and Umbelliferæ (Carrot, Dill etc). Between the elongated form and the hollow concave bowl, there are various gradations.

Thus the arrangement of the floral organs on the Thalamus is called

Hypogynous, when all the different parts of the flower stand freely on the conical, convex or at least flat receptacle in tiers. The term literally denotes that the other floral structures stand below the Gynœcium (Hypo = under) which occupies the topmost part. Fig. 146

Perigynous, when a flat floral axis is sunk a little in the centre so that its sides grow up as a rim, making it look like a saucer and the Calyx, Corolla, and Stamens are borne on the annular margin with the carpels in the centre. It is so called because the three outer floral organs stand not *below* but *round about* the Gynœcium (Peri = around) Fig. 147.

Epigynous, when a deeply concave floral axis bears the Gynœcium in the cup, so that its sides become fused with those of the Carpels and all the other floral parts are inserted on the Gynæcium. (Epi = upon) Fig. 148. The Carpels, which in the above case (perigynous) form the whole wall of the ovary, (Fig. 147.) spring in this case (epigynous) from the inner surface of the concave Thalamus, and only close up the cavity above where they develop the style and stigma. From the relative position of the ovary, it is called *superior* in the hypogynous flower, and *inferior* in the epigynous.

FIG. 146.

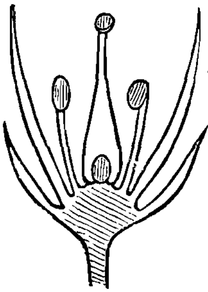


FIG. 147.

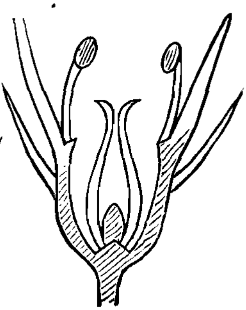


FIG. 148.

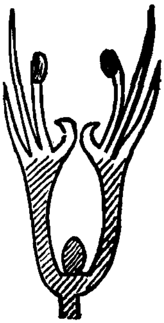


Fig. 146. Hypogynous. Fig. 147. Perigynous. Fig. 148. Epigynous Flowers.

Hypogynous flowers form the characteristic feature of a large number of plant-families, *e. g.* Papaviraceæ (the Poppy-family) Ranunculaceæ (the Aconite family) Nymphæaceæ (Lotus family) and generally of all those that fall under the great sub-class of Dicots—the Thalamifloræ. Perigynous flowers characterise the families Rosaceæ (the Rose family), Myrtaceæ, Rhamnaceæ (the Kul or Byar—*Zizyphus*—family) etc; and the Epigynous, those known as Umbelliferæ (carrot) Cornaceæ, Rubiaceæ (*Ixora*—Rungun, Kookur-chura) etc.

Peculiar Forms of the Thalamus.—In some cases the potential internodes of the thalamus become developed into elongated structures. As regards terminology,

1. *Stipe* is the general name of a stalk or elongated internode of the floral axis.

Fig. 149.

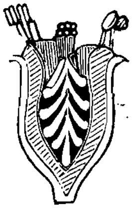


Fig. 150.

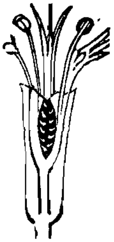


Fig. 151.

Fig. 152.

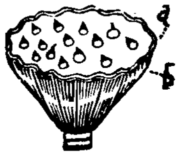


Fig. 149. Concave hollow thalamus of Rose. Note the Perigynous Stamens.

Fig. 150. Anthophore of *Pink.*

Fig. 151. Elongated torus of Geranium showing the mature fruit bursting away.

Fig. 152 Fleshy flat topped torus of Water Lily with carpels sunk in it.

2. *Gynophore* is the stalk that is interposed as an elongated internode between the carpels and the stamens—it is the stalk of the Gynœcium. The term Gonophore is applied to the stalk which elevates the carpels from the stamens and both from the perianth, as in *Gynandropsis heptaphylla* (Hurhurria). The gynophore of the Lotus (Fig. 152) is enlarged into a large flat-topped fleshy mass, on the upper surface of which a large number of isolated carpels are distributed.

3. *Carpophore* is the elongated terminal internode of the thalamus, which is prolonged between the constituent carpels of the gynœcium as a central axis, as in Geranium (Dopaty or Domooty), and in many Umbelliferæ.

4. *Anthophore* is the elongated floral internode between the calyx and corolla, as in the Pink family, Fig. 150

5. *Gynobase* is the short, thick stipe in the flowers of the orange family, on which the gynœcium rests.

The Perianth.

The floral envelope or the Perianth consists of two parts —the outer whorl of green leaves called Sepals and an inner whorl of usually coloured leaves called Petals. The whorl of sepals, whether free or united, is called the Calyx ; that of the petals, the Corolla. In most Angiosperms the Perianth is differentiated into the calyx and corolla. But there are quite a number of cases where the calyx or corolla or both may be wanting. Thus.—

1. **Achlamydeous** flowers are those wherein the perianth is altogether wanting ; the whole flower being reduced to the essential organs of reproduction. In the kutchoo and other Aroids, the spadix is occupied by clusters of minute flowers— of which the lower ones consist of female and the upper of male sexual organs only. The flowers are thus both unisexual and Achlamydeous. *Pothos officinalis* (Guj pippul) another Aroid, has on the other hand hermaphrodite flowers each with a perianth of six leaves. Again, in the amentaceous flowers of the Pepper family (Piperaceæ :—*Chavica Betle*, the Betle plant ; *Piper nigrum*, the Black pepper or murich) the perianth is wanting, the flowers are unisexual and borne in the axils of minute scales. When, as in the case of Pothos, the perianth consists of leaves all alike without any distinction between calyx and corolla it is called

2. **Monochlamydeous**. In such flowers there is either a reduction or suppression or metamorphosis of the whorls— calyx or corolla. Flowers consisting of only one undifferentiated whorl of floral envelopes are found as a characteristic feature in many families ; such for instance, as in Chenopodiaceæ (Palung), Urticaceæ (the Fig family) etc., where the perianth is scaly or chaff like or not coloured. Coloured and

corolline monochlamydeous perianth occurs in the families Nyctaginaceæ, Amarantaceæ, Liliaceæ etc. Mirabilis Jalapa the common 4 o'clock plant has flowers of variegated colours —white, crimson, yellow or a mixture of these or spotted. The perianth arises as a tube or funnel from the axils of a whorl

FIG. 153.

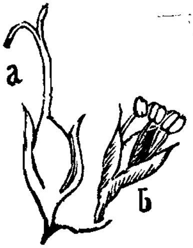


FIG. 154.

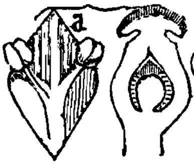


FIG. 155.

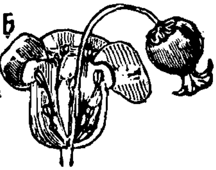


Fig. 153. Unisexual Flowers of the Fig. The Perianth monochlamydeous.

Fig. 154. Achlamydeous Flowers of Piper (cubeb).

Fig. 155. Inflorescence of Euphorbia, the cup-shaped structure is not perianth but involucre (Bracts). In the centre a Female flower around which are the Male flowers.

of 5 green bracts which must not be mistaken for a calyx. *Basella*—the succuleut climbing herb known in Bengal as Poin-shak—has a similar petaline perianth. In *Celosia* (morugphul—the cockscomb) the flowers have very bright and coloured perianths which make the whole clustered and crested spikes appear as golden, crimson or purple coloured cock's comb. Petaloid perianth forms the characteristic feature of Liliaceæ to which our Aloe (Ghrita kumari), Onion (*Allium cepa*), Asparagus (*A. racemosa*—satamuli) etc., belong. In *Ricinus communis* (the castor-oil plant) similarly, the perianth consists of only one whorl of sepaline leaves, the corolla being suppressed.

3. **Dichlamydeous** flowers are those where the perianth is differentiated into calyx and corolla, as in most Dicots and in some Monocots. They are called *heterochlamydeous*

when the calyx and corolla stand out prominently as differently coloured whorls, and *homochlamydeous* when, as in Palms, the two whorls are almost alike in colour.

Modifications of the Perianth. Deviations from the leaf-like character of the perianth segments occur in some cases. These are due to various causes which will be referred to subsequently. For examples, the imperfect perianth of Grasses consists of two or three dry scales called *Lodicules*; the calyx of Compositæ (Sun flower, Marigold etc) is usually transformed into a tuft of delicate threads called *Pappus*; in Aconite, Nasturtium, Geraniaceæ (Dopaty or Doomuthy) some of the perianth members are modified into hood-like structures or tubular beak-like sacs. These are called *Nectaries* on account of the sweet liquid secretion which is usually collected in them.

FIG. 156.

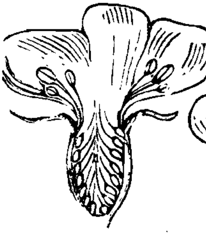


FIG. 157.

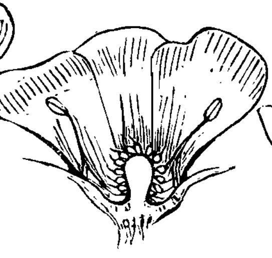


FIG. 158.

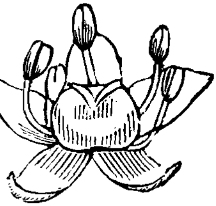


Fig. 156. Dichlamydeous flower of Rose. Thalamus hollow, from the surface a number of Pistils.

Fig. 157. Dichlamydeous flower of Strawberry. Pistils on the club-shaped receptacle.

Fig. 158. Monochlamydeous flower of Chenopodium. In the centre the Pistil.

Union of parts.—Whether the perianth consists of one or two whorls, the members of each whorl may become fused so as to form a single body. Cups, bells, tubes, saucers and other analogous forms may thus arise from their union. The prefix *gamo*—or *sym*—added to the terms petal and sepal indicates the state of such an union. Thus a *gamosepalous* Calyx is composed of coherent sepals; a *gamopetalous* corolla of coherent petals. In contrast to this state of union the free, ununited condition of the floral envelopes is denoted by the prefix *poly*-or *apo*; thus polysepalous calyx and polypetalous corolla are those where the sepals and petals respectively are free. It sometimes happens, notably in Monocots that two perianth whorls—those of the sepals and petals—coalesce into a single tubular or funnel-shaped form, so that the distinction between calyx and corolla is obviated. In *Crinum asiaticum* (Sookh-darshan), for instance the large white flowers have only corolline perianths with six segments in the border which speak of its coherent character.

The Calyx—The constituent parts of the Calyx, the sepals, are almost without exception sessile that is they are not stalked. Primarily the Calyx is of two sorts—*polysepalous* and *gamosepalous* or, in other words a Calyx may be composed of sepals either all united into a coherent body or free. A *polyphyllous* (*i.e.* composed of ununited phyllomes) Calyx is *disepalous*, *trisepalous*, *tetrasepalous* *pentasepalous* and *polysepalous*, according as the number of sepals present in the whorl is two, three, four, five, or more. Thus, the Calyx of the Poppy and plants belonging to its family (Papaviracæ) consists of only 2 sepals and hence it is disepalous. The Calyx of the Mustard and other plants of the same family (Cruciferæ) is composed of 4 sepals and hence, tetrasepalous. In general, the Dicot calyx is composed of 5 sepals or is pentasepalous; the Monocot, trisepalous. And even when the Calyx is gamophyllous, little notches, indentations or lobes present on its border or open end, indicate the number of sepals which has formed it. Thus in Rubiaceae (munjeet) the calyx is generally very small, cup shaped, and cut into 4 notches at the border; it is a tetrasepalous gamophyllous calyx. In Malvaceae (Java, Simul, etc) the gamophyllous calyx is valvate in the bud and when it opens out the border is seen to be five-cleft. Usually however the terms disepalous, trisepalous etc are not applied to the gamosepalous calyx which is better described as 2-cleft, 2-parted, 2-notched or by similar expressions. The part of the gamosepalous calyx widely incised at the border and just above the tube formed by the coherence of the sepals is called the *throat* or *faux*.

The position of the Calyx deserves mention. In a hypogynous flower it is naturally below the ovary and other floral organs; it is then called *inferior* or *free* and the ovary is *superior*. But in Epigynous flowers since all other floral members take their origin from the confluent head of the ovary and thalamus, the calyx is situated *upon* the ovary and hence, is called *superior*, the ovary being inferior. In perigynous flowers, on the other hand, a gamosepalous calyx becomes generally fused with the thalamus and the walls of the ovary; when this takes place the calyx is said to be *adherent*. It is found, for example in the families Compositæ and Myrtaceæ.

Duration of the Calyx. Like the leaves, the duration of the perianth whorls varies greatly in different plants. Thus the calyx is—

1. *Caducous*—when, as in the Poppy, it falls off as soon as the flower-bud opens.

2. *Deciduous*—when it remains on the thalamus till the Corolla falls off.

3. *Persistent*—when the calyx remains even after the corolla has fallen off. A persistent Calyx may simply remain as a crumpled dry appendage or may take part in the formation of the fruit. In *Dillenia* (Chalta) Plantain and Guava (*Psidium guava*) the calyx grows along with, the fruit and enveloping the latter forms a thick or hard rind. Such a calyx is called

Marcescent.—In *Physalis* (Tepari), on the other hand, it grows during the maturation of the fruit into a bladder-like expansion which it completely invests and is then called

Accrescent.—Other examples of the persistent calyx we find in *Trapa* (water chestnut—*paniphal*), where the horns of the fruit are formed by the lignification of the Calyx teeth; in the *pappus* of Compositæ, the persistent calyx is modified into scales, bristles or hairs or other feathery structures; in the Apple, Pear, Water melon and Cucumber the adnate Calyx growing with the fruit forms a firm rind; that is it is marcescent. It should be observed that the accrescent calyx is outwardly not recognisable as having once been a simple calyx, but in Guava, Dillenia and other fruits having a marcescent calyx the tube only of the latter becomes adherent and hard while the calyx-lobes or parts assume a shrivelled and withered appearance.

6. *Operculate*—when, as in the case of the Datura (*D. Strammonium*—the Dhutra), the lower part of the calyx is persistent and remains attached to the fruit and the thalamus while the upper part separates by a transverse and circular slit it is called *operculate* or *calyptrate*.

Forms of Calyx.—

1. When the sepals are free, the Calyx is *polysepalous*. When they are equal on size and form and are arranged symmetrically about the axis or thalamus, the Calyx is *regular*.

2. When the sepals are united, the Calyx is *gamosepalous*. A gamosepalous Calyx may be REGULAR of which there are several forms:—

(*a*). *Tubular*—an elongated Calyx with sides running almost parallel.
(*b*). *Campanulate*—*i.e.* a bell shaped Calyx.
(*c*). *Infundibuliform*—*i.e.* funnel shaped.
(*d*). *Urceolate*—*i.e.* expanded in the middle and narrowing towards base and apex.
(*e*). *Inflated or globose*—*i. e.* shorter than above and almost globular.

3. Of the forms of the IRREGULAR Calyx the following **are** the most important.

(*a*). *Galeate* or *hooded—i.e.* one or more of the sepals form a helmet-like structure arching over the other parts, as in Aconite (Kat-bish.)

(*b*). *Spurred—i.e.* one or more of the sepals of the polysepalous or a part of the gamosepalous Calyx prolonged downwards into a tubular process, as in the Garden Nasturtium.

FIG. 159. FIG. 160. FIG. 161. FIG. 162. FIG. 163. FIG. 164.

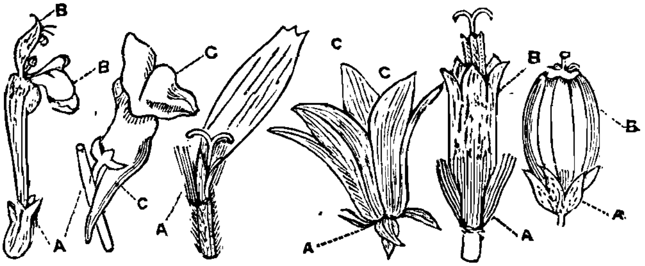


Fig. 159. Bilabiate Corolla. A, the calyx; B, the lips of the corola. A Bifid stigma below the upper lip.

Fig. 160. An irregular gamopetalous corolla,—Personate. Note spur (c). (Of Scrophulariaceæ).

Fig. 161. Ligulate Corolla of sunflower. Calyx-pappos. Stigma-bifid.

162. Campanulate or Bellshaped Corolla.

163. Tubular Corolla of Compositæ. Calyx with pappus. Style, befid.

Fig. 164. Urceolate corolla.

A—calyx.

B and C—Corolla.

(*c*). *Saccate—i.e.* pouched and dilated at the base, as in Salvia.

(*d*). *Gibbous—i.e.* with a shallow pouch at the base, as in many Cruciferae.

(*e*). *Labiate* or *Bilabiate—i.e.* irregularly drawn out on each side so as to form two lips; it is gamosepalous and characterises the family Labiatæ (Toolsy : Podina : Salvia etc).

The leaves of the Calyx, the Sepals, are usually exstipulate ; but in certain flowers, specially in those belonging to the Rose family (Rosaceæ) the stipules of the sepals form a whorl. Such an outer series of small sepal-like structures, standing just below the sepal is called the *Epicalyx*. An almost similar whorl is also invariably found in the Java family (Malvaceae :—Simul cotton, Mallow etc) ; but here the epicalyx is an aggregation of bracts as in the involucre.

The Corolla :—It is the most attractive part of the flower owing to its often brilliant colouring. Its duration may be like that of the Calyx—thus, it is caducous in many poppies ; but usually it remains so long as fertilisation has not taken place. Its main function is to protect the reproductive organs during the early stages of their formation and to invite insects and other small winged animals to effect pollination. In many flowers, however it forms only an insignificant part, for example, in grasses. Like the Calyx, the Corolla may be polypetalous or gamopetalous, regular or irregular. In a regular polypetalous Corolla the petals are equal in size and form and are symmetrically arranged on the axis, as in Poppy. Lotus, Magnolia, Rose etc. An irregular Corolla, whether gamopetalous or polypetalous, results from the unsymmetrical growth of its parts. Of the regular polypetalous corolla the following are the more important forms :—

A. Forms of Polypetalous Corolla :—

I REGULAR :

1. *Cruciform or cruciate :* a corolla of four similar petals arranged in the form of a cross ; it is characteristic of the Mustard family of plants (cruciferæ).

2. *Rosaceous* : a corolla with roundish and spreading petals, as in Rose and its family. The petals are 5.

3. *Caryophyllaceous :* a corolla with 5 long-stalked petals which spread out their lobes above and are enclosed below within a tubular calyx, as in the common garden Pink and its family (Caryophyllaceæ).

4. *Liliaceous*: a corolla of 6 perianth segments **arranged** on the thalamus so as to give the appearance of a funnel, **as** in the common Lily and Tulip.

II IRREGULAR :

5. *Papilionaceous*: it is the peculiar irregular corolla of the pea and all plants belonging to its family (Papilionaceæ). It consists of 5 petals, one large, called the *Vexillum* or *standard*, two lateral—*wings* or *alæ*, and two lower, fused to form a boat shaped structure called the *karina* or *keel*. The name comes from its supposed resemblance to a butterfly.

FIG. 165. FIG. 166. FIG. 167.

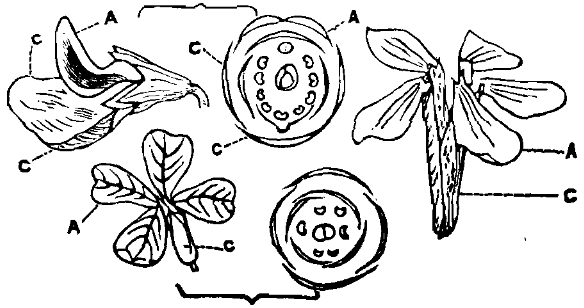


Fig. 165. Papilionaceous Corolla of Pea. A, the vexillum. To the right the cross section. Æstivation, vexillar.

Fig 166. Cruciform flower of mustard. C, the calyx. A, the Corolla.

Fig. 167. Caryophyllaceous Corolla, the petals are clawed (c) and spreading above (A).

B. Forms of Gamopetalous Corolla :—

I. REGULAR :

1. *Tubular*: a corolla nearly cylindrical. as in the disc-flowers of many Compositæ (Surjamukhi, Genda etc).

2. *Rotate*: a corolla with no limb or tube, but spreading widely from the very base, as in the Brinjal (Begun—*Solanum Melongena*), Potato (*S. tuberosum*), Tepari (*Physalis*) etc.

3. *Campanulate* or *Bellshaped*: a corolla rounded at the

base and gradually expanding out so as to appear as a bell the sides being slightly divergent ; the length of the tube is not more than twice the breadth. Ex. in some Solanaceæ and Campanulaceæ.

4. *Infundibuliform* or *Funnel-shaped :* a corolla having the appearance of an inverted cone, like a funnel, as in the Tobacco (*Nicotiana Tabacum*). Here the sides of the tubular limb, gradually diverge away very widely at the top, as in Datura (Dhutra--*D. strammonium*).

5. *Hypocrateriform* or *salver-shaped* : a corolla with a long narrow tube spreading out at right angles at the top like a saucer, as in the Kalmi-lota (*Ipomea*), Kunja-lota (*Asclepias odoratissima*), Gool fering (*Vinka Rosea*), the Indian Jasmines (Jui, Mallika etc).

6. *Urceolate :* a corolla swollen in the middle and narrow at base and contracted in the month, as in many Ericaceæ, specially in *Vaccinum.*

II IRREGULAR :

1. *Ligulate* or *strap-shaped :* a corolla tubular and narrow at the base and opening out as a flattened expansion. The tube appears to split open on one side and diverge away on the other. The Corolla here is composed of three or five petals all fused into a tube, the upper part only bearing three or five notches which point to the gamophyllous character : otherwise it simulates a single petal. It is common in the ray flowers of many Compositæ as in *Helianthus annus* (Surjamukhy).

2. *Labiate, Bilabiate* or *Lipped :* a corolla having its expanded portion divided into two lips (superior and inferior) one of which is generally more prominent. The upper or superior lip is usually composed of two fused petals and the lower or inferior of three, though the reverse is also found. It gives the name to the family of plants known as Labiatæ in which it occurs as a distinguishing feature.

3. *Ringent* : it is a bilabiate Corolla with the lips widely open, as in Bakash (*Justicia Adhatoda*), Hule-Khusa (*Phlomis*)

and many plants of the families Labiatæ, Acanthaceæ and Verbenaceæ.

4. *Personate* or *masked*: it is a bilabiate corolla with the throat or opening closed by a projection of the lower lip called the *palate*. It is common in the herbaceous plants of the family Scrophulariaceæ.

5. *Gibbous* or *Saccate*: a personate or ringent Corolla with a pouch like expansion at the base, as in Pathur-Choor (*Plectranthus*).

FIG. 168.

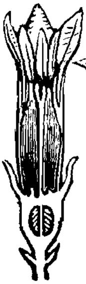


FIG. 169.

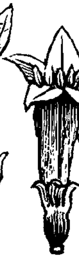


FIG. 170.

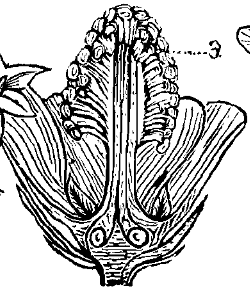


FIG. 171.

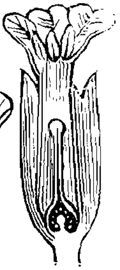


Fig. 168. Longitudinal section through a tubular flower (epigynous). Stamens, epipetalous.

Fig. 169. The same—Entire.

Fig. 170. Longitudinal section through a flower of Java. Stamens monadelphous and epipetalous.

Fig. 171. Longitudinal section through a flower of Primrose. Hypogynous structure. Stamens, epipetalous.

Modifications and appendages of the Corolla.—A foreshadowing of these have already been noticed in the Labiate, Ringent, Saccate etc., corolla. Petals, in case of polyphyllous corolla, and parts of the tube of the gamophyllous are frequently suppressed, transformed into pouch-like reservoirs called Nectaries, where honey is secreted, or prolonged into spurs or hoods and modified in various other ways. A departure from the usual sessile nature of the floral leaves is found in the petals of Caryophyllaceous flowers. The stalk of the petal, corresponding to the petiole of the leaf is called the *Unguis* which means a claw, and the flower with stalked petals is called Unguiculate. The expanded part of the petal above this claw is the *limb*. Unguiculate corollas form the characteristic feature of many plants *e.g.*, in the Henna family (Lythraceæ—*Lawsonia inermis*—menthy or mendy), and in the Pink family (*Dianthus*—Caryophyllaceæ). In Passiflora (Passion flower—Jhumkolota) a whole series of ligule-like structures arises from the throat of the corolla, enhancing the beauty of the large blue flowers. This is called the *corona*. In the Daffodil, Borago, and many other plants having a gamopetalous corolla the throat is usually provided with scaly outgrowths which, though not so very prominent as the corona, undoubtedly are very interesting things, for it is sometimes difficult to find out their true morphological nature.

The Prefloration or æstivation of the Flower.—This subject has already been touched upon. (See page 96) The individual parts of the floral envelopes which alone are somewhat leaflike, may be folded, plaited, rolled etc. as in the case of leaf-vernation. But the relative position of the floral leaves in the bud or what is called the Prefloration is the more important question. Besides the three already mentioned, *i.e. valvate imbricate*, and *contorted*, the following are the other important kinds of Æstivation :—

Induplicate.—it is a form of the valvate only ; here the margins of the individual floral leaves are folded inwards on themselves.

Quincuncial, it is a form of the imbricate ; there are 5 parts or lobes of which two are external wholly—two internal wholly and one partly internal, partly external.

Vexillary,—it also is a form of the imbricate ; the term is particularly applied to the Æstivation of the flower of the Pea. and its family. Fig. 165. In this a large petal, called the vexillum is folded over the others of which the two lower unite into a boat shaped structure, and the two lateral partially close upon the sides of the latter.

Plaited involute, plaited convoute, etc., are peculiar æstivations found commonly in the Potato family (Solanaceæ)—Datura, for instance, belonging to the same family has a tubular corolla (which is really formed by the congenital union of the 5 petals), the component parts of which are folded or plaited in the bud.

The following Schedule will give the Student a synopsis of the characters of the floral envelopes in some of the important Indian Plants.

A.

Plants.	Perianth.	Number.	Insertion.	Cohesion.	Form.	Æstivation.
JAVA (*Hibiscus Rosa-sinensis*)	Dichlamydeous with epicalyx	Calyx—5 fid Petals—5	Hypogynous	Calyx—gamosepalous Corolla—polypetalous	Regular	Calyx—Valvate Corolla—Contorted
KRISHNA KALI (*Mirabilis Jalapa*)	Monochlamydeous with a whorl of Bracts	Corolla— - lobed	Hypogynous	Gamophyllous	Regular Infundibuliform	Imbricate
ORANGE (*Citrus Aurantium*)	Dichlamydeous	Calyx—5 parted Petals—5	Hypogynous	Calyx—gamosepalous Corollo—polypetalous	Regular	Imbricate
MUSTARD (*Sinapis dichotoma*)	Dichlamydeous Ebracteate	Sepals—4 Petals—4	Hypogynous	Polyphyllous	Regular Cruciform	Imbricate
PADMA (*Nelumbium Speciosum*)	Dichlamydeous	Sepals—8 Petals—8	Hypogynous, a few inner petals epigynous	Polyphyllous	Regular	Imbricate
CASTOR-OIL *Ricinus* (*ommunis*)	Monochlamydeous	Calyx—3-5 parted	Hypogynous	Gamophyllous	....	Imbricate

B.

Plants.	Perianth.	Number.	Insertion.	Cohesion.	Form.	Æstivation.
SURJAMUKHI (*Helianthus Annuus*)	Dichlamydeous with Palets	Calyx—2 parted. Corolla—5 lobed.	Epigynous	Gamophyllous	Calyx—Pappose. Corolla—Tubular	Imbricate
METHY OR HENNA (*Lawsonia inermis*)	Dichlamydeous	Calyx—4 toothed. Corolla—5 Petals.	Perigynous	Calyx—Gamosepalous. Corolla—Polypetalous	Regular, Petals—Corrugated.	Calyx—Valvate.
PEA (*Pisum Sativum*	Dichlamydeous	Calyx—5 cleft Corolla—5 Petals.	Perigynous	Calyx—Gamosepalous. Corolla—Polypetalous	Irregular Papilionaceous	Petals—Involute.
LITCHI (*Nephelium Litchi*)	Monochlamydeous	Calyx—4 parted. Corolla—0	Hypogynous	Gamosepalous	Regular, spreading.	Imbricate, Vexillar.
BRINJAL (*Solanum Melongena*	Dichlamydeous	Calyx—5 parted. Corolla—5 parted.	Hypogynous	Gamophyllous	Rotate.	Imbricate Plaited convolute.
SEPHALIKA (*Nyctanthes arbortristes*)	Dichlamydeous	Calyx—5 toothed. Corolla—7 parted.	Hypogynous	Gamophyllous	Calyx—Campanulate. Corolla—Hypocrateriform	Contorted.
GANDHARAJ *Gardenia florida*)	Dichlamydeous	Calyx and Corolla with uncertain segments.	Epigynous	Gamophyllous	Infundibuliform	Valvate.

CHAPTER VIII.

The Essential Organs of Reproduction.

The sporophylls, as has already been observed, are differentiated into the male and the female sex-bearers. In the great majority of Dicots and Monocots these two organs are developed in the same flower. But there are many other cases where one or other or both of the sexual organs may be completely absent, just as it happens with the Perianth. Sinecure flowers having no sexual organs are not at all reproductive themselves but may help in bringing about the reproduction in other flowers. They occur characteristically in the peripheral zone of the Capitulum and are called *Neuter*.

1. When both the sexes are present in the same flower, *i.e.*, the Andrœcium and the Gynœcium are formed in the same flower, it is called Bisexual or Hermaphrodite or Monoclinous. It is the rule in Angiosperms in general.

2. When male and female organs *i.e.*, the Andrœcium and the Gynœcium are developed on different flowers, they are called Imperfect, Unisexual or Diclinous. Thus in the Fig. the Castor-oil plant (Ricinus), the Willow (*Salix tetrasperma*—Barun or Pani-juma), the Nutmeg (*Myristica fragrans*—Jay-phal), Crotons, in the Cucumber family of plants, the stamens and pistils are formed on different flowers.

3. Unisexual flowers may be Staminate when they bear only the male organs or stamens, or Pistillate when they bear the pistils only. They are called

4. Monœcious, when staminate and pistillate flowers are borne on the same individual plant, as in the families Arum (kutchoo), Ficus (Fig, Banyan etc), Urtica (Lal-Bichuti—

U. interrupta), Amaranthus (Notya shak—A. Oleracens), Cocos (Narikal—the cocoanut), Pines (Deodars), Crotons, the Cucumber and other plants of its family (Cucurbitaceæ) etc.

5. Diœcious, when staminate and pistillate flowers are formed on different individuals—one producing only male and the other the female organs ; as in Willows, Pandanus (Ketuky or Kea,) Cannabis (Ganja, the narcotic—C. Sativa,) Smilax (Topchini), Dioscorea, Myristica (Nutmeg—Jay-phal), Phœnix (the Date Palm—Khejjoor) etc.

5. Polygamous, when the same plant bears hermaphrodite, staminate and pistillate flowers, as in many Palms.

FIG. 172. FIG. 173. FIG. 174. FIGS. 175, 176, 177, FIG. 178.

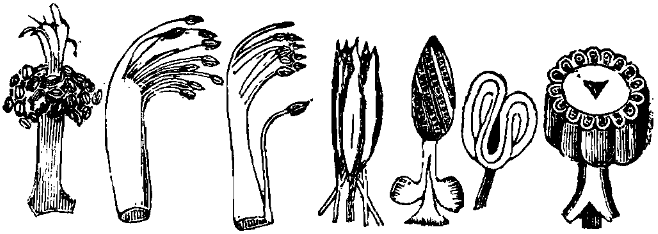


Fig. 172. Monadelphous Stamens of Malvaceæ.
Fig. 173. Monadelphous Stamens of Papilionaceæ.
Fig. 174. Diadelphous Stamens of Pea.
Fig. 175. Syngenesious Stamens of Compositæ.
Fig. 176. Syngenesious Stamens of Cucumber.
Fig. 177. One anther (Sinuous) of the same.
Fig. 178. Cross section through same showing the sinuous Anthers.

The Andrœcium.

The collection of male sporophylls or Stamens is called the Andrœcium, Its universal position is between the Perianth on the outside and the Gynœcium on the inside. It is, however, *hypogynous*, *perigynous*, or *epigynous* according at it stands below, around or above the ovary. The word

Andrœcium comes from the Greek *andria* (=man: metaphorically used to signify the male stamens) and the terms descriptive of the stamens of a flower are formed by prefixing a suitable numeral before the term. Thus ;—

Monandrous flower has only one stamen ;
Diandrous has two ; *Triandrous*, three ;
Tetrandrous, four ; *Pentandrous*, five ;
Hexandrous, six ; *Heptandrous*, seven ;
Octandrous, eight ; *Enneandrous*, nine ;
Decandrous, ten ; *Dodecandrous*, twelve ;
Polyandrous, any indefinite number.

A typical stamen is segmented into three parts—filament, anther, and connective. The filament is the stalk of the stamen and corresponds to the petiole of a leaf. The Anther is the club shaped sac corresponding to the blade of a leaf.

The connective is the part which connects the filament to the anther and is homologous with the midrib of a leaf. Before going into a dètailed description of the parts of the stamen it will be convenient to give here the other descriptive terms that are usually employed.

Didynamous Stamens : where there are four stamens of which two are short and two long. Fig. 198.

Tetradynamous Stamens : where there are six stamens of which four are long and two short. Fig. 199.

Monadelphous Stamens : where the filaments of a whorl of stamens cohere to form a single body or tube. Similarly *diadelphous*, *triadelphous*, *polyadelphous* etc. are terms denoting the number of such united tubes or bodies, being two, three, and many respectively in the three cases.

Syngenesious Stamens : where they cohere in their anthers, the filaments remaining free.

Gynandrous Stamens ; where they arise upon the Pistil—being an extreme case of Epigyny.

In the following table examples of the different kinds of stamens are given.

ANDRŒCIUM.	EXAMPLES.
Monandrous...	Dulalchampa (*Hedychium Coronarium*). Chandra-moolika (*Kæmpferia Galanga*). Bhooi-champa (*K. rotunda*), Turmeric (*Curcuma*), Ginger (*Zingiber*) etc.
Diandrous...	Shephalika,the Jasmines, Bakash, Bhoominim (*Gratiola, Serrata*) Punarnava (*Bœrhavia procumbens*) and many other plants belonging to the Families Oleaceæ, Acanthaceæ. Scrophulariaceæ, Labiatæ, etc.
Triandrous...	Cyperaceæ (Mootha), many Grasses, as in Khus-kush (*Andropogon*), Sugar-cane plant (*Saccharum*), Durba (*Panicum*), Wheat (*Triticum vulgare*), and in many other Graminæ (the Grass family.)
Tetrandrous...	Manjeet, Rangun, (*Ixora*), and many Rubiaceæ ; Isupghul (*Plantago*), Water chestnut (*Trapa Bispinosa*). Gandha bandhuli (*Oldenlandia*) etc.
Pentandrous...	(This is most common). Kalmi, Sakarkand aloo (*Convolvulus*) ; Kadamba, Gambir (*Uncaria Gambier*) and many other Rubiaceæ ; Potato, Brinjal, (*Solanum*), Datura, and in almost all Solanaceæ ; Kool (*Zizyphus*), Doopaty (*Geranium*), Banana, etc, etc.
Hexandrous...	Sookh-darshan (*Crinum*), Onion (*Allium cepa*) Ulatchandal (*Gloriosa*), Satamuli (*Asparagus*), Rajanee-Gundha (*Polyanthes*). Bamboo (*Bambusa*), and in many other Monocots.
Heptandrous...	*Jonesia Asoka* (Asoka or Usok).
Octandrous...	Bakul or Mulsari (*Mimusops elengi*). Methy or Henna (*Lawsonia inermis*), Pan-Murich (*Polygonum*), etc.

Enneandrous...	Tejpata (*Laurus Malabarica*), Akash—valli, the parasite (*Cassytha filiformis*).
Decandrous...	Kanchan or Yooga-patra (*Bauhinia*), Soondali (*Cassia*), Kalkashinda (*Senna*), Madhabee-lota (*Hiptage Madablota*), Sajeena (*Moringa pterygosperma*), Nim (*Melia*), Badam (*Terminalia Catappa*) etc.
Dodecandrous...	Nooniya or Looniya shak (*Portulaca*), Shij —Tekata shij (*Euphorbia*).
Polyandrous...	Guava (*Psidium*), Nag-phanee (Cactus, Gulab-jam, Jambolan (*Eugenia*) Darimbo (*Punica*), Nashpati (*Pyrus*) Gaub (*Diospyrus*); Acacia, Lajja-baty-lota (Mimosa), Poppy, Lotus, and in many other Dicots.
Didynamous...	Podina, Lavendar, Toolsy, many Acanthaceæ, Labiatæ, Scrophulariaceæ, etc. Til (*Sesasmum orientale*), Begonias, etc.
Tetradynamous	Mustard family (Cruciferæ), as Sarisha, Cabbage, Moola etc.
Monadelphous	Mallow family (Malvaceæ—Java, Cotton etc), Ulat-kamul (*Abroma augusta*), Kunak-champa (Ptersopermum) etc.
Diadelphous...	Tamarind, Sissoo, the Timber plant (*Dalbergia sisso*), Palas (*Butea frondosa*), Shun, Ratti and all plants of the pea family (Papilionaceæ).
Syngenesious...	All plants of the family Compositæ such as Sunflower, Genda, Kusum (*Carthamus Tinctorius*) Somraj (*Serratula Anthelmintiae*).
Gynandrous...	In all Orchids and in Eshar Mool (*Aristolochia Indica.*)

The Androecium is composed of the male sexual organs or Stamens. Each stamen usually consists of two pairs of pollen-sacs at its upper end beneath the apex, which are included under the term *Anther*, and a slender and often very long stalk called the *Filament.* The two halves of the Anther are united and at the same time separated by a part of the filament called the *Connective.* But the filament and the connective are not the essential parts of the Stamen; they may be absent. And a leaf bearing pollen-sacs only may as well be called a Stamen.

FIG. 179. FIG. 180, 181. FIG. 182, 183, 184, 185, 186.

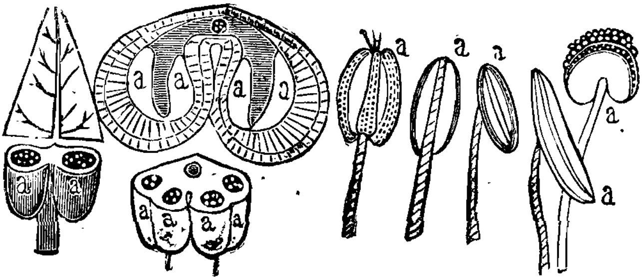


Fig. 179. Diagram to show the formation of Anther; a, the sacs.

Fig. 180. The same in cross section; a, a, the sacs, showing the partition walls intruding.

Fig. 181. The same to show the bags of pollen grains. Quadrilocular anther.

Fig. 182-185. Attachment of anther to filament.

Fig. 182. Innate. Fig. 183. Adnate.

Fig. 184. Dorsifixed,

Fig. 185. Versatile.

Fig. 186. Unilocular anther of Java splitting transversely: a, the anthers.

The Filament, though usually slender and filiform, may in some cases be flat and leaf-like. In normal flowers what are called *petaloid filaments* are matters of common observation. In Nymphæa and Nelumbium (Lotus family) such flat, leaf like and coloured filaments form a characteristic feature. In Canna, again, the filament is petaloid and bears the pollen-sacs at the tip of the leaf. On the other hand, in many degenerated flowers known commonly as *Double flowers e.g*, double Rose, double Mallow etc, the otherwise slender stalk like filaments of normal flowers are degenerated into flat and expanded and often highly coloured leaf like structures. In many of these cases the *doubling* results from the complete transformation of the stamen into a petal. Witness, for example, many flowers of Aparajita (Clitoria ternatea), Java (Hebiscus) etc.

At first sight, in ordinary cases the filament would be regarded as the homologue of the leaf-stalk, the stamen being a metamorphosed leaf. But the petaloid stamens point rather to the fact that the filament corresponds to the leaf-blade. But as these are rather abnormal cases the general view held is that the filament corresponds to a leaf-stalk and the Anther to the lamina. In Wheat, Rye, Rice, Maize, Flax, Bamboo, Cyperus, Scirpus and in many other cases the filament is thread-like, long and slender. But departures from the filamentous character are more often observed. Thus besides the petaloid filament referred to above, it is generally very broad in Asclepiadaceæ (Akanda—*Calotropis gigantea* ; kunjalata—*Pergularia odoratissma etc*). and Apocynaceæ (karavy—*Nerium oleander*; Taugor—*Tabernæmontana* ; Gool-phiringhi—*Vinca rosea* ; etc). In some of them it is hooked or prolonged above the anthers as a projection. Such appendages are also found in many other cases and are particularly noticeable in the stamens of *Allium* (Onion, Garlic etc). Fig. 191. In *Ricinus communis* (the castor-oil plant) the Stamens are much branched. Fig. 190. In Cucurbita (cucumber family) there are five stamens at the inception but later on they are fused peculiarly so that the stunted filaments cohere into a columnar body on which the anthers grow very rapidly forming vermiform coils. Fig. 192.

The Anther.—It is the apical portion of the blade of a staminal leaf. Imagine the right and left half of the lamina infolded towards the midrib, as shown in Fig. 179, and we get the typical *two-locular* Anther with the midrib as the CONNECTIVE. The chambers or sacs (technically called THECA) are in their early stages divided into two by a partition wall which stretches from the connective, through the cavity, to the opposite wall. (See Fig. 180). The young Anther is thus composed of 4 cells in each of which pollen grains are produced. The *quadrilocular* Anther thus formed, becomes however two locular at maturity, by the disorganisation or absorption of the partition wall formed within the chambers. But in Mallow and its family (Malvaceæ—*Java* etc.) the two chambers become confluent and produce only one polliniferous cavity. The Anther becomes then *Unilocular*. In the Anthers of the Mimoseæ (Acacia—Babla; Mimosa—Lajjabaty lota etc.) the pollen sacs are very curiously formed. There are usually as many as eight chambers formed by the development of partition walls within each of the 4 cavities of the quadrilocular anther. In each of these loculi pollen grains are produced in large numbers.

Form of the Anther.—The sinuous *vermiform* Anther of Cucurbita has already been mentioned. Generally Anthers are more or less *rounded*, *oval* or *elliptical*, as in the Almond. In many Grasses they are *linear* and forked at each extremity so as to resemble the letter *x* in form.

Variations in the form of the Anther are sometimes due to the dimensions of the connective and pollen-sacs. Thus in Ranunculaceæ (Aconite family). Magnoliaceæ (Champaka), Nymphæaceæ (Lotus family) and Papaviraceæ (Poppy family) the connective is large and broad and the pollen-sacs form only narrow linear borders. In Salvia (Labiatæ) the connective assumes the form of a bar or lever running transversely at the top of the filament. In Grasses, many Lilies and Gentians the connective is very small and delicate so that the Anthers are left freely to move as if on a pivot. In *Mirabilis jalapa* (Krishna kali) the pollen sacs are bulky and the connective is slender. (See Fig. 189),

The attachment of the Anther to the Filament may be principally in three different modes. Thus, it is

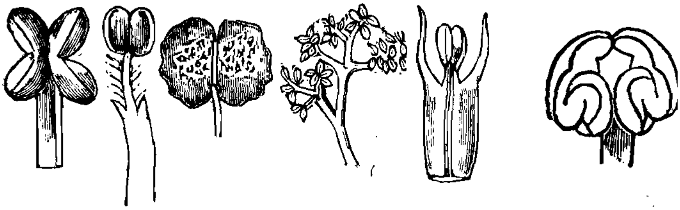
1. *Innate or basifixed* (Fig. 182), when the Anther is fixed directly on the top of the filament so that the lobes or pollen-sacs are on the two sides of the connective.

2. *Adnate* (Fig. 183), when the connective appears to be a direct prolongation of the flament; as in Magnolia and Water Lily.

3. *Dorsifixed* (Fig. 184) when the filament is attached to the back of the Anther so that it is immovable.

4. *Versatile* (Fig. 185), when the Anther is attached at some point of its back or front to the tip of the filament, so that it can move freely as on a pivot; as in all Grasses, Lilies etc.

FIGS. 187,188, FIG. 189. FIG. 190. FIG. 191. FIG. 192.



Different kinds of anthers and filaments.
Fig. 187. Anthers of *Cacao.* Fig. 188. Stamen of *Aconite.*
Fig. 189. Anther of *Mirabilis* (krishnakali)
Fig. 190. Branched stamen of *Ricinus* (castor oil)
Fig. 191. Flat stamen of Onion (*Allium*) with appendages.
Fig. 192. Sinuous, convolute anthers of Cucurbita.

Again with regard to the direction to which an Anther faces, it is called

Extorse when facing outwards or away from the axis and towards the perianth, as in Magnolia.

Introrse when facing inwards or towards the axis of the flower as in the Lotus family.

The Dehiscence of Anthers is accomplished in various ways. At maturity, the pollen grains remain simply heaped in the pollen sacs and they are discharged by the bursting of the sides of the anther. Openings or chinks that are thus formed usually extend from top to bottom of the Anther and are called *Sutures* or *Lines of dehiscence*. There are four different ways in which Anthers shed their pollen grains: these are—

1. *Longitudinal* or *Sutural Dehiscence*. This is the usual mode. Here each Anther lobe is split open by a longitudinal slit along the sutures.

2. *Transverse dehiscence*. Here the Anther is cut horizontally or transversely. It is common in unilocular Anthers as in Malvaceæ (Java, Simul:etc). Fig. 186.

3. *Valvular Dehiscence*. Here semicircular slits arise in the Anther walls and open out in the form of valves or trapdoors. (Fig. 200). It is of rare occurrence but is met with generally in the Camphor (*Cinnamomum Camphora*) and Dalchini (*Cinnamomum Zeylanicum*) trees, and in many species of Berberis.

4. *Porous dehiscence*. Here small round or irregular pores or openings are formed on the anther walls and the pollen grains are ejected out through them. It occurs in Solanum, Senna, Polygalas, Euphorbia and many other plants.

In the Cacao plant (*Theobroma Cacao*) a curious aperture is opened out at the top of the four cells of the anther. In many plants of the family Curciferæ the anthers are spirally twisted after dehiscence. In some Liliaceous plants the longitudinal opening of the linear anthers results in the formation of a globular structure after the dehiscence. In many cases the discharge of the pollen is accompanied by a movement of the stamen. In Mulberry, for example, the filament uncoils like a spring at the moment of dehiscence of the anthers, and the pollen grains are thus forcibly ejected and dispersed.

In Grasses the versatile anthers swing freely in the air and dehiscing, allow the very light and dry pollen-grains to be driven before the wind.

The Pollen grains.—The pollen is produced from a layer of generating cells (*archesporium*) lining the interior of the Anther chambers. It consists of separate grains, the size and shape of which, though uniform in the same plant or species, differ in different species or families. It is generally oblong or oval but may as well be polygonal, crested, angular grains and so on. In versatile Anthers and in many other cases they are powdery ; in many others, on the contrary, they are viscid, sticky glutinous and aggregated. They are usually formed in fours from the mother cells (*archesporium*) in the interior of the Anther chambers, and as they complete their growth the inner walls of the Anther become in most cases obliterated. It is during this stage that the lines of suture and pores are formed on the external walls of the Anther.

A pollen grain has two coats,—the inner soft membrane enclosing the active and generative protoplasm (*Spermatoplasm*), called the *intine* ; and a rather firm exterior coat enveloping and protecting the young pollen, called *extine*. It is on this

FIG. 193. FIGS. 194,195,196. FIG. 197.

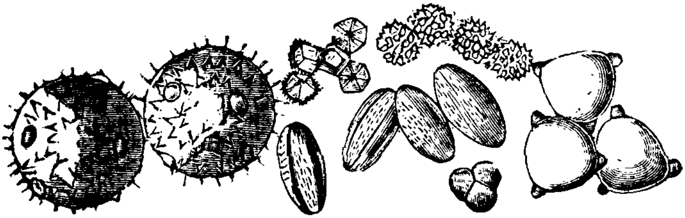


Fig. 193. Pollen of *Cucumber* (with circular lids).
Fig. 194. Pollen of *Taraxacum* (Hexagonal).
Fig. 195. Pollen of *Gentian* (Oval).
Fig. 196. Dotted pollen of cirsume.
Fig. 197. Pollen of *Circæa alpina* (triangular).

extine wall that the infinite variety of excavations and sculpturings which give the pollen the peculiar appearance when seen under the microscope, is formed. On the pollen roundish grains of Malvaceous plants, for instance, there is a large number of briskly projections. In Magnolia and Water Lilies, a single furrow runs over the surface from one end to the other of the oval or elongated grain. In Poppies, Roses, Almonds, many Solanaceous plants (Potato, Bringel etc), in Gentians, many Papilionaceæ, Scrophulariaceæ etc, there are three, occasionally more, grooves like the above. The pollen grains of *Basella* (Poin-shak) are cubical or prismatic. Crystalline pollens are the characteristic feature of the plants of the Pink family (Caryophyllaceæ) and in Compositæ. In the Passion-flower (Passiflora) and Cucumber family (Cucurbitaceæ) the large round grains are provided with little lid-like processes on the *extine*, which may be pushed out by corresponding projections of the *intine*. The term *perine* is sometimes applied to the external layer of the pollen grain from which the protuberances etc, arise.

The above are examples of cases where the grains remain isolated and free. But in certain other cases they are aggregated in small colonies. Thus in Pines (Deodar), as well as in Onagraceæ (Kesaradam—*Jussieua repens*; Panphal or Singhara—*Trapa bispinosa*), the pollen consists of three or four blended cells. Coherent masses of innumerable pollen grains blended together by a viscid secretion into what appear like bunches of grapes, form the characteristic feature of the Orchids and Asclepiads (Akanda—*Calotropis gigantea*). These are called *Pollinia*; while the aggregates of four pollens in the Onagraceous plants are called *tetrads*.

Under favourable conditions of moisture and warmth the pollen grains emit tubes called *pollen-tubes*. These result from the growth and elongation of the intine through the opening, or excavations or lids of the extine. The protoplasmic mass filling the interior of the grains is collected at the advancing tip of the pollen tube and is the sole agent by means of which the female is fertilised; for the tube is formed normally when a ripe pollen falls upon the ripe stigma of a Carpel.

The Gynœcium or Pistil.

The Gynœcium is the terminal part of a flower. It makes up the whole flower in some Aroids where it is Achlamydeous and pistillate. It consists of one or more metamorphosed leaves called *Carpels*. It may be *Monocarpellary*, when there is only one carpel ; *Dicarpellary*, *Tricarpellary*, *Tetracarpellary*, *Pentacarpellary* etc, when there are two, three, four and five carpels respectively, or may be *Polycarpellary*, where there is an indefinite number. Synonymous with these are the terms *Monogynous*, *Digynous*, *Trigynous* etc.

FIG. 198. FIGS. 199, 200. FIG. 201. FIGS. 202, 203.

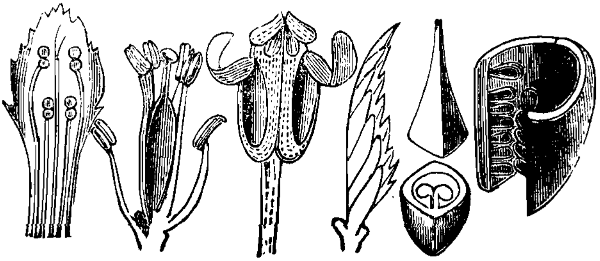


Fig. 198. Didynamous stamens.
Fig. 199. Tetradynamous stamens.
Fig. 200. Stamen of Laurus—Anthers opening by valves.
Fig. 201. A carpellary leaf.
Fig. 202. A carpel formed.
Fig. 203. A carpel leaf cut through to show the ovules.

The Gynœcium may be *simple* or *compound*. A simple Gynœcium consists of either a solitary or a number of carpels remaining quite free, and is called *Apocarpous*. A Compound

Gynœcium consists of two or more carpels united together into a single structure, and is called *Syncarpous*. A Monocarpellary Gynœcium is necessarily simple or Apocarpous ; a dicarpellary Gynœcium may be apocarpous or syncarpous, depending on whether the carpels are free and ununited in the first case, or united into a coherent body in the second.

The essential parts of the Gynœcium whether apocarpous or syncarpous, are—

1. A closed Ovary in which ovules are developed.
2. A Stigma or receptive surface upon which pollen grains are received and develop pollen tubes for fertilisation.
3. A Style or stalk that supports and carries up the stigma so as to keep it in a better position for the reception of pollen.

The Carpels.—That the Carpels are specially modified leaves is evidenced by the occurrence of degenarations in what are called *double flowers*. In many Rose, Mallow and in Aparajita in particular, the staminal and carpellary leaves are developed in the form of petals. The formation of the Pistil from a leaf may be best understood if we imagine a carpellary leaf flolded along the midrib so that the blade thus incurved lengthwise becomes fused by its margins—thus producing a closed sac, the Ovary. Figs. 201—3 show schematically the formation of a simple pistil from a leaf. Imagine, again, a whorl of carpellary leaves arranged symmetrically on the thalamus ; the margins of each leaf infolded along the midrib may become separately fused, so that each leaf produces an ovary ; or all the margins of the different leaves may be fused together so as to form a single ovary. In the first case, we get the apocarpous Gynœcium ; in the second, the syncarpous. The prolongation of the apex of the leaf thus forming an ovary is the style, and some portion of this growing out sometimes in the form of a head, more generally in a forked manner, forms the stigma.

The carpellary leaf being thus *involute*, the suture or line of junction of the margins faces towards the axis or centre of the flower. It is called the *inner or Ventral* suture as opposed to the *outer* or *Dorsal* suture i.e. that corresponding to the midrib of the leaf. The ventral is the only proper suture of the carpel but the suture-like appearance at its back has brought in the other term in use.

The following points lead us to the conclusion that the carpels are modified leaves.

1. The Mono-carpellary pistils of the Pea and other plants of the family Leguminosæ possess externally the ordinary characters of leaves, except that they are folded into a sac like cavity.

2. In Java, Aparajita, Roses and in many other flowers, the carpels often revert to ordinary leaf-like expansions by *doubling*.

3. In some such cases the monstrous carpel leaves exhibit in their margins rudimentary ovules, as have been occasionally observed in some flowers of Cruciferæ.

4. The production of ovules on the margin of the Ovary is analogous to the formation of adventitious buds on the margin of foliage leaves, Bryophyllum (Pathur Kuchi) for instance.

5. The venation in the carpel is generally like that of the leaves, as evident from the ripe coat of the Tamarind.

The typical Dicot Gynœcium should consist of five carpels, and that of the Monocot, three. But as a rule, the pentamerous Gynœcium of Dicots is found far less commonly; while deviations from the trimerous condition occur in only a few Monocots. The simplest case of the apocarpous pistil is where there is only one carpel in the flower; as in Peas, Beans, all pulses, Aparajita, Kalkashinda, Babla, Lajja-baty-lota etc. The Monocarpellary pistil forms one of the distinguishing features of the Leguminosæ—a family to which the above plants belong. In Lotus and Water Lilies the Gynœcium consists of several separate carpels seated on little depressions on the flat-topped fleshy receptacle. It is polycarpellary and apocarpous. In Water Melon and Cucumber it is syncarpous. In the Potato and Datura the syncarpous Gynœcium results from a fusion of two carpels. In Poppy there is a large number of carpels united together to form a syncarpous Gynœcium. The following classification will help the student to remember the structure of the Pistil in almost all the plants he has occasionally to deal with.

CLASS I. Apocarpous.

CASE 1. CARPEL SOLITRY :—

Examples.—Leguminosæ, Myristicaceæ (*Myristica fragrans*—Nutmeg, Jayphal), Combretaceæ (*Terminalia Catappa*—Badam, *T. chebula*—Haritaki, *T. Bellerica*—Bahera), some Rubiaceous plants (e.g. Peach—*Amygdalis*, Apricot—*Prunus*), some Anacardaceæ (Mango—*Mangifera indica*).

CASE 2. CARPELS TWO OR MORE, SOMETIMES MANY—ALL FREE :

Examples.—Ranunculaceæ (the climbing garden *Clematis* Aconite—the kat-bish plant), Magnoliaceæ (champak), *Magonlia*, *Illicium* (the star Anise), Nymphæaceæ (Lotus family), many Rosaceæ (Rose, Bramble), many aquatic plants (e.g. the Pondweed—*Potamogeton*, the water plantain—*Sagittaria*), etc.

CLASS II, Syncarpous.

CASE 3. CARPELS TWO, UNITED :—

Examples.—Solanaceæ (Potato, Brinjal, kantikari, Datura), Scrophulariaceæ, (Bhumi nim—*Gratiola serrata)*, Gentianaceæ (Chiratta), Apocynaceæ (Karavy—*Nerium*, Karmcha—*Carrisa*) Asclepediaceæ (Akanda, Ananta-mul, Doodh-lota, Kunja-lota,) Oleaceæ (the Jasmine family) Bignoniaceæ (the Parul), Pedaliaceæ (Til—*Sessamum indicum*), Convolvulaceæ (Kalmi-Shak). Boraginaceæ (Hatisoor), Acanthaceæ (Bakash), Labiatæ (Toolsy, Podina), Verbenaceæ (the Teak tree), Cruciferæ

(Mustard, Cabbage), Umbelliferæ (Carrot, Anise), Rubiaceæ (Manjeet), Compositæ (Sunflower), Bixaceæ (Nutkun or Lutkun—*Bixa Olerana*), Caryophyllaceæ (the Pink family), Myrtaceæ (Jambolan, clove) Urticacæ (the fig family) etc.

CASE 4 CARPELS THREE, UNITED :—

Examples.—Dipterocarpeæ (Shal—*Shorea robusta*), Linaceæ (Linseed—*Linum Usitatissimum*), Malpighiaceæ (Madhaby-lota —***Hiptage Madhoblota***), Cucurbitaceæ (the cucumber family), Euphorbiaceæ (castor-oil plant, Veranda, Shij, Crotons), Palmaceæ (the Palm family), Dioscoreaceæ (the Yam-family), Liliaceæ (Onion, Garlic, Aloe), Scitaminæ (the ginger and Arrowroot family), Amaryllidaceæ *Crinum*), Cyperaceæ (Mootha), Graminæ (the Grass family), etc.

CASE 5. CARPELS FIVE, UNITED : —

Examples.—Malvaceæ (Java, Cotton plants, Sthal-padma *Hibiscus Mutabilis*, Dharous, Bhindee or Ram-torai *H, esculentus*), Sterculiaceæ (Kanak Champa—*Petersopermum Acerifolia*) the chocolate and cocoa plants—(*Theobroma*). Tiliaceæ (the Jute—*Corchorus Capsularis*, Phalsa—Grewia Asiatica), Geraniaceæ Amrul Shak—*Oxalis*, Dopaty—*Impatiens*), Meliaceæ (Nim—M. *Azadiracta*, the Mahogany—*Swæcietenia*), Primulaceæ (the primrose family), Plumbaginaceæ (Chitra—*Plumbago Zelanica*), etc.

It should be observed that in the majority of Dicot plants the Gynœcium is dicarpellary or pentacarpellary, and that it is almost universally tricarpellary in Monocots. Polycarpellary Pistils occur, however, in not a few Dicot plants ; thus, in Sapotaceæ (Bakul—*Mimusops Elengi*) the syncarpous Pistil is composed of eight carpels ; in *Diospyros* (Gaub) there are again eight carpels ; in Rhododendrons there are no fewer than ten ; in Rutaceæ (Orange, Lemon, Bilva) there are as many as ten, twelve, or an indefinite number of carpels cohering to form the compouud Pistil. Similarly the Pistils of Papaviraceæ (Poppy family) Annonaceæ (custard apple—Ata—

Anona squamosa), and Dilleniaceæ (chalta—*Dillenia indica*) are formed by the union of quite a large number of carpels.

Syncarpous Pistils may be either completely united, or as is far more common, may be united only at the basal part constituting the ovary. In the Pink, for example, the dicarpellary pistil is united at the base to form the ovary while the style and stigma are quite distinct. In Java and Mallows the union extends to the style but the stigma is five cleft. In most syncarpous Pistils the stigma is more often than not divided into parts corresponding to the number of carpels concerned. Thus in the Labiatæ and other Dicarpies the stigma is bifid or two cleft ; in Euphorbiaceæ and many Monocots it is trifid and so on. In Primrose the ovaries, styles and stigmas are all united.

The Ovary.—Whether compound or simple, the ovary is usually *sessile* on the thalamus ; but where, as in the case of Pink, and *Gynandropsis*, it is stalked or supported on a cushion or projection of the thalamus, it is called *Stipitate*. (See Gynophore). The form of the thalamus and the calyx-tabe often determines the position of the ovary—it is called *Superior* or *inferior*, according as the other floral members are hypogynous or epigynous on the receptacle. In a monocarpellary Pistil the shape of the ovary is generally irregular, as in the Pea family ; but where there are many carpels, they, as a rule, are arranged symmetrically around the thalamus even when the flower itself is irregular and unsymmetrical ; such, for instance, as in Labiatæ, Verbenaceæ, Acanthaceæ etc.

The number of carpels involved may often be found out by examining a cross-section of the ovary. For the carpellary leaves when uniting to form a syncarpous ovary, often cohere by their margins in a central axis—thus making as many chambers as there are carpels. The chambers, thus formed are called *cells* or *loculi* and the partition walls separating the cells are called *dissepiments*. For instance, the Pistil of the Canna, Palms, Lilies and of many other Monocots is syncarpous—the ovary is *tri-locular* or *three celled* and there are three dissepiments. Besides these *normal* or *true* dissepiments, there are formed in some cases, other *false* or *spurious* partition walls which divide the ovary into a large number of loculi making it *multilocular*. In Labiatæ, Boraginaceæ and other families the dicarpellary ovary becomes divided into four chambers by the formation of spurious dissepiments. More often, however, the dissepiments are absorbed during the stages of maturity of the ovary ; for instance, the Poppy plants develop a syncarpous ovary which is multilocular when young, but the partition walls break down as it grows old when it is *unilocular*. Even in some monocarpellary ovary as in *Cassia Fistula* (Soondali or Suvernuka—Hind, Umultuss) such spurious dissepiments occur.

In many syncarpous ovaries there is only one *loculus* formed. In such cases the margins of the carpels do not become confluent in the centre but unite towards the circumference of the whorl, the margins being but partially folded inwards. The number of carpels involved here may be told from the separate styles or stigmas or from the midribs running over the outer surface of the ovary. The unilocular trigynous Pistils of Orchids, Cucumber, Cyperaceæ and the Bamboo are cases in point. In Compositæ (Sunflower family) there are two carpels forming an unilocular ovary—the stigma being bifid. The formation of the unilocular ovary of the Poppy has already been explained.

The Placentas:—Generative surfaces are always normally developed on the interior of the ovary and are called *Placentas*. The placenta is the surface on which ovules are borne. It is a cellular outgrowth from the confluent margins of the carpels. Where there is only one carpel, as in Leguminosæ, it is formed on the inner surface corresponding to the ventral suture. Sometimes in syncarpous ovaries it projects into the interior of the ovary as a thick mass of tissue. The placentas are variously distributed in the ovaries of various families of plants but in each family, genus, or species their mode of formation and disposition is constant. The term *Placentation* denotes the manner in which they are developed and distributed in the ovary.

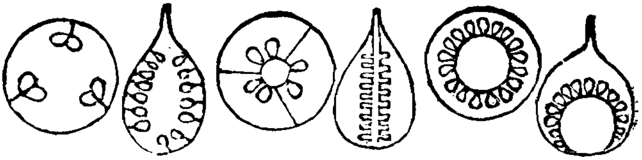
Kinds of Placentation.—

1. In apocarpous ovaries, the placenta normally arises at the inner side of the ventral suture through its length. As there are two leaf margins at the suture, and as the placenta is an outgrowth from the leaf margin, the ideal placentation in a monocarpellary ovary would be along two parallel lines in the ventral suture. This however is rarely met with. The placentation in the above cases is called *Marginal.*

2. In syncarpous ovaries we can distinguish three kinds of placentation. Thus it is

(*a*). *Axile.*—When in a multilocular compound ovary the carpellary margins become confluent at a central axis and develop placental surfaces here, so that the ovules originate from it and remain inclosed in each of the loculi or cells. Here the marginal placentation of the first case has been shifted towards the centre and hence is called axile. It is the only placentation of syncarpous many-celled ovaries.

FIGS. 204, 205. FIGS. 206. 207. FIGS. 208, 209.



Diagrams to illustrate Placentation
Figs. 204, 205. Parietal
Figs. 206, 207. Axile.
Figs. 208, 209. Free central.
Figs. 204, 206, 208. Cross section of ovaries.
Figs. 205, 207, 209. Longitudinal section of ovaries.

(*b*). *Parietal.*—When the ovary is syncarpous and unilocular the placental surfaces are developed on the fused margins of the leaves towards the periphery. Gradations between the parietal and axile placentation occur, as, for example in Cactus (*C . Indica*—Nagphanee) where the ovules are seated directly on the wall or parietes of the ovary ; in Passiflora and Cucurbita, where the placentas protrude into the cell of the ovary and finally in Poppy, where the incomplete dissepiments bearing the ovules run almost to the centre of the ovary. In the last case had the placentas united in the axis and produced ovules on it the ovary would have had axile placentation.

(c). *Free Central*—where there is a central column or generative surface in the interior of the ovary and ovules are borne upon it quite unconnected with the wall or sides of the cavity. It also is connected with unilocular ovaries. A section cut transversely through the ovary of a Caryophyllaceæ or Primulaceæ will show up an unilocular ovary with a central isolated axis on which the ovules are borne.

(*d*) *Basal*—It is a modification of the *free central.* Here the placenta is at the base of the ovary, and à single ovule is borne upon it.

Examples of Placentation.

1. *Marginal* :—In Peas, Beans and almost all plants of the family Leguminosæ, where the ovary is monocarpellary ; in many Rannuculaceæ and in other apocarpous ovaries.

2. *Axile* :—In almost all syncarpous multilocular ovaries. e.g. in Lilies, Plantains, Datura, Tobacco, and other plants belonging to the families Solanaçeæ, Scrophulariaceæ. Myrtaceæ (Guava, Pomegranate, Jambolana) Lythraceæ (Henna or Menthy), Linaceæ (Tisi—Linum Usitatissimum), Malvaceæ etc.

3. *Parietal* :—In Papaviraceæ (Poppy, Shealkanta—*Argemone Mexicana*), Cruciferæ (the Mustard family), Violaceæ (the Violet family), Cactaceæ (Nagphanee—*Cactus Indica.*)

Orchids, Cucurbitaceæ (Cucumber family), Passifloraceæ (the passion flower family), Papayaceæ (Papaey—Carica pawpaw), etc.

4. *Free Central* :—In Caryophyllaceæ (the Pink family), Portulacaceæ (*Portulaca Meridiana*—Looniya or Nooniya-Shak), Santalaceæ (Chandan—*Santalum Album*), Primulaceæ (Primrose family), Plumbaginaceæ (Chitra or Ranghchitra—(*Pumbago Zeylanica*), etc.

5. *Basal* :—In Polygonaceæ and Compositæ.

The mode of attachment of the ovules to the plancenta is called *pendulous*, as in Magnolias, Geraniums, Oxalis, etc ; it is *erect*, as in Compositæ, Anacardiaceæ (Mango, Pistachio-nut), etc.

The Style.—It is the prolongation of the midrib or summit of the carpel and arises usually from the centre of the upper surface of the ovary. In some Rosaceæ (Strawberry, for instance), however, one side of the ovary grows faster than the other and the style becoming thus displaced appear to be *lateral*. This displacement and the consequent obliquity is sometimes very pronounced, so that the style appears to arise from the base and then is called *basilar*. Again in Labiatæ

FIG. 210. FIG 211. FIG. 212. FIG. 213.

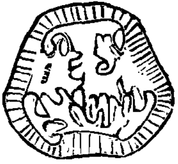


Fig. 210. Apocarpous Gynœcium of *Aconite.*
Fig. 211. Syncarpous Gynœcium of Primrose.
Fig. 212. Gynœcium of Flax.
Fig. 213. Cross section of ovary of Cucurbita.

and Boraginaceæ, the style appears to originate from a deep depression in the centre of the syncarpous ovary which is imbedded in the thalamus, so that the style appears to arise from the latter. Such an arrangement is called *Gynobase,* and the ovary in such cases is called Gynobasic. In Geraniums, however, the thalamus itself is prolonged through the pluri-carpellary ovary and the styles becoming confluent with it form what is called the *Carpophore.*

In form the style is usually cylindrical, filiform or columnar and sometimes prism-like. In Crocus (Jafran) it is long, divided into three parts above which attain considerable size, and sometimes becomes hollowed out like a cup. Similarly in some Euphorbiaceæ, the three parted style bifurcates once more in the segments, so that the upper part of the style appears to be divided into six parts. The style may be hollow, as in many Lilies, Viola and Agave. Sometimes it is very small and thick and in *Vitis* particularly appears to be a mere constriction of the upper part of the ovary.

The Stigma.—This is that part of the style where pollen grains, when received, produce pollen tubes, and form the *receptive spot* of the carpels. When mature and ready for receiving the pollen grains it is generally covered with a viscid secretion and usually with short hairs which are mere secreting glands. It is developed as a cellular structure originating from the inner part of the style. Its surface forms the entrance to the open channel of the style. In Grasses the stigmas are provided with a large number of hairs and are called *feathery.* In Compositæ, where they are bifid, each part is *linear* and beset with small glandular hairs. In Papaviraceæ and in Nymphæaceæ the sessile stigmas appear as many-rayed stars or radiating ridges on the top of the flattened ovaries. In the Cucumber family they are thick and globular and may be called *lobed.* In syncarpous Gynœcium the stigma is often divided—thus it may be bifid, or trifid etc, or bilobate, trilobate etc.

The Ovule.

The ovules arise from the plancenta as conical bulgings. These soon become enlongated into oval or elliptical bodies and are in most cases supported on stalks, called *funiculus.* In Plumbaginaceæ the funiculus is very long while in some Grasses it is completely wanting. It is the macro-sporangium of Angiosperms. The bulk of the oval body supported on the funiculus consists of a soft cellular structure called *Nucellus.* This soft structure is really the vital part of the Ovule, for it is in it that the ovum is developed. Usually the Nucellus is protected by two coats or integuments' which grow up round it from the base of the funiculus and ultimately enclose it leaving a little space at some part exposed. The exposed part thus left by the coats forms a short canal called the *micropyle.* In most of the higher Dicots (Gamopetalous) there is only one integument ; Monocot ovules, as also those of the apetalous and polypetalous Dicots have two integuments. Usually a third coat arises on one side as a ridge or as a small cup, as in many Myristica. This is called *Aril* and is generally formed subsequently to the other integuments. The part of the nucellus from which the integuments arise and which stands just in front of the funiculus is called *chalaza* The point where the body of the ovule is attached to the funiculus is called the *hilum.* Of the integuments the outer coat is called the *primine* which in the ripe ovule or seed forms the testa ; the inner coat, the *secondine* or *tegmen.*

The micropyle or *foramen* forms a short canal passing through both coats. But in many cases the openings of the two coats do not correspond i.e. are not in one line : the portion of the canal that passes through the outer coat has been distingiushed as *exostome* ; and the orifice of the inner, as the *endostome.*

Forms of Ovules.—The different parts of the ovule, as noted above, seldom become so disposed as to make it straight with the parts symmetrically disposed. FIG. 214. On the other hand,. various bendings and curvings and displacements may occur. Of the several forms of the ovule the following are the most important :—

1. **Orthotropous,** atropous or straight, as shown in FIG. 214. Here the ovule is perfectly straight and vertical; at least the separate parts are symmetrically arranged. Thus beginning from the placenta from which the funiculus arises we have successively—

FIG. 214.

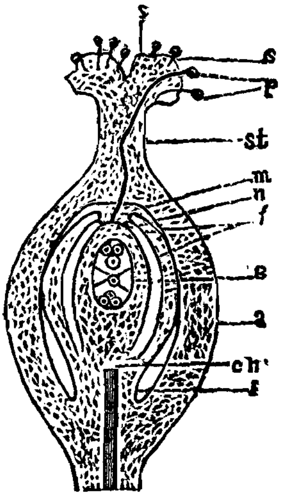


Fig. 214. Diagram to show parts of ovule. S, the befid stigma with the Pollen grains P, a pollen producing the pollen tube. St, the style; M, the micropyle N, the nucellus; I, the integuments; E, the embryo-sac; a, the ovary; ch, the chalaza; f, the funiculus.

the funiculus,
the chalaza,
the integuments,
the nucellus,
the endostome and
the exostome.

It should be observed that in this form the micropyle is exactly opposite the chalaza in one straight line. Orthotropous ovules characterise the Polygonaceæ (Panimurich—*Polygonum barbatum*) and Piperaceæ (the pepper family—Black pepper—*Piper Nigrum ;* the Betle plant—*Chavica Betle* ; Pipul—*C. Roxburghii*, Cubebs etc). Fig. 215

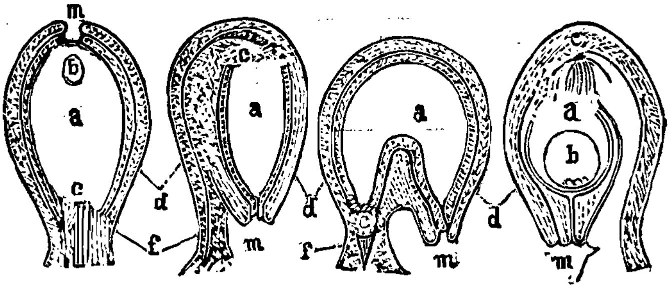
2. **Campylotropous**. Here the nucellus is bent upon itself—in the form of the letter U. The curving of the ovule in this case is due to a much greater development of the upper or convex side. The micropyle comes near the funiculus, being almost in contact with the chalaza. Fig. 217. This form is comparatively rare but characterises the Grasses and the Pink family (Caryophyllaceæ).

3. **Anatropous**. This is the usual form of the Angiospermous ovule. Here as shown in fig. 216 the nucellus together with its integuments is inverted bodily, so that the micropyle faces the point of origin of the funiculus from the placenta (*Hilum*). In this case, the micropyle, nucellus and the chalaza are in one line ; but the funiculus runs up the side of the ovule and coalescing with its surface forms a ridge called *Raphe*. Examples :—in many dicots, as the Apple, Cucumber, Sunflower, Lily etc.

4. **Amphitropous.** This is a form intermediate between the last two. In it the body of the ovule is straight but turned and twisted so that its longitudinal axis is at right angles to the funiculus. It may be seen in the ovules of the Poppy.

The Nucellus :—It is the kernel of the ovule. In it the macrospores are developed. As a rule, only one macrospore —the *embryo-sac*, is formed in each nucellus. The *embryo-sac* is developed as a large sac or cell towards the micropylar end of the nucellus. Three sets of small cells are found to occupy the interior of the Embryo-sac. Of these the upper set or that which is towards the micropyle contains the *ovum* or *egg-cell*. The morphological nature of the ovules has not yet been settled beyond doubt. As a rule, they are marginal buds ; that is they are borne upon the margins of the carpels. They always originate laterally and have seldom been found to be the terminal structure of a flower. Relying on these facts some Botanists hold that the ovule is either a metamorphosed leaf or a lobe of a leaf. But in some cases as in Piperaceæ the ovule is actually the terminal part.

FIG. 215. FIG. 216. FIG. 217. FIG. 218.



Diagrams to illustrate the different forms of ovules.

Fig. 215. Orthotropous.

Fig. 216. Anatropous.

Fig. 217. Campylotropous.

Fig. 218. Diagrammatic section through ovule of Lily.

(*a*), the Nucellus; (*b*), embryo-sac; (*d*), integuments; (*m*), the micropyle; (*e*), the chalaza.

The following schedules point out the way in which the essential organs of a Flower are to be studied. Students are recommended to prepare similar schedules for other plants.

JAVA (*Hibiscus Rosa Sinensis*).

PEA (*Pisum Sativm*), or Aparajita (*Cletoria ternatia*).

Organs	Number	Insertion	Cohesion	Adhesion	Number	Insertion	Cohesion	Adhesion.
ANDRŒCIUM								
Stamens	Indefinite	Hypogynous	...	Adherent to base of Petals	10	Hypogynous	...	Inferior
Filaments	Indefinite	...	Monadelphous		10	...	Diadelphous	
Anthers.	1—celled	...	...	...	2—celled	...	...	...
GYNŒCIUM								
Carpels	5	Superior	Syncarpous	Free Superior	1	Superior	...	Superior
Stigmas	5	...	Free	...	1	...	...	Free
Styles	5—fid	...	...	...	1	...	...	...
Ovary	5—locular	Superior	Syncarpous	...	1—locular	Superior	...	...
Ovules.	Indefinite	Placentation Axile	...	...	Indefinite	Placentation marginal	...	Superior ...

	Lotus (Nelumbium Speciosum)				*Banana (Musa Sapientum).*			
Organs.	Number.	Insertion.	Cohesion.	Adhesion	Number.	Insertion	Cohesion.	Adhesion.
Andrœcium								
Stamens	Indefinite	Hypogynous	Free	Inferior	5	Epigynous	Free	Superior.
Filaments	Indefinite	Hypogynous	Free	Inferior	5	Epigynous	Free	
Anthers	2—celled	...	Free	...	2—celled		Free	
Gynœcium	...	...	...	...	...	...	...	...
Carpels	Indefinite	Superior	Free	Superior	3	Inferior	Syncarpous	Inferior
Stigma	Indefinite	...	Free, distinct	...	Three	...	Three lobed	...
Styles	Indefinite	...	Free, distinct	...	...	...	Cylindrical	...
Ovary	Indefinite	Superior	...	Imbedded in a fleshy flat topped receptacle.	3—celled	Inferior	Syncarpous	Inferior
Ovules	1 in each Ovary	Placentation Marginal ; Pendulous.	...	...	Indefinite	Placentation axile.	...	...

CHAPTER IX.

Reproduction and Phenomena incident thereto.

It has already been pointed out in the Introduction that every existing vegetable life derives its existence from ancestral forms. Reproduction and Multiplication, then, are the essential vital requirements of every existing plant species. In the life history of every plant, there is a stage where it is rejuvenated in order to produce a new offspring; and as death ensues, sooner or later, the rejuvenated part, the offspring or its germ, must, as a matter of necessity, separate from the parent. But as the conditions of existence for a delicate germ or embryo, are far too uncongenial for such living matters, and as there is a continual struggle for existence, plants always take the safeguard of producing a large number of these rejuvenated parts, so that, one or other or some of them may live through the struggle and become independent organisms. This is the significance of multiplication, or the production of a very large number of seeds or buds or spores.

Thus, the essential requisites of reproduction are the *Rejuvenation*, *Separation* and *Multiplication* of the individual species. In order to carry out these functions of reproduction every plant, or family or class of plants has adopted contrivances most suited to square with its mode of existence. The infinite diversity of forms of reproduction, we may best encompass under two distinct classes :—(1) Vegetative, Monogenetic or Asexual ; and (2) Sexual or Digenetic reproduction.

Vegetative Reproduction.—In the lower Cryptogamia, the asexual is the chief mode of reproduction ; a part of the plant protoplasm rejuvenates, becomes more condensed and separating from the parent takes a fresh start in life. These reproductive bodies are variously named in the various classes ; but are collectively included under the term SPORE

In higher plants, on the other hand, a more or less specialised part is separated off from the vegetative region of the parent and produce directly a new plant which is, in almost all cases, an exact reflexion of the parent. These reproductive bodies are called Buds, examples of which we have already got under Bulbils (P. 48). The cultivated Banana plant, for instance, is never raised from the seed ; it propagates asexually by buds which remain under ground ; indeed in some varieties of Banana the seeds are never produced. Again, many *Dioscoreaceæ* no longer reproduce themselves in the sexual manner, cultivation having stereotyped their habit of reproducing vegetatively. In the Garlic, Lotus and some water plants small reproductive bulbs are formed instead of flowers ; and these separating from the parent and falling in the soil give rise to new plants.

In higher plants, reproduction by flowers is, of course, the rule ; but cases abound where, due to inhospitable situation or other threatening environmental causes flowers are not formed and are replaced by small buds or bulbs. The development of bulbs in the inflorescence of Globba has already been mentioned (P. 48). Many annuals have been known to produce reproductive shoots—Suckers, Bulbs etc, when their flowers are artificially removed by pruning,—the shoots thus formed reproducing the annual from year to year, which thus become, in effect, perennials. What is called "Sprouting"—a phenomenon familiar to agriculturists,—is due to the development of the embryo while it is still within the fruit. It happens in the cereals, when they are thoroughly drenched by a too heavy rain just before the harvest.

One necessary factor for the production of flowers in Phanerogams is the scarcity of water. Too much water, as a rule, prevents the formation of flowers. Many Pondweeds (e.g. *Potamogeton*) and water plants (e.g. the American *Elodea*

Canadensis) have scarcely been found to flower, still they choke up the whole watery surface by reproducing themselves vegetatively by buds. Water plants, as a rule, fructify in seasons when the water is at a low level i.e. in winter, or just before or after that.

Further examples of plants reproducing chiefly asexually by vegetative buds, are in the European Lesser Celandine (*Ranunculas ficaria*), the Coral-root (*Dentaria bulbifera*) and in many Lilies. One remarkable instance is in the Alpine *Lilium bulbiferum.* Here the small flowers that are formed, have lost all reproductive properties, unless they are revived by insect pollination. These non-fruiting plants produce a large number of bulbils from the axils of the leaves; and these are light enough to be disarticulated in autumn and dispersed by the wind.

Since in many cases, the same plant exibits the two modes of reproduction—sexual, and asexual, there must necessarily be a **significance of sexual reproduction.** As a matter of fact, it has been observed that vegetative reproduction repeats the character of the parent in the offspring *in toto.* Plants raised from cuttings, Bulbs, Tubers and Bulbils resemble the parent entirely. In many of the lower plants (Algæ and Fungi), it has been definitely ascertained that a sudden change in the physical surroundings occasions the development of sexual organs. The present theory is that the descendant resulting from a sexual union can withstand better the multifarious conditions of the terrestrial surface with all its gradual modifications, than that produced vegetatively. Plants are necessarily called upon to vary with the variation of temperature, moisture, etc, of their environment. Hence vegetative reproduction, repeating as it does the ancestral character in gross, would be ill-suited to produce descendants that can exist in harmony with the changed conditions of their environment. Sexual reproduction, however always ends in producing offspring sharing characters somewhat intermediate between those of the male and female parents. Of a large number of seeds, varying ever so little from one another, and dispersed over a wide area, some at least may outlive any very great climatic or other environmental disturbances; and thus, while maintaining the main characters of the parents would not altogether be deaf to the call of environment to adapt themselves to their immediate surroundings. Descendants, however, "do not exhibit a uniform mean between the parents, but some may resemble the father, others the mother. Variations appearing in single individuals will, unless they are of an absolutely dominating character, become modified and ultimately lost by crossing with ordinary individuals. In such a case sexual reproduction tends to maintain the constancy of the species. In other cases, as when both parents tend to vary in the same direction, the deviation from the ancestral form may be increased by sexual reproduction as two systems of waves may reinforce one another if their periods coincide "*

While vegetative reproduction by buds, bulbils etc., are almost exclusively found in many herbs or herbaceous water plants, it is in no wise rare in many trees and shurbs, though Conifers and Palms are altogether devoid of it. The winter buds of *Utricularia* and *Pistia*, the leaf buds of Bryophyllum produced in the marginal indentations, the latent buds of many Begonia leaves are further examples. Instances also occur in many Ferns (*e.g. Asplenium Viviparum*, *A. bulbiferum*, *etc.*) which normally produce reproductive buds from the lamina.

Sexual Reproduction.

It should be observed that while stress of physical conditions may call upon a dying plant to reproduce itself vegetatively, the labour of reproduction is normally divided between two distinct masses of Protoplasm. The union of the male

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* From Strasburger, Text-Book of Botany, Eng: Trans: Second Edition, P. 275.

and female sexes thus differentiated is called *fertilisation*; and the task of initiating a new plant devolves upon the structure formed by such union.

In some of the lower Cryptogams both the sexual organs are motile and similar (Gametes). But in throughout the higher Cryptogams the male sexes alone are motile, while the female remains stationary as an inviting organ. Even in the Gymnosperms, the male sexes are motile and search out the female, and then fusing with it produce the seed. The actual union of the sexually differentiated cells is a rather simple phenomenon in the lower plants; the motile male cells are naked, while the female cells are enclosed within a sac, called *Archegonia.* In Phanerogams, however, the reproductive protoplasm remains enclosed in specialised structures—the essential organs of reproduction. The male fertilising substance, called *spermatoplasm* remains within the pollen grains; the female, called *ooplasm*, is developed within the *embryo-sac* of the ovule. The double walled pollen grains of Angiosperms do not move about in search for the female ovules like the *spermatozoids* of cryptogams, but are carried by external agencies as wind, water, animals etc. The ovules, similarly, do not expose themselves freely, but are protected by the ovaries in which they are produced. In contrast to the non-motile male cells and the covered ovules of the Angiosperms, the Gymnosperms have motile spermatozoids and naked ovules *i.e.*, without any investing layer of ovary. Sexually, then, in the scale of complexity, the Gymnosperms occupy a place intermediate between the lowly-differentiated Cryptogams and the highly-differentiated Angiosperms.

It should be observed, here, that the Doctrine of Adaptation to Environment, may with advantage, be applied in explaining the diverse phenomena of sexuality. Living as they do in what we may call humbler situations, as stagnant, or clear water, shady places, etc., the lower Cryptogams do not produce very complex mechanisms for effecting their sexual reproduction. The motile spermatozoids can very readily swim in the water, and attracted by certain sugary excretions from the female organs, finally reach them, and perforating their walls become fused with the female Ooplasm. The water and other environmental factors of the media in which they live render all these possible. The same process, however, could not go on in the higher plants; for they are in a great measure land plants, or at least have habitats where the struggle for existence is hard. Sudden changes of temperature, of moisture, wind and other physical agencies are much too frequent; and add to that the mutual struggles between plant and plant on one hand and between plants and animals on the other. Necessarily, they fashion their aerial reproductive organs in a variety of ways, and adopt contrivances in harmony with their environment. The flower is such an adapted structure and it becomes more and more complex as the plant organisation rises in the scale of complexity, and as its response to environment is more and more called forth. Protective mechanisms against climatic and other similar catastrophies, enveloping sheaths to limit excessive loss of water, inviting and attractive structures for ensuring the safe transport of pollens and their deposition on the stigmas, can always be observed in the higher Phanerogams, where there is ærial fertilisation, while they are universally wanting in plants fertilised under water. All those modifications of the flower that give rise to the different forms of the Corolla, the Stamen, the Pistil etc, are produced solely as a result of the adaptation to environment of the floral organs. The colouring of petals, the union of petals, the distortion in the symmetrical shape of the Corolla, the lengthening of the stamens, the curvature of the filaments and styles, the formation of nectaries and glands—all these operate with the same end in view, and are essentially dependent upon the ways and means by which different plants become fertilised.

Adaptation for the Protection of the Sexual Organs.

The simple male cells of Cryptogams, as has already been observed, are naked and motile. Many water plants, specially those that remain submerged—Zostera, for instance—develop their pollen as long filamentous bodies without the protective layer of extine. They are merely carried by currents of water, until they are intercepted by stigmas of ovaries of other plants of the same species, and then they fertilise. Higher plants, however, are mostly aerial, or subaerial, or at least, fertilise and fructify above water. In plants having a habitat in water, *the opening of the flower and the fertilisation go on over the* surface. In most cases pollens are never dispersed under water; while in many, the contact with water or moisture results in their death, or in rendering them functionless. It is with regard to affording this protection against water and moisture that the manifold contrivances in the flower are resorted to. It is to be emphasised here, that every floral part is, directly or indirectly, in relation to fertilisation and fructification.

Unlike the pollen of some submerged aquatic plants, all the great Phanerogamous plants have their pollens protected by an additional coat of extine. The markings and excavations on this coat and their significance will be refered to later on. As a further safeguard against the injurious action of water the grains are generally provided with a hairy or waxy coating. But these are quite insignificant things so far as protection is concerned.

In cases where the floral enveloping leaves are not developed, special leaves in the form of Bracts or foliage, are employed to serve as protective organs. In spathaceous flowers, for instance, the roofing of the spathes not only prevents rain drops from wetting the stamens and the pollens but diminishes radiation from the structures beneath. In all Aroids (Kutchoo, etc), in the Banana plants and many spathaceous Palms, the clustered flowers are always protected during their maturity by long and smooth Bract leaves. They protect the whole cluster with its secretion of nectariferous juices till fertilisation takes place, and then detach themselves and fall to the ground. Rain drops pattering heavily on the imbricated bracts of the Banana, on the thick smooth and hoodlike spathe of the Aroids, have but little chance of moistening or drenching the flowers. Instances may be multiplied of plants in which the green leaves act as sheathing or covering and protecting agents. In many such cases, so long as the flowers are unopened and in the bud, the axillary stalks that bear them remain short; but as soon as the flower begins to open the stalks elongate and bending downwards place the flowers under the shelter of the leaves. The latter drain away the rain drops, and prevent excessive loss of heat by radiation or of water by evaporation, from the flowers.

Remarkable as it may seem, it is curious to find that all plants in which the flowers are fully developed and gloriously coloured do not in general produce any conspicuous bracts; and that these latter are always associated with Achlamydeous flowers. The gamopetalous corollas of Scrophulariaceæ, Campanulaceæ, Convolvulaceæ, Boraginaceæ, etc, always droop downwards presenting their open faces towards the earth. Their silky and smooth surface while draining out rain and moisture allow free entry to winged creatures who come in search after honey, and unwittingly carry the pollen on their shoulders, to be deposited on other flowers that they visit. Many irregular corollas have their parts so disposed as to ensure the stamens and pistils safe protection against rain and wet. Development of some of the perianth leaves as hood-like coverings occurs in the Ranunculaceæ, Scrophulariaceæ and in many bilabiate corollas. Personate corollas have their queer structures adapted fully to protect the reproductive organs enclosed within. Lipped corollas protrude their upper lip and roofing over the stamens afford them protection. Campanulate, rotate, and funnel shaped corollas of many gamopetalous plants are pendulous. Salver shaped corollas though open to the sky are so contracted in their throat as to prevent rain drops from entering into the tube below where the essential organs lie enclosed. Any drop of water that may fall on them will no doubt close their orifice but the next blow of wind will surely shake it off. Papilionaceous flowers are so constructed as to keep their sexual organs always enclosed in the boatshaped lower petals with the vexillum arching over them.

All these contrivances for pollen-protection, correspond however mainly with the adaptations for pollen-transport; and we shall have occasion to revert to their consideration. But as a clear evidence of adaptation and the importance of pollen protection, we may, mention the following cases where a movement of the perianth takes place normally on the approach of danger.

The large flowers of the Water Lily (*Nymphæa*) spread out their beautiful floral leaves and become the centre of attraction for insects hovering round, only so long as the sun shines resplendent on them. But as soon as the sun goes down and dew drops lurk behind, or when a cloudy or rainy day threatens, the flowers close—the petals are folded inwards and the stamens and pistils thus saved from a thorough drench. In many Magnolias a similar closing of the petals occur. Many garden Poppies bend their flower stalks on the approach of night, so that, the bright flowers opened during the day face the sky, and droop down pointing towards the earth during the night. In this way they prevent the deposition of dew drops on sexual organs. A similar movement takes place in the capitulate stalks of many Compositæ. The far famed Surjamukhi (*Helianthus*) is a singular case in point. Whatever be the direction of the sun, it nods its flower stalks so as to present its capitulum always towards the sun. In other composites as in the Marigold (*Calendula*), Dandelion (*Taraxacum*), Lettuce (Lactuca) etc, the ray flowers of the capitula open out in fine weather as golden rays. The sun shining fully on them make them visible from a great distance and render them objects of common attraction. But in bad weather and at night the ligulate florets of the periphery close and cover with their strap-shaped corolla the whole centre of the capitulum. The inconspicuous tubular flowers of the disc, thus get protective services from the strap-shaped flowers of the margin.

Movements of the corolla resulting in the complete closing of the open throat or end, on the first scent of a rainy weather or dewy night, occur also most conspicuously in tubular, funnel-shaped, rotate and other forms of gamopetalous flowers. Thus, in Datura, the infundibuliform corollas are fully opened in a bright day; but in the evening and night and in moist weather, they close up by a twisting movement. They then take up a form almost exactly as they had in the bud. The rotate flowers of the Potato, similarly, are widely open during the day, but fold up and take up a drooping position in the afternoon—a position which they maintain while the night lasts. Twining plants of Convolvulaceæ and Acanthaceæ, commonly used on garden railings, and gate-fronts have their very beautiful bell-shaped or slightly irregular flowers hanging freely in the air with their open mouths pointed toward the earth. But as a chill wind or one laden with moisture blows, indicating the near approach of a shower, the expanding ends of the corollas twist round and securely close the opening. On being once more warmed up by a clear sun they expand again and hold out afresh their charms to the insect world.

Dispersion of Pollen.

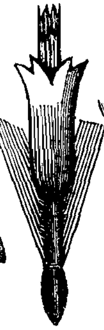
The transport of pollen to the female sexual organs, i.e., to the stigmas, is called *Pollination*. From the construction of hermaphrodite flowers it might be supposed that the pollen fertilise the ovary of the same flower. As a matter of fact, however, it has been definitely ascertained that flowers usually *cross*, i.e. the pollen of one flower is carried by some agent to the stigmas of other individuals of the same species. In the former case the flower is said to be *Self-pollinated* or *Self-fertilised* or *Autogamous ;* in the latter, it is *Cross-pollinated* or *Cross-fertilised* or *Allogamous.* In the language of Darwin "Nature abhors perpetual self-fertilisation." As a result of the most profound investigation, Darwin came to the conclusion that plants produced from cross fertilisation had the advantage over those produced by self-fertilisation in being more hardy and better able to withstand vicissitudes of environment.

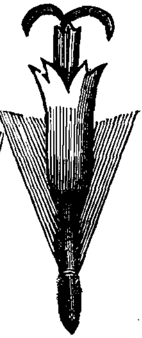
The main agents for pollination are (a) the wind and (b) the insects. Phanerogams, accordingly are called *Anemophilous* or wind-fertilised, and *Entomophilous* or insect-fertilised plants. In a few cases, where water is the medium in which the plant lives, it acts as the carrier of pollen ; and such plants are on that account called *Hydrophilous.*

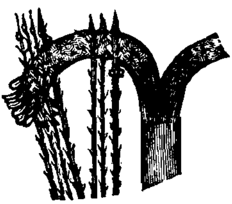
Adaptations for Anemophily.—As pollination by wind depends upon the nature of the agent, an enormous amount of pollen is produced in wind-pollinated flowers. And in order to be better adapted to be shaken off the anthers and carried by the wind, the pollen grains here are dry and light. Connected with this mode of dispersion is the rudimentary development of the perianth and the separation of the sexes. Anemophilous plants are mostly diœcious or monœcious ; and even when they are hermaphrodite, they ripen their anthers and stigmas at different periods. Thus all these contrivances are for inter-crossing. The cloud of pollen dusts is a very remarkable feature in many Pine forests. Flowers suspended in catkins as in Willows, Conifers, etc, are all wind-pollinated ; so also are all other amentaceous trees. In Grasses and Sedges the versatile anthers remain pendulous, and playing with the wind use it as an agent for conveying their pollen. In many Conifers, besides the pollen grains being dry, there are little sac-like protuberances on their surface, which make them still more buoyant. Nectar and other sweet secretions of the flower are as a rule absent. The perianth segments do nothing more than afford protection against rain and moisture: hence they are not otherwise adapted to make them attractive to insects and birds.

In keeping with these conditions are the different forms of the stigma to be covered by these *dusty pollens.* In hermaphrodite wind-pollinated flowers, the stigmas and anthers rarely mature at the same time:—While the pollens of one flower are being discharged, the stigmas of the same flower are withered or may be quite immature. In function then, if not in form, these flowers are monœcious or diœcious. Apart from the time of maturity the form of such stigmas is significant enough. In Grasses the stigmas are dissected into a large number of feathery parts; they catch like a spider's-web the pollen-dust that must be carried past them. In other cases, the stigmas are globular or flat or otherwise expanded to net in the flying pollen grains. The stigmatal surface, again, is often sticky so that pollens once caught can not easily be shaken off the stigma again by the wind.

FIG. 219, 220. FIG. 221. FIG 222. FIG. 223.







Adaptations for Entomophily.—By far the great majority of land plants pollinate through the agency of insects, birds and other small animals. In the rich South American climates,it is the humming bird that is fastened upon as a carrier of pollen. Plants that pollinate through such birds are called *Ornithophilous.* In all these cases of Entomophilous and Ornithophilous plants the quantity of pollen grains formed is not so large as in the anemophilous plants; for instead of having the plant-energy spent in the production of an enormous quantity of pollen, here we have got an extra adaptation for enticing winged animals, and thus,for ensuring the safe transport of pollen. Brightly coloured perianths, odoriferous secretions, sweet and luscious honey exuded in Nectaries, nourishing pollen grains, etc are some of the devices which allure insects and birds. The pollen grains are further adapted by being smeared with a sticky and sugary secretion, and by the formation of burs, ridges, and other forms of sculpturings, so that they are easily attached to the bodies of winged visitors of the flower. In some cases the adaptation of the pollens for transportation takes the form of their being joined by thin threads of mucilage; in Asclepiadaceæ and Orchidaceæ, the pollen grains form cohering masses called *Pollinia.* All these are, no doubt, contrivances for detaching the pollen from their reservoirs and tying them on to the head, limb or body of insects. Correlated with this sticky, glutinous or armed character of the pollen, is the roughness and glutinosity found as a common feature of the stigmas of these plants. Many insects are known to live in the interior of flowers clustered in an inflorescence. In their movement to and fro, they pollinate stigmas that could not otherwise have been provided with the pollen. This is best seen in the hypanthodium of the Fig and other allied plants (*Ficus*). Small beetles, flies and insects are known to take shelter in the comfortable and warm interior of campanulate, funnel-form and similar large flowers. In their daily entrance and exit they necessarily become the vehicle for transporting pollen from flower to flower.

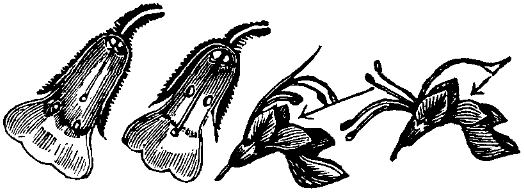
Besides these small winged insects and birds, large animals also take part in pollen transport. Thus the foul stench of many species of Arum and other spathaceous Monocot herbs is the attraction for many creeping animals, such as snails. The creatures living ordinarily on decaying and putrid matter find a very pleasant and warm home in the interior of the chamber of the spathe, and as they travel from one plant to another carry the burden of pollen on their shoulders.

Adaptations for Intercrossing.

In allogamous or cross-fertilised flowers, the pollen of one flower is transferred to the stigma of another. When crossing takes place between different flowers of the same species, it may happen between neighbouring flowers of the same plant, or between those of two different individuals of the same species. The former mode is called Geitonogamy, and the latter Xenogamy. Anything beyond the latter, as when crossing takes place between two different individual species, is no true crossing but hybridisation.

Flowers must necessarily be *crossed* when they are unisexual. The existence of monœcious, diœcious, and poly gamous flowers points clearly to the adaptations for *crossing*. But though sexual isolation can only result in inter-crossing, it must not be supposed that it is the only mode by which allogamy is attained. ɩt is however in many hermaphrodite flowers that the adaptatons for inter-crossing become more striking, and add more weight to the proposition "Nature abhors perpetual self-fertilisation." Autogamy or self fertilisation can only strictly happen in hermaphrodite flowers; but they are necessarily crossed in by far the great majority of cases where colour, odour, nectar and other agents for alluring insects are developed. As further adaptive contrivances for crossing, many hermaphrodite flowers mature their sexual organs at different periods in point of time. In some the stigma may be ripe while anthers of the same flower may be quite immature; so that, the ripe stigma, while quite free to receive pollen from other flowers where the anthers having attained maturity are shedding the pollens, preclude any possibility of being fertilised by the pollen of its own flower. In function though not in form, these flowers are unisexual.

FIG. 224. FIG. 225. FIG. 226. FIG. 227.



Figs. 224, 225. Heterostyled flowers of *Primula*. Fig. 226, 227. Protandrous flowers. Fig. 226, Anthers bursting; Stigma immature. Fig. 227. Filaments recurved having done their work; Stigma—mature and bifid. The arrow indicates the path of a fly brushing the Anthers of one flower and the Stigma of another

This contrivance in a hermaphrodite flower of intercrossing by maturing the sexual organs at different times has been called Dichogamy by Conrad Sprengel who first noticed and described it. Dichogamous hermaphroditism is indeed an advantage over diœcism, as all flowers and all plants are able to produce seeds in such cases. The term *protandry* is used to denote the fact that the anthers of a dichogamous flower mature and shed their pollens before its stigma is ripe for the reception of pollen; similarly, *Protogyny* means that the stigma attains maturity before the stamens.

Another contrivance connected with dichogamy is the interchange of position of stamens and stigmas. Protandry being the more frequent form of dichogamy, many gamopetalous flowers develop their stamens as long protruding structues with the anthers standing out prominently before the showy flowers and discharging their load of pollengrains to the wind and insects. Later on, when the function of the anthers has been carried out, the stamens coil or otherwise shrink back, and the stigma now attaining maturity is brought forward by the growing style to the same place occupied previously by the ripe anthers. Since this position is directly in the path of insects and bees as they come to visit the flowers, the pollen brushed away from the discharging anthers of one flower are transported to and deposited on the stigma of another. Figs. 219, 220 show the relative position of the stamens and styles in the dichogamous flowers of the Bhant (or Bhantaka or Ghentu —*Volkameria infortunata R.*). The plant grows generally under the shade of large trees, and flowers about February in Bengal and Behar. The flowers are pretty large and white with a tinge of red. The long filiform stamens and style enrolled in the bud, straighten out when the flower opens ; the filaments remaining straight discharge the pollen, while the style is recurved downwards ; soon after they roll downwards and the style then grows upwards and the stigma opens out in the form of two long lips. The receptive spot is now developed and the stigma is ready to receive pollen.

In many other species of Volkameria and Clerodendrons and other verbenacious garden plants the same phenomenon can be observed. Protandry abounds also in many flowers of *Gentianaceæ, Campanulaceae, Geraniaceae, Malvaceae, Scrophulariaceae* etc. Liliaceous and Umbelliferous plants are stated to be all protandrous ; and generally the flowers of Compositæ, Labiatæ, Caryophyllaceæ and Papilionaceæ, so far as has been observed, are protandrous. Figs. 221, 222 illustrate the way in which the protandrous Compositæ flowers effect their pollination. Here, it should be observed, the stamens are short and united by the anthers (sygenesious) which form a tube through which the style protrudes out. The pollen grains being discharged by the ripe protandrous stamens, on the surface of the still elongating and immature style and stigma, are carried aloft by the latter. The stigma thus pushes the pollen before it out of the tube of the anthers and holds it in the path of insects which travel over the surface of the flat inflorescence in which the flowers are aggregated. In their way, they visit other flowers where the stigma *is ripe by this time, and transfer* the pollen. The stigma which carried the pollen upwards now bifurcates, and diverging, developes the receptive surface in the inner face while the pollen grains are on its outer surface.

Protogynous flowers are less frequently met with. Here the stigma receives pollen before the anthers of the same *flowers are ripe ; so that, fertilisation takes place by the* pollen of older flowers. In the Mustard family (Cruciferæ), for instance, the pistils are mature before the stamens. In Scrophularia, again, the slightly irregular corolla is approached by bees from the front, and there they meet the protruding and mature stigma while the stamens are still coiled within being yet not fully developed. As further examples, the Solanaceæ, Rubiaceæ along with the Cruciferæ are exclusively protogynous. In many species of Plantago the flowers are clustered in spicate inflorescences. The upper flowers protrude their styles and stigmas while still unopened and receive the dry and dusty pollen brought in by the wind from other flower-clusters. The lower flowers next open out in acropetal succession, and the filaments now come out and dangle in the air with their versatile stamens which discharge their pollen to the wind ; the style and stigma of the flowers gradually fall away having performed the work, and the opening of the flowers proceeds from the base up to the top, long after they have been fertilised by pollens brought from other flowers.

All these instances of dichogamy are pregnant with significance. For it is a well-known fact that all flowers of a species, living in similar conditions of environment do not open on the same day, still less at the same time. Were all the flowers on an inflorescence opened at the same time and were all of them protandrous or protogynous, xenogamy would be the only thing that could occur and the next step to hybridisation would not be very far off. Plants, however, have little tendency to run into hybrids ; and they try to avoid to run into the other extreme of self fertilisation. The only legitimate crossing can take place by Xenogamy and Geitonogamy, and dichogamy is an adaptation to carry out these forms of fertilisation.

Another contrivance for bringing about intercrossing is the production of styles and stamens of different lengths in different individual species. This *heterostyly*, as it is called, has been proved by Darwin to be a potent factor in effecting crossings in plants where it occurs. Fig. 225 shows a long styled Primrose (*Primula*) ; Fig. 224, a short styled one. The pollen grains of the latter are larger and the stigmatic outgrowths shorter, than what we find in the former. As a result of experiments, Darwin who investigated the matter fully, came to the conclusion that fertilisation is most successful when pollination of the stigma takes place by the pollen of stamens situated at the corresponding height. The position of the different kinds of stamens and styles, is so adapted that insects visiting the flowers touch correspondingly placed sexual organs with the same portions of their body. The *pollen grains, again, in many such cases of heterostyly*, have been found to be less potent on the stigma of the same flower than on that of another. Closely connected with this **Dimorphic Heterostylism,** where, as in the above case, the sexual organs are of two different lengths, is the production of three forms as to the reciprocal relative length of stamens and styles—called *Trimorphic Heterostylism.* The classical example is in *Lythrum Salicaria*, for a full and detailed description of which the student is referred to Darwin; Forms of Flowers: Chapter IV.

Some irregular flowers present very curious mechanisms for cross pollination. They are not dichogamous or dimorphic. By far the majority of such flowers falls under the two families Papilionaceæ and Orchidaceæ. In the former, the pollen grains carried by the insects are in separate grains, though each is adapted to stick to the bodies of insects and other winged pollen carriers. In the latter, the pollens are in masses—coherent bags of pollen are formed as a result of the very sticky secretions given out from the stamens in their anther-cells, besmearing and enveloping the pollen like jelly.

The adaptation of the Papilionaceous flowers for pollen transport consists essentially in this:—the diadelphous ten stamens discharge their pollen within the boatshaped petals and on the hairy surface of the style just below the stigma. Winged creatures, allured by the bright corollas, alighting on the wing like carina of the flower, depress by their weight the *keel* in which the sexual organs lie bidden. In their attempt of sucking up honey at the base of the corolla-tube, they besmear their bodies, especially the abdomen with the pollen. In visiting other blossoms in succession, they brush the stigma with their pollen-laden bodies and thus effect pollination.

In the common Bean plants the adaptation is still more remarkable. Here the keel enclosing the sexual organs is prolonged into a narrow twisted coil. The coiled style bears an oblique stigmatic surface, and a little downwards the hairs for carrying the pollens are developed. In the untouched flower the pollen and the stigma and their carriers are concealed from view, but as soon as the karina is weighted with the pressure exerted by an alighting insect, the style projects up, comes to view, touches the body of the insect and become pollinated. A more obstinate pressure will bring the hairy part of the style with its load of pollen grains in contact with the insect and thus transfer them over to its body. Thus a bee seeking honey, will alight upon the petal-wings and pressing it shift some of the pollens upon the stigma and carry some from it.

It is in the Orchids, however that the most exquisite adaptations are to be observed in their infinitely diversified forms.

Autogamy or Self-fertilisation.

In Wheat, Barley, Canna, Flax and many other plants self-fertilisation takes place either exclusively or in conjunction with cross-fertilisation. Drawin held the opinion that the cross is the only kind of legitimate sexual union in plants, and autogamy is injurious to a certain extent; but Kerner maintains that where inter-crossing fails, autogamy "assumes an importance of its own, and the contrivances which have been observed to bring about autogamy are no less numerous than those which favour cross pollination." Figs 228-32 show the discharge of pollen upon the stigma of the same flower. Soon after they come out from the bud the flaments are diverging, but as the anthers become mature they curve inwards, and bring their ripe anthers almost in contact with the ripe stigma upon which the grains are dusted (See fig. 230). Soon after the pollination, the anthers drop off, the filaments and the decapitated stamens roll inwards in the form of coils. (Fig 231). Certain compositæ flowers growing in situations rarely visited by insects, bees etc, bend their revolute split stigmas downwards on to the dissected and hairy calyx. Here pollen grains already carried by the style during its elongation, and sprinkled down over the pappus, have been caught, and now become attached to the sticky stigmatic surface thus

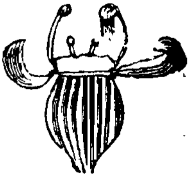
FIG. 228.

FIG. 229.

FIG. 230.

FIG. 231.

FIG. 232.



bent down. Fig. 223. In Argemone Mexicana (Shealkanta) the wide open petals catch the discharged pollen grains during the day, and closing over at night, bring some of the grains in contact with the ripe stigma, thus effecting its fertilisation. In what are called **Cleistogamic flowers**, *i.e.* those which never open (literally "closed up"), the adaptation for self-fertilisation is unmistakable. These are very small, inconspicuous flowers, formed generally on or near the ground and adapted by self-fertilisation to carry on reproduction when intercrossing fails.

To sum up, it may be stated,

(1). That in the more showy flowers of plants living in sunny and lively localities, cross pollination goes on almost exclusively.

(2). That where insects and other flower-visiting creatures are rare, self-pollination is the rule or at least, preponderates; though it takes place more frequently than Darwin had reason to think.

(3). That in cleistogamous flowers self-pollination is all that can take place.

The effect of Pollination, or the transport and deposition of pollen on the stigma, is fertilisation. The result of pollination is seen to be the withering, shrivelling and turning brown of all structures outside the ovary. The result of fertilisation is fructification or the formation of the fruit.

Soon after the proper pollen falls upon the proper stigma, the former produces the pollen tube which makes its way down to the ovary; and there meeting the ovule, penetrates into it and fertilises the *Ovum*. The spermatoplasm of the pollen tube fuses with the Ooplasm, and the result of this fusion is the Embryo.

The effect of fertilisation is not restricted to the production of the seed; but other parts of the flower also undergo modifications to carry out new functions, such as protection and dissemination of the seed. Hence the product of the changes induced by fertilisation, either in the flower, flowering axis, or the inflorescence is the FRUIT.

CHAPTER X.

The Fruit.

It is hard to define the Fruit—for here also, as in all other similar morphological questions, we have to face a large variety of structures that are undoubtedly Fruits—for here also, complications and metamorphosis and modifications of a typical, an ideal structure, make it difficult for us to cover the description of the thing under a generalisation. For in the gradual course of development of the flower we come to a final stage where all further progress ceases, and the changes that have been induced in it by fertilisation of the ovary, become permanently unalterable in the shape of a fully grown, mature structure, called the Fruit. Hence, it is no new morphological part of the plant—it is only a fertilsed ovary with which have been incorporated those persistent parts of the flower that have undergone changes consequent upon fertilisation. The flower, as will be remembered, is only a metamorphosed shoot, so modified as to carry on the physiological function of reproduction, and the Fruit, similarly, is a shoot where the modification has been carried a step further, so that another particular physiological function may be carried out effectively—that is, the preservation and protection of the seeds and their dispersion to the best advantage.

The above statements are very clearly borne out from a consideration of the composition of a few typical Fruits :—In the fruit of the Pea (Matur) the progressive development of the carpel can be traced apparently with ease ; what was before merely an elongated carpel in the flower has, in the fruit, become more capacious to give accommodation to the ovules which have matured into seeds, leaving only the style and stigma to die down and wither away.—Here then the fruit is simply a mature ovary—a seed vessel, with the wall of the carpel developed into a rather strong and hard coat, which we call the *Pericarp*, and the ovules matured into seeds. Not so simple is the case with the Cocoanut fruit or the Mango. For though we can distinctly recognise the seed that is in the Cocoanut or Mango, it goes without saying that the pericarp must have undergone some remarkable change, ultimately culminating in the fleshy coat in one case, and a fibrous one in the other. The Apple, the Orange and the Melon present still more difficult cases; for though the seeds are there all right within, the pericarp is curiously separable into two parts, and it is not easy at first sight to determine to what floral part they must be referred to. A still more difficult case we get in the Jack fruit and the Fig. In none of the two latter plants do we get flowers of any appreciable dimension, but, instead, a very large number of scaly flowers aggregated together on the fleshy and swollen mass of the main rachis, forming an inflorescence, the peculiarity and structure of which have marked it off from all other sorts. The Inflorescence then, in these cases, has fructified into an Infructescence, and we look in vain for any trace of the Pericarp. If we cut straight longitudinally through the Jack fruit we find the central fleshy rachis very clearly marked out from the rest of the pulpy mass which consists of a promiscuous mixture of floral leaves, bracts and carpels of all the flowers rendered succulent and fleshy. The number of flowers can be told from the number of seeds present, and the pulpy mass adherent to each seed represents the carpel.

The Fig fruit is similar in composition though a little different in form and texture. The fleshy rachis here, instead of being central, as in the Jack fruit, forms a hollow but closed cup, or funnel, and inside, on the surface of the wall of the cavity are found very small seed like structures.

The Pea fruit ranks first in our consideration—almost unrivalled for its simplicity of structure, and conspicuous for its common occurrence, the way in which it works out the function allotted to it is still more simple. When it is quite mature and too old to imprison the seeds within itself, it simply bursts at its two sides and thus lets go the seeds.

Closely allied to the above, but differing as regards the number of seeds present and of the opening faces, is the fruit of the Champak—better known in Bengal by the name Kantali Champa (*Michelia Champaca.*) The free carpels of the flower mature into plum shaped fruits hanging in bunches from a short branch, and each fruit splits when ripe on one face only and gives out the seed within. In contrast to the mode of dehiscence of the Pea fruit, the dehiscence in this case is only on one side—the margin or line along which the splitting takes place being called the suture. In both the above two cases the dehiscence is sutural. And if we recall the structure of the carpel it will be apparent that formed as it is by the infolding of a metamorphosed leaf along its midrib, the simplest carpel can have two sutures—one along the line where the margins of the leaf become fused—the ventral, and the other along the midrib—the dorsal. In the case of the Pea fruit, it dehisces by both sutures, while in the Champaka, only the ventral suture opens out.

Next, take the fruit of the mustard plant. If we examine the ovary still unripe, we find that it is made up of two carpels, united at the margins, and bearing a number of ovules on the placentas that originate along these lines of union. The ripe fruit bursts along these lines which must hence be called sutures, and the pericarp splits out into two parts which diverge away from the apex forming what are called, the two valves. It presents an apparent analogy to the Pea fruit—for in both cases the pericarp is divided into two almost similar halves;—but note that, in the Mustard fruit, the seeds are attached to a membranous partition wall called the ***replum***, in the median plane between the two valves, and this is always wanting in the Pea fruit; that the latter is apocarpous, whereas the former is syncarpous ; and that the dehiscence though sutural in both cases, occurs by the ventral suture only in the former and by both dorsal and ventral sutures in the latter.

Next examine the Datura fruit. It also is syncarpous. It also is dehiscent. Here also we find two carpels united together in the very young ovary, but during its ripening into the fruit, a false partition wall—false because it is of later growth—is interposed into each of the two cells of the maturing ovary, making it appear four celled. When at maturity the fruit dehisces, four valves open away from the centre leaving there the vestige of the placentas and the seeds. Other cases of dehiscent syncarpous Fruit we get in our common Cotton plant (*Gossypium*), in the Malva or Mallow Family, as for instance, in the Rukta Java (*Hibiscus Rosa sinensis*) and Ramtoroye (*Hibiscus esculentus*), and in the elastic fruits of Geranium (Dopati : *Impatiens Balsamina*), a common garden plant all over India.

It is to be remarked here that, in all the above cases, the dehiscence is always sutural i.e. regularly along the lines of junction. But it may not be quite regular or sutural,—it may be irregular. And this irregularity may happen either by a *transverse* splitting of the fruit into two halves,—one upper and the other lower, or by the formation of openings called pores on the whole surface, or only a part of the pericarp of the fruit. The transverse or *cicrcumscissile dehiscence* as the former mode is called, occurs in the minute fruits of the Coxcombe (Celosia) and Amaranthus. The Coxcomb, commonly known in Bengal as Morogphul, is a rather showy herbacious plant producing flowers which are individually very small and inconspicuous, but very showy in the clusters in which they are always aggregated. Each flower produces a small fruit, the pericarp of which is thin and hard, and splits into two parts, the upper falling away as a cup or lid from the lower—and in the cup-like hollow of the latter is to be found only one small hard and black seed. An excellent example of the second kind of irregular dehiscence, generally going by the name of *porous dehiscence* is in the Poppy fruit (of the Opium tree). Here the fruit is syncarpous, and it has parietal placentas, though these instead of remaining quite over the inner surface of the ovary extend towards the centre in the form of projecting walls and on these the seeds are borne. The fruit, however, does not open by valves, but numerous openings, like windows, are thrown out from the upper flat surface of the fruit, and it is through them that the seeds are dispersed. Thus

The Modes of Dehiscence are :—

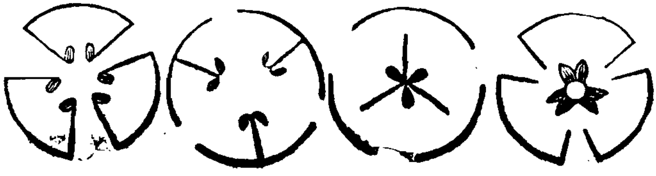
1. Sutural or Regular or Normal—when the pericarp breaks up along either the ventral or dorsal or both sutures.

2. Irregular or abnormal—when the dehiscence is not sutural but may be either (*a*) transverse or circumscissile, or (*b*) porous.

Kinds of Sutural Dehiscence :—

1. *Septicidal Dehiscence* :—where in the case of a syncarpous fruit the septa or partition walls of the cells are cut through, thus dividing the pericarp into as many parts as there are

FIG. 233. FIG. 234. FIG. 235. FIG. 236.



Diagrams to illustrate the Dehiscence of Fruits.

Fig. 233. Septicidal—each partition-wall cut in two—constituent carpels separated and opening by the ventral suture.

Fig. 234. Loculicidal—each loculus opened by splittings of the constituent carpels along the midrib or dorsal suture.

Fig. 235. Loculicidally septifragal.

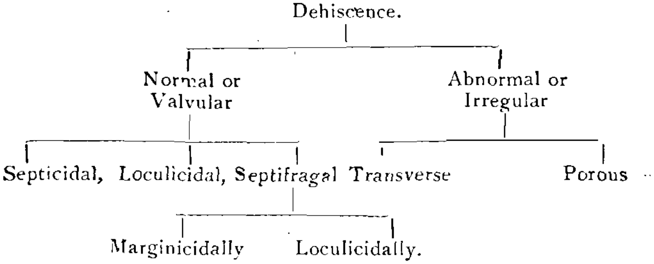
Fig. 236. Septicidally septifragal—septa or partition walls remaining intact—valves only falling away.

carpels and then each of these parts dehisces along the ventral suture as illustrated in the diagram Fig 233. Here the placentas are in the central column where all the margins of the carpellary leaves have become confluent, and which, at dehiscence lets go the carpels, each in its turn to be opened out along the ventral suture. In the whole Mallow family (Ramtoroye or Bhindee or Dhanrosa, Java, Sthalapadma, Cotton etc) this is very clearly seen. But in certain cases each of the split carpels may dehisce again by both the sutures.

2. *Loculicidal dehiscence*—where the pericarp opens along the dorsal suture of each carpel—the septa or partition walls remaining unsplit and attached to both the central placental column and the carples as in figure 234. Thus, each loculus or cell of the fruit is split only at the back and otherwise remains intact. Examples, in many fruits of the Mallow Family.

3. *Septifragal dehiscence*—where the septa or partition walls remain intact attached to the central column and the valves or the parts of the split pericarp fall away from them. If, in case first, we suppose that the splitting of the pericarp into carpels does not extend right to the central column by the bipartition of each septum but stops short at the outer edge of the septum, and if the valves then break away from the walls, the dehiscence becomes *septicidally* or better *marginicidally septifragal*. Similarly, if in case two, the partition walls remaining attached at the centre let go the valves, the dehiscence becomes *loculicidally septifragal*. The dehiscence of the Mustard fruit is a case in point. Since the two valves break away from the margin of the septum which is left behind with the seeds attached to it (*replum*), the dehiscence is of the marginicidally septifragal mode.

It will be possible now to give a tabular view of the different modes of Dehiscence of the Fruit—



We have been dealing so far exclusively with dry dehiscent fruits. The Pea fruit, the Mustard fruit, the Poppy fruit, and those of the Cotton, Celosia and Champaka differ widely from the Mango, or Lichi, or Water melon, in the fact, that the former have all dry and dehiscent pericarps, whereas the latter is fleshy or succulent. But there are fruits that are dry and still indehiscent. Witness for example, the fruit of the Rice or Wheat plant. And fleshy fruits are naturally indehiscent. With reference to the texture of the pericarp, then, fruits may be fleshy or dry; and with reference to the dehiscence, fruits may be dehiscent or indehiscent. Here at last we have found the threads of our classification—we may divide Fruits as

1. Dry
    - Dehiscent
    - Indehiscent
2. Fleshy
    - Dehiscent
    - Indehiscent

We may next proceed to classify and name the different kinds of fruits falling under each of these types. But it should be noted, here, that the terms referred to above apply only in the case of what are called Simple Fruits, i.e. those that result from the ripening of a single Pistil, and that there are fruits more complex in structure such, for example, as what we get from the ripening of a number of Pistils either belonging to one flower or different flowers on a receptacle. Hence there are :—

1. Simple Fruits—resulting from one Pistil.
   - *(a)* Dry Dehiscent.
   - *(b)* Dry Indehiscent.
   - *(c)* Succulent or Fleshy.
2. Aggregate Fruits—resulting from a cluster of separate Carpels belonging to one flower, united together into a mass.
3. Multiple Fruit—resulting from a cluster of separate Carpels belonging to different flowers on a common rachis, united into a mass.

Take a supposititious case. A long rachis bears a number of, say, sessile flowers in each of which the Gynœcium is composed of a number of carpels. Now if the Gynœcium be syncarpous, that is, if the Carpels be all united together to form one ovary then the resulting fruit would be clearly a simple one. But if the Gynœcium be apocarpous, that is, if the Pistils be separate and not united so that a number of ovaries is formed, then the resulting fruit would naturally be many from each flower, all clustered together on a very short stalk. The number of Fruits in the first case, the number of clusters in the second case, would no doubt correspond to the number of flowers that was on the rachis, The second case is one of the aggregate Fruit. Next, suppose the rachis compressed down to form not an elongated axis but a globular or flat or hollow structure. The flowers naturally would be clustered now, and if the fruits of all the flowers being thus aggregated adhere to one another either by becoming fleshy or by being simply superposed, then the resultant structure would be a multiple Fruit.

We next come to the nomenclature of the

Dry Dehiscent Fruits or Pods.

A. Apocarpous—that is, from a single carpel.

1. **Follicle**—is an apocarpous and monocarpellary pod dehiscing by only one suture (generally the ventral). In the

Champaka already alluded to above, the Fruit is aggregate and is composed of Follicles. In Magnolias, where the flowers are large, beautiful and odoriferous, as also in the Aconite or katbish plant of Darjeeling and in the Madar (akanda) the fruits are Follicles.

FIG. 237.

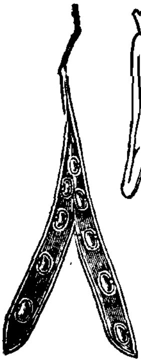


FIG. 238.

FIG. 239.

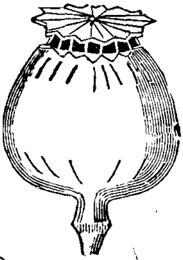


FIG. 240.

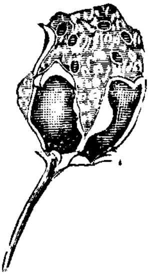


Fig. 237. Legume of *Pea* ; seeds attached toward the ventral surture.

Fig. 238. Silique of *Mustard*. Below, a Silicle or Silicula. Note the two valves and the replum.

Fig. 239. Capsule of *Poppy*. Note the pores formed like windows below the spreading top.

Fig. 240. Capsule of *Cotton*, bursting into five valves.—Note the hairy seeds.

2. **Legume**—is an apocarpous and monocarpellary pod dehiscing by both sutures, being thus divided into two valves. In all the great Pea family of plants Legumes are characteristic. The different pulse plants, the sensitive plant (Lajjabati lata), the thorny Babla tree, the Hemp plant, the Indigo plant, the Dhak (Palas) all have legumes and all come under the very big family called Leguminosæ—indeed the term Legume is restricted to the fruits of this family.

3. **Loment**—is a legume which has become transversely jointed above and below each seed—thus there is always a constriction of the pericarp between two seeds. As for example, in the Soondali (*Cassia fistula*) where spurious dissepiments running between the seeds make the fruit many celled. It is sometimes not dehiscent as in the Tamarind, Sisso, Santal wood, etc.

B. SYNCARPOUS—that is, from a compound ovary.

4. **Capsule**—is an one celled or many celled syncarpous dry dehiscent fruit. It may dehisce in any of the modes of dehiscence—regularly or irregularly, septicidally, loculicidally or septifragally. It may consist of two, three or more carpels. The fruits of the Malva, the Java, the Poppy, the Cotton plants are all capsules. But two special kinds of the Capsule have received substantive names,—these are :—

5. **Silique**—is a narrow two valved Capsule with two parietal placentas from which the valves separate in dehiscence. It is a capsule of 2 carpels with marginicidally septifragal dehiscence. Fig. 238. Examples, in the Mustard, the Radish, the Turnip plants. The Silique is the characteristic fruit of the family of plants known as Cruciferæ just as the Legume is of the Leguminosæ. It is generally of an elongated form, like the Legume ; but in some Cruciferous plants the fruit is flat, short and compressed. These are called *Silicula* (diminutive of Silique).

6. **Pyxis** or **Pyxidium**—is a capsule with irregular circumscissile or transverse dehiscence as in Celosia (coxcomb-morogphul), Amaranthus etc.

7. **Diplotegia**.—Inferior fruits are usually indehiscent (see Pepo, Cypsela) ; but in some cases they become capsular. These inferior capsular or dehiscent fruits are called Diplotegias. Thus of dehiscent syncarpous fruits, those that are superior are called Capsules ; those that are inferior, Diplotegias.

Dry Indehiscent Fruits.

In these the pericarp never dehisces, but may be either hard and bony, or membranous ; and when membranous it may either be closely applied to the surface of the seed enclosed within, or may remain loose, only as a bladder-like covering. Indehiscent dry fruits are generally one seeded and this precludes them from dehiscing and thus dispersing the seeds. But in some cases, special appendages are developed on the pericarp, which help in the dispersion of the fruit by making it more light and ready for transport. Of these the following are the most important.—

1. **Samara**—is a dry indehiscent one seeded winged fruit. In the Sal (a big Timber plant—*Shorea robusta*) Fruit, for instance, five large wings are attached to a cluster of five one seeded indehiscent pericarps. In the Madhabilota (*Hiptage madhoblota*) plant, the Fruit consists of three capsules each provided with 3 long wings. Fig. 242. The function of the wing is to make the Fruit lighter and more buoyant, and

FIG. 241. FIG. 242. FIG. 243. FIG. 244.

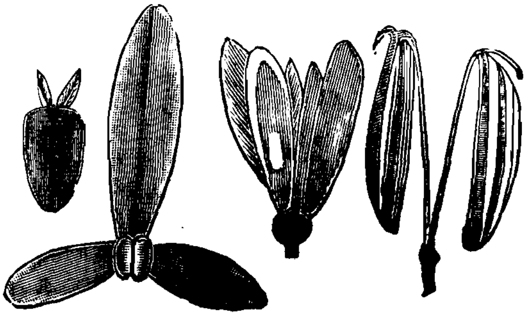


Fig. 241. Achene of *Sunflower* with pappus of two scales.
Fig. 242. Samara of *Madhobylota* with three wings.
Fig. 243. Winged fruit of *Sal*—of five winged Achenes.
Fig. 244 Fruit of *Umbelliferæ*—a Cremocarp.

thus to facilitate the dispersion by wind. A similar function is carried out by the tuft of hairs so conspicuously present in the small compressed seed of the Madar (akanda) as to make it a matter of common observation about February in Bengal. But such tufts of hairs are also formed on the top of small one seeded indehiscent fruits called

2. **Achenes** as in the marigold (genda) and sunflower (Surjamukhi). The Achene in such cases results from an inferior ovary, and the calyx being adnate becomes incorporated with the fruit and forms at the top a tuft of hairs, or a set of teeth or scales only, called Pappus.—In other cases as in the twining Clematis, the Buttercup and other Ranunculaceous plants such hairy appendages are not found and the fruit is not inferior. Hence whether originating from a superior or an inferior ovary, one seeded, hard, dry, indehiscent seed-like small fruits are called Achenes. The term Achene, however is more particularly applied to monocarpellary fruits ; Whereas

Cypsela is the name given to an achene with an adnate calyx and derived from a bicarpellary Pistil having a syncarpous and unilocular ovary. It is the characteristic fruit of the Compositæ, and is always inferior.

3. **Nut** is a hard one seeded indehiscent achene-like fruit but much larger and produced from a syncarpous 2-3 celled ovary containing 2-3 ovules, only one cell and one seed being left in the Fruit, the rest being turned abortive. Such fruits are commonly found in many plants belonging to the Cupuliferæ specially in Oak, Hazel and Beech. When the outer coat of this fruit becomes fibrous it is called a fibro drupaceous Nut, as in the Cocoanut, the Almond, the Betelnut etc.

4. **Caryopsis** is the fruit of the Graminæ—the Grass family, e.g, of Wheat, Rice, Barley etc. It is a superior one celled one seeded syncarpous fruit with a very thin membranous pericarp adhering and conforming to the seed. Of all

ruits this is most likely to be mistaken for a seed. It may be defined as an Achene in which the pericarp of the fruit and the testa of the seed are fused together into an inseparable mass.

5. **Schizocarp** is a dry syncarpous fruit which at maturity separates into two or more dry indehiscent one-seeded parts. *A particular kind of the Schizocarp is the fruit of the* Umbelliferæ, called *Cremocarp*. Fig. 244. The latter is composed of two united carpels with one seed in each, and splits at maturity into two parts, called *mericarps*, joined to a common central axis called *carpophore*. When the Schizocarp is many-celled and splits up into a number of dry indehiscent 1-seeded fruits, it is called *Carcerule*; as an many Mallows and Geraniums. Fig. 151. In Ricinus (castor oil) and some Euphorbias, the syncarpous fruit bursts with elasticity into the separate constituent carpels (usually three). This form of the schizocarp is called *Regma*, and the constituent parts—one-seeded, oue-celled, dry and indehiscent, are called *Cocci*. The schizocarp differs from the capsule in being indehiscent, so far as the dispersion of the seeds are concerned; the Capsule by bursting lets go the seeds, the Schizocarp by bursting lets go the constituent carpels only.

FIG. 245.

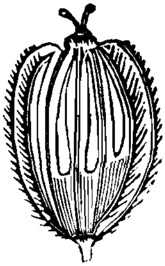


FIG. 246.

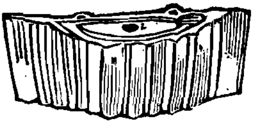


FIG. 247.

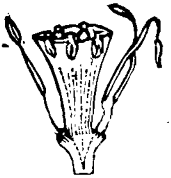


Fig. 245. Vertical section through a Schizocarp of *Umbelliferæ*.
Fig. 246. Transverse section through same.
Fig. 247. Fruit of Lotus, showing carpels embedded in the flat-topped receptacle.

Succulent Fruits.—The wall of the ripe ovary becomes the wall of the fruit or the Pericarp. In Leguminosæ and other apocarpous plants the Pericarp is dry and membranous and leaf like or *foliaceous* ; so also is it in many dry fruits. But in succulent fruits it exhibits three layers or regions, the tissues of which are developed differently ; the outer one or the external coat is then called the *Epicarp* or *Exocarp* ; the middle, the *Mesocarp*, and an inner, the *Endocarp*. The inner layer in some cases becomes hard and is then called the *Putamen* or *Stone ;* the mesocarp when fleshy, soft and succulent is called the *Sarcocarp*.

Succulent or fleshy fruits are naturally indehiscent ; they are generally either fleshy throughout or homogeneous in texture ; or provided with a cartilaginous or any firm rind on the outside and a hard stone inside i.e. heterogeneous in texture. But in some cases, as in the Walnut the succulent fruit is dehiscent. Hence we may classify succulent fruits under two heads.

A. Succulent Indehiscent Fruits :—

I. TEXTURE HETEROGENEOUS.—

1. **The Drupe** or Stone Fruit. Here the pericarp is differentiated mainly into two parts : the inner hard Endocarp or *Stone or putamen* within a fleshy. mesocarp or sarcocarp. On the outside the sarcocarp is enveloped by a thin coat, the epicarp. The endocarp encloses only one seed with a membranous testa. The fruit of the Mango, the Peach, the Plum, and the Apricot are typical examples. The Cocoanut is also a Drupe but it is better described as a fibro-drupaceous Nut. In the Almond, similarly, the fruit is Drupaceous ; the seed is enveloped by a thin woody shell—the endocarp—which in its turn is surrounded by green covering layer formed of the combined epicarp and sarcocarp. If a stone-fruit happens to have a firm undifferentiated layer on the outside, it passes into the Nut.

2. **The Pome.** Here the endocarp is cartilaginous, the

Fig. 248.

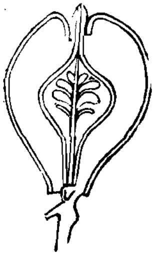


Fig. 249.

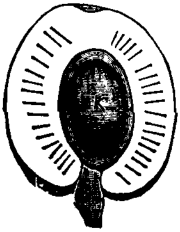


Fig. 250.

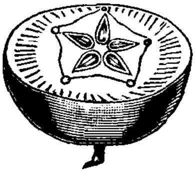


Fig. 248. Vertical section through a Pome, showing the cartilaginous endocarp and the fleshy mesocarp enveloped by a thin exocarp.

Fig. 249. Vertical section through a Drupe. K, the seed within a hard endocarp.

Fig. 250. Transverse section through Apple, (Pome), showing the five cells and the cartilaginous endocarp.

rest of the texture being like that of the Drupe. It results from two or more carpels of a bony or cartilaginous texture enclosed in a succulent and adnate calyx and receptacle. Hence it is an inferior fruit. As a matter of fact, the term is specifically applied to the Apple, the Pear, (Naspati—*Pyrus Communis*), the Quince and the Loquat (*Mespilus Japonica*). In the Apple the superior cup-like calyx tube encloses the five imperfectly fused carpels which are seated in the hollow cup-like thalamus. The carpels finally fuse with the cup and form on ripening an almost homogeneous mass. The succulent mesocarp is hence derived from the calyx or the thalamus, and the carpels enclosing the seeds become bony and parchment-like. It is the characteristic fruit of one section of the family Rosaceæ (Pomeæ) ; the Drupe characterises another section (Drupaceæ).

3. **The Pepo** or Gourd-fruit, is the name given almost exclusively to the fruit of the Cucumber or Gourd family (Cucurbitaceæ). In texture, it is almost the obverse of the Pome. That is, here the exocarp is cartilaginous and the endocarp and the mesocarp become blended into a sarcocarp.

The fruit is inferior, the exterior rind being the further development of the adnate calyx which becomes completely incorporated with the inferior ovary. It is normally one celled with three parietal placentæ, but may become supriously three celled by the projection of the placentæ to the central axis where they fuse. The seeds are always attached to the revolute placental surfaces. The structure and formation of the placentæ can be very well seen in the Cucumber, the Melon etc. The Papaw fruit resembles the pepo in many respects, but it arises from a superior ovary and hence may be called a Superior Pepo. When the external covering or exocarp is not cartilaginous the Pepo becomes a Berry—i.e. a fleshy fruit having a homogeneous texture.

4. **The Hesperidium.** It is a term applied solely to the fruits of the Orange family, as Orange, Lemon, Lime etc. It is a superior fruit with a leathery rind. The Orange, for instance, is a multilocular compound or syncarpous fruit with an axile placentation. The epicarp, mesocarp, and partly the endocarp forms the leathery skin which is peeled off and thrown away. The edible portion is formed by the papillar outgrowths from the placentæ, which fill up the loculi along with the seeds. The walls of these loculi are made up of a thin and membranous endocarp.

II. TEXTURE HOMOGENEOUS.—

5. **The Berry.** It is a fleshy fruit wherein the pericarp is fleshy throughout. The Grape, Banana, Tomato, Tepari, Brinjal etc, are examples. The pulp here is produced from the parietal placentas which develop as a large fleshy mass ; the seeds, however, are small and many, and dispersed loosely in the pulpy mass. (cf. the Pepo and Drupe). The term *baccate* (fr. Bacca = Berry) is used in describing any fruit of a pulpy nature. The Date, it should be observed, is easily mistaken for a *Drupe ;* but it is not so ; it is a *Berry ;* for the stone is not the Endocarp but the testa of the seed. The outer skin is the epicarp ; the pulpy mass underneath, the

mesocarp or sarcocarp and surrounding the stone is a thin membranous endocarp. In many varieties of Banana the seeds have disappeared through long cultivation. The Berry is distinguished from the Drupe by the absence of a hard endocarp and usually contains more than one seed which is generally provided with a hard testa. In Drupes, the stone is the endocarp, while the testa forms a thin and membranous layer investing the seed within this hard endocarp.

FIG. 251.

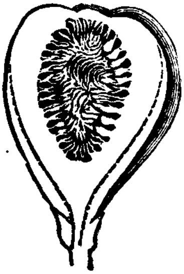


Fig. 251. TheFig-fruit—*Syconus.*

B. Succulent Dehiscent Fruits.

1. THE SUCCULENT CAPSULE. As the name indicates, the Capsule here is fleshy, as in Balsams.

2. THE DEHISCENT DRUPE. In Walnut the outer succulent layer bursts. The endocarp is stony and surrounds a thin skinned seed exactly as in the Drupe.

3. THE DEHISCENT BERRY. Many Cucurbitaceous fruits remain succulent during maturity and bursts while ripe. These may be called Dehiscent Berries.

Aggregate Fruits.—These result from the simultaneous ripening of a cluster of carpels belonging to one flower and crowded on the convex or club shaped receptacle. The best example is in our Champaka (Michelia champaka) where the aggregated carpels imbricate over one another and each become a ripe follicle. The best English name for an aggregate fruit is **Syncarp**. But the term is not very strictly used. In Magnolia, Rose, and many other families such aggregate fruits are formed ; in all such cases the thalamus is conical or elongated and upon it the carpels are disposed in a spicate or capitulate form. When the thalamus itself becomes fleshy and becomes organically united with the fruit, it becomes an

Accessory or Anthocarpous Fruit.—As the term denotes, here some conspicuous part of the fructification belongs to the floral envelopes or the rachis. In Krishnakali (Mirabilis), for instance, the lower part of the perianth remains enveloping the fertilised pistil when the upper part has fallen by a transverse splitting, and grows with the fruit as a thickened and indurated mantle. In Tepari (Physalis), the calyx though not forming an organic part of the enclosed fruit, is accrescent. In the English Blackberry or Bramble the convex receptacle bears a number of Pistils on its surface, and on ripening becomes succulent and almost homogeneous with the latter.

In **Multiple or Collective Fruits**, on the otherhand, the floral members are necessarily accessory. Here an inflorescence becomes a fruit. In Mulberry the fleshy balls are not the ovaries of a single flower but belong to different flowers ; so also in the Jack fruit and in the Fig. The fruit of the Mulberry and the Pineapple is called a **Sorosis** ; it is formed from a spike. In the latter the fleshy axis becomes fused with the sessile Pistils. In the former, the axis remains slender but is rendered succulent along with the Pistils of the separate flowers that are borne upon it, the perianth also remains behind and becoming fleshy, unite them into a compact fleshy and succulent mass. In contrast to this spicate form of the infructescence, the Fig-fruit is called a **Syconus**.

It results from the ripening of a hypanthodium. The female flowers borne upon the hollow surface of the concave rachis ripen into achenes, popularly regarded as seeds.

FIG. 252.

FIG. 253.

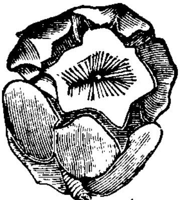


FIG. 254.

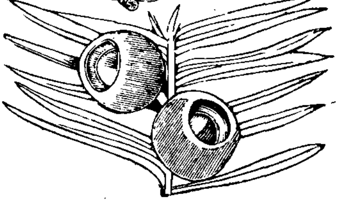
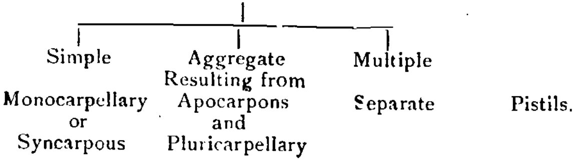


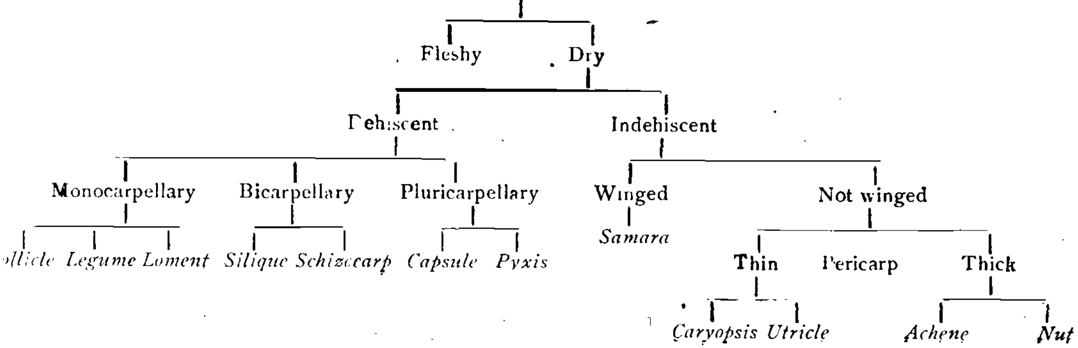
Fig. 252. A Pine Cone.
Fig. 253. Galbulus.
Fig. 254. Fruit of Taxus—Baccate.

The Strobile or Cone (Fig 252) is a scaly collective fruit. It characterises the fruit of the Pines and other Conifers. Here naked seeds are borne upon the upper face of each scale. It is generally conical in shape and the scales become usually very thick and hard. In Hop the scales are membranous and the little seed-like fruits are achenes. In many Cypresses and Conifers the strobile becomes rather globular and it is then called a **Galbulus**. The scales here, also differ from those of the Cone; for they are more broad and peltate at the outside. (Fig 253). The number of scales again, involved in the galbulus is much smaller than that in the Cone. Another kind of Gymnospermous fruit is shown in Fig 253. It is the fruit of the Yew (*Taxus baccata*). It appears to be a berry, but it consists simply of a naked seed surrounded by a fleshy cup with an opening at the apex.

Classification
I. of Fruits.



II Of Simple Fruits.



III Of Simple Fruits.

- Fleshy
  - Dehiscent
    - *Dehiscent Capsule*
    - *Dehiscent Drupe*
    - *Dehiscent Berry*
  - Indehiscent
    - Homogeneous *Berry*
    - Heterogeneous (in texture)
      - With stone *Drupe*
      - Without a stone
        - Epicarp
          - Thin *Pome*
          - Thick
            - Inferior *Pepo*
            - Superior *Hesperidium*
- Dry

CHARACTERISTIC FRUITS OF COMMON INDIAN PLANTS.

Plants.	Fruit.	Insertion.	Cells.	Seed.
AKANDA *(Calotropis gigantea)*	Follicle	Superior	1 locular	Hairy (*Comose*)
PEA (*Pisum Sativum*)	Legume	Superior	1 locular	Seeds many—kidney shaped
SOONDALI (*Cassia fistula*)	Loment	Superior	Many—celled through false dissepiments	
GILLA (*Mimosa Scandens*)	Loment—Several feet in length	Superior	Many—celled through transverse joints	Seeds many—subovate
SARISHA (*Sinapis Dichotoma*)	Silique	Superior	2—celled many-seeded	……
JAVA (*Hebiscus Rosa-Sinensis*)	Capsule	……	……	……
ISUPGUL (*Plantogo Ispaghula*)	Capsule—Circumcsissile dehiscence	Superior	2—celled	2—seeded
PANIPHAL (*Trapa bispionosa*)	Nut—Triangular and Spinous		1—celled	1—seed
CADAMBA (*Anthocephalus Cadamba*)	Capsule	Inferior	4—celled	Many—seeded
BRINJAL *(Solanum Melongena)*	Berry with persistent Calyx	Superior	2—celled	Many—seeded
SAGOON—TEAK (*Tectona grandis*)	Nut enclosed within an accrescent Calyx	Superior	4—celled	4—seeded
TOON (*Cedrela Toona*)	Oblong reniform Capsule		5—celled	Many—seeded, seeds winged

MADHABYLOTA (*Hiptage Madhablota*)	Samara—three Capsules	Superior	Each Capsule three winged and 1—celled	1—seeded
CHAMPAKA (*Michelia champaka*)	Follicle bursting dorsally	Superior on a convex thalamus	Each Carpel 1—celled	Seeds pendulous—1 in each cell
LITCHI (*Nephelium Litchi*)	Berry	Superior	1— celled	1 seeds—seed with Aril
KANTAL (*Artocarpous integrifolia*)	Sorosis	......	......	Seeds—many
TURBOOJ (*Cucurbita Citrullus*)	Pepo	Inferior	1—loc. or falsely 3-loc.	Seeds—many ; attached to reflexed parieta placentas
FIG (*Ficus carica*)	Syconus or Hypanthodium			Seeds—many
ORANGE (*Citrus Aurantium*)	Hesperidium	Superior	Many—celled	Many—seeded
CASTOR-OIL (*Ricinus communis*)	Regma separating into 3 cocci	......	......	......
GRAPE VINE (*Vitis vinifera*)	Nuculanium or Superior Berry	Superior	1—celled	1-seeded
SUNFLOWER (*Helianthus Annus*)	Cypsela	Inferior	1—celled	1-erect seed
DHAN (*Oryza Sativa*)	Caryopsis	Superior	1—celled	1-seeded
COCOA NUT (*Cocos Nucifera*)	Fibro-drupaceous Nut	Superior	1—celled	1-seeded
SHAL (*Shorea robusta*)	Samaroid Nut	Superior	Nut 1—celled	1-seeded
SHEPHALIKA OR SEULI (*Nyctanthes Arbortristis*)	Capsule—Compressed obcordate	Superior	2—celled	2-seeded
TEPARI (*Physalis peruviana*)	Berry with accrescent Calyx	Superior	......	8-seeded

Natural Orders and their Characteristic Fruits.

NATURAL ORDER		FRUITS
Ranunculaceæ (Aconite family)	...	Achene, or Follicle (Aconite), or Pods.
Magnoliaceæ (Champaka family)	...	Follicles.
Papaviraceæ (Poppy family)	...	Capsules—Multilocular—∞ Seeded.
Cruciferæ (Mustard family)	...	Silique or Silicula.
Caryophyllaceæ (Pink family)	...	Capsule—Unilocular—∞ Seeded.
Malvaceæ (Cotton or Mallow family)	...	Multilocular Capsule or Carcerule.
Geraniaceæ (Geranium family)	...	5—Celled Capsule bursting with explosion, or Regma.
Rutaceæ (Orange family)	...	Hesperidium in the Oranges (*Aurantieæ*) or Berry with a hard epicarp (Bael,Kathbel etc.)
Vitaceæ or Ampelideæ (Grape-vine family)	...	Berry or Drupe.
Leguminosæ (Pea family)	...	Legume or Loment.
Cucurbitaceæ (Cucumber family)	...	Pepo or Succulent Berry (rarely).
Umbelliferæ (Carrot family)	...	Cremocarp.
Compositæ (Sunflower family)	...	Cypsela.
Asclepiadaceæ (Madar family)	...	Follicles (A pair of).
Graminæ (Grass or Grain family)	...	Caryopsis.
Coniferæ (Pine family)	...	Strobile, Galbulus or Berry.

CHAPTER XI.

The Seed.

The fruit, as has already been said, [illegible] the results in some very extensive changes in the ovule. The embryo, the direct consequence of fertilisation, undergoes a period of rest after it has attained a definite stage of differentiation ; during this period of embryonic developement, the ovule becomes greatly modified in size, shape, texture, etc., to form the mature **seed.**

In the ripe ovule or seed, the outer ovular coat becomes the *testa* as a firm, usually hard coat. The testa may be applied to the surface of the seed conforming to it, or may remain quite free. But the *tegmen* or *endopleura*—that corresponding to the inner ovular coat, is, when present conformed to the seed and envelopes the kernel.

Thus the essential parts of the seed are the coats and the kernel. The coats are variously appendaged

The Appendages.—These are formed as outgrowths during the ripening of the ovule.

(*a*) The *Caruncula* is an outgrowth formed from the outer opening of the ovule *i.e.* the *micropyle* of the seed. It forms a small ridge or handle in the seed of Euphorbia, Ricinus (castor-oil plant) etc. A protuberance of the raphe or at the hilum of the seed receives the name of a *strophiole.*

(*b*) *The Arillus* is an incomplete seed covering formed as a cup around the seed between the time of fertilisation and its ripening. In Lotus such an outgrowth developes from the top of the funiculus and growing into a sac-like covering, almost entirely encloses the seed. In many Euphorbias, and in Ricinus, a similar covering originates from the micropyle and grows downwards over the testa; this is called an *Arillode* or false Aril.

(*c*) *Wing*—like appendages of the testa are developed in some seeds, as in many Bignoniaceæ (e. g. Parul, Paral or Patali—*Bignonia suaveolus*) and in Conifers. Sharp edges on the seed are found in Sajina (Moringa pterigosperma).

(*d*) *Coma* is the tuft of soft hairs formed at some points of seeds. In akanda and in many other *Asclepias*, the coma is formed at one point only. In the cotton plant, the seeds are completely covered with very long and soft hairs.

Markings on the surface of the seed are formed on many plants. In the poppy seed, and in that of tobacco, for instance, small ridges or projections can be seen very distinctly.

The Kernel of the seed consists of the *Embryo* and a nutritious food for it called ALBUMEN.

1. THE ALBUMEN.—It is a tissue filled up with starch, oil and many reserve food-matters which provide nourishment to the Embryo. In all seeds, the Albumen is present during the growing stages of the Embryo. Usually however, in many Dicots, the embryo feeding upon the Albumen absorbs it entirely. Such seeds are called *exalbuminous*. Examples are in the Pea, Tamarind, Almond, etc where the seeds consist of only the *testa* and the *embryo*. In what are called *albuminous* seeds, this food material persists, and is subsequently utilised, not during the growth of the embryo, but during the germination of the seed. In all Grasses, Cereals, Poppies, Cocoanuts, etc the seeds are albuminous.

After the fertilisation of the ovum, the embryo-sac becomes filled with a reserve food-material called *Endosperm*. It is this endosperm which nourishes the embryo during its early stages. Food-material formed in the seed outside the embryo-sac, in the nucellus, is called *Perisperm*. Both these kinds of food are, however, collectively called the Albumen. In exalbuminous seeds, the endosperm and perisperm are both absorbed; in the albuminous seeds, both may persist. In

Lotus (*Nymphæa*) both endosperm and perisperm persist; in Poppy, Oat, and in many other plants, the embryo is enclosed within the endosperm ; in the Date the endosperm forms a hard stone ; in Cocoanut, it is a hard tissue ; in Coffee, Castor oil and in all umbelliferous seeds, the endosperm is oily. In Canna, the albumen is all perisperm.

The texture of the albumen varies in different seeds. Thus, it is called

1. *farinaceous* or *mealy*, when it can be readily pulverised and consists essentially of starch ; as in the Cereals, Grasses etc :

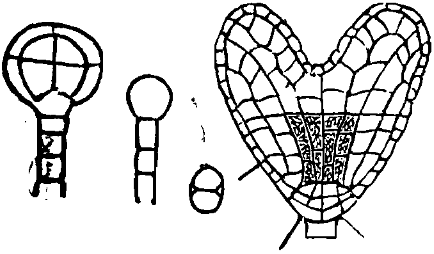
2. *Oily*, when saturated with oil ; as in Poppy, Mustard, etc :

3. *horny*, when it is hard and bony ; as in most Palms :

4. *mucilaginous*, when it swells up readily in contact with water ; as in Malvaceæ :

5. *ruminated*, when it presents sinuosities in a cross section, being folded irregularly upon itself ; as in Custard Apple, and many Annonaceous and Myristica plants.

FIG. 255. FIG. 256. FIG 257.



The Embryo. As shown in figs 255-57 the fertilised ovum soon undergoes divisions and subdivisions and develops into the Embryo. At first the ovum is divided into two cells, which by repeated divisions again become dfferentiated into two parts—the elongated part (fig 256) is especially adapted to suck up nourishment from the outlying tissues of the nucellus, and is called the SUSPENSOR. The other part is more like a globe (fig 255), and becomes differentiated, generally before the seed is ripe, into one or two *Cotyledons* or seed leaves, a *radicle* and *hypocotyl.* The constant number of Cotyledons in Angiosperms is one in Monocots, and two in Dicots; in Gymnosperms there is no constant number; it may be two or several.

The Monocot embryo is often a cylindrical body. The Cotyledon lies at the upper part and is usually split on one side to lodge the *plumule* or initial bud; the lower part is the blunt radicle. In Dicot embryos the Cotyledous are relatively large, equal, and lodge the plumule in the notch between them.

The radicular end of the embryo is always directed towards the micropyle of the seed; the Cotyledons point to the opposite end.

CHAPTER XII.

Dispersion of Fruits and Seeds.

If all the seeds of a large leafy plant fell vertically down over the ground within the small circle of which the boughs are radii, the conditions of life offered to them are far from favourable. For the soil on which so many seeds have fallen has probably been robbed of its many nutritious things by the parent, and the scanty remains would not be quite sufficient to feed all the seedlings. Moreover, the large canopy of the parent while affording shelter is inimical to the seedlings in as much as it cuts off sunlight and the free play of air. The struggle for existence between the seedlings, again, would be too keen, and all of them may die in consequence. Hence, in the economy of plant-life, dispersion of fruits and dissemination of seeds become an universal necessity. Thus, the fructification and the ripening of the seed are usually accompanied with the development of structures that help dispersion.

All those contrivances which operate to disperse the pollen are also employed for the dissemination of seeds. The agencies through which this takes place are accordingly, (1) wind, (2) water, (3) animals, (4) tissue—tension resulting in explosions, and (5) accidental transport through railways and steamships.

Where the wind is the dispersing agent, special appendages n the form of wings or hairs or at any rate, structures calculated to increase the buoyancy and lessen the weight of the seed or fruit are formed. The winged seeds of the *Begonias*, the appendaged seeds of *Moringa*, the comose seeds of *Gossypium* (Cotton) and Asclepias, the pappose achenes of many Compositæ, the wing-like persistent calyx of the *Shoreas* (sal) and *Dipterocarpuses*, the flying capsules of *Hiptage madhoblota*, the Pine seeds with their attached membranous bracts, are all adapted to be dispersed by the wind. Some of them are more or less flattened and lie in the same plane as the winged expansion. In this way their centre of gravity is so placed that they always present the broad side to the direction of descent, and thus they float lightly in the air in an almost horizontal position. In the garden *Clematis*, the small achenal fruits are provided with long feathery styles. In *Dandilion* and many other composites, the hairy pappus closes in moist air, and when dry, opens out widely making the fruit more buoyant.

Buoyancy is also a requisite contrivance in fruits and seeds dispersed by water. The Aril of Lotus, for instance, leaves always a film of air interposed between the testa and the outer aril. Like a cup floating in water, the arillate seeds of the Lotus float and are carried by currents of water. The fruits of many marsh-plants, such as, the Sedges (carex), Water Plantains, *Sagittaria*, etc, are provided with a membranous and dry utricular covering. The enclosed air within the fruit makes it, in such cases, light enough to be carried by currents of water. In some fruits, large water-tight tissues enclosing large air-spaces are developed in the pericarp. The *Cocoanut*, for instance, and many Palm-fruits are thus provided with floating mechanisms, and they have often been known to be carried by Ocean currents to distant parts of the world. The appearance of Palms on the isolated and uninhabited Coral Islands of the Pacific is thus explained.

Where animals are the disseminating agents the contrivances adopted are infinite in their diversities. A few of these only can be mentioned here. In the dehiscent fruits of the Magnolia, the coloured and attractive seeds remain suspended in midair by fine threads ; they are thus rendered visible from afar, and birds carry them away. In Berries and other succulent fruits, the edible pulp affords a valuable food to birds and animals, and the small seeds escaping mastication come out with the excrements. Many such small seeds remain attached to the beaks of birds, and in their act of wiping the beaks against boughs of trees, they involuntarily disperse the seeds. Hooks, beaks, hairs, burs, bristles, feathers etc, developed on the fruits or the seeds, attach them to the bodies of many animals who thus involuntarily act as agents of transport.

Certain fruits dehisce with a sharp explosion. The explosive action necessarily ejects the seeds with some degree of force, and they are thus scattered over a comparatively wide area. One curious instance is in the Sqirting Cucumber (*Ecballium Elaterium*). The end of the stalk on which the young pepo is borne projects into the interior of the fruit like a stopper. When it is ripe the fruit is detached from the stopper-like stalk which thus leaves an open mouth on the bottle-shaped fruit. As it falls, the seeds with a mass of mucilage are squirted out with considerable force, through the opening. In *Geranium* a similar explosion takes place during the fruit-dehiscence; and so also in many species of *Oxalis.* In Acanthaceæ (*Justicia*, *Acanthus* etc.) and in Euphorbiaceæ (*Ricinus*) the bursting of the fruits amounts to a regulation detonation. In many Legumes of Mimosæ and Papilionaceæ, and in many Capsules of Malvaceæ and Sterculiaceæ, the opening of the pericarp is almost simultaneously followed by a spiral twisting of the split-parts of the fruit.

Any traveller who has forced his way through grassy meadows or other thickets, can bear witness to the manner in which many dry fruits and seeds adhere to the clothes. What applies to man, of course applies none the less forcibly to animals or other inanimate objects of locomotion. In these days of extensive travel and commerce it is not to be wondered that not only the useful plants have been distributed widely over the earth, but that weeds even have found new places of growth where they were never known before.

PART II

MORPHOLOGY

(INTERNAL)

ANATOMY AND HISTOLOGY.

CHAPTER XIII.

General Considerations.

Anatomy (Gr: ana + temnein = to cut) in its widest sense denotes the science which deals with and studies the internal structure of organic bodies so far as dissection helps us in understanding it; and Vegetable Anatomy is better designated Phytotomy (Gr: phyton = plant + temnein = to cut). But the more particular microscopical examination of the internal structure of organic bodies and the tissues of which they are composed, followed by a study of their behaviour and reactions with microchemical stains and reagents is the specific province of Histology (Gr: istos = tissue + logos = knowledge).

The revelations of the microscope which came to be applied to the study of the internal structure of plants and animals at about the last decade of the 17th century were startling for their novelty. The Italian Malpighi and the Englishman N. Grew, the founders of vegetable Histology, were the first to point out that all plants or parts of plants, when examined under the microscope, appear to have a honeycomb-like structure; that they are built up of a great number of "cells", some empty, some full of a certain viscid matter; and that, distributed in this honeycomb-like mesh of cells, there is a number of little tubes and fibres in various modes of aggregation. It was not until after the lapse of a century and a half that Hugo V. Mohl discovered that the viscid substance found in the interior of cells is the primordial living essence of plants; that it is to this slimy substance that all vital functions are in effect to be attributed. Accordingly in 1846 he gave the name of

Protoplasm to the substance of which the cell contents are composed. With the discovery of the Protoplasm and its recognition as the basic principle of life begins an era of the most unparalleled activity and progress in the study of the Biological sciences.

Subsequent investigations have shown that the chambers called cells are really the products of the protoplasm. Being the only living entity of a plant it produces during its growth and development a countless number of organic substances which go towards the building up of the whole vegetable mechanism. The most important of these is a matter having the same chemical composition as cellulose. This is secreted by the protoplasm at first as a thin enveloping membrane, and then subsequently developed and differentiated in various ways in accordance with the functional requirements at different parts of the plant. Thus, the protoplasm is not only the starting point of vegetable life, but it is also the creator of all vegetable structures. The membranous layer alluded to above, called the cell-wall, is developed by the protoplasm at the expense of its own energy and matter, and finally usurping its place forms the sole physical constituent of the plant. While the protoplasm grows, its substance is diminished and transformed into other more permanent particles of matter: at the expense of vital forces inherent in the protoplasm inert lifeless masses of matter are produced; and these only are left behind to testify to its miraculous power when dying or being removed, it closes the cycle of a plant-life.

As has been noted in the Introduction (p 5) it is possible for the protoplasm under certain conditions to exist for a time without an investing layer of cell-wall, but as a general rule, it always secretes almost uniformly over its outer surface particles of cellulose matter which hardening or uniting form a continuous protective coat. In the growing points of stems and roots, in every multiplying part of plants, in fact during all the embryonic stages of a plant, this cellular membrane remains rather as a thin and delicate film investing a highly active colourless protoplasm. But this thin membrane gradually undergoes remarkable changes in growth and development by the addition of matters continually formed by the active protoplasm. As a result of this the individual cell-cavities in some cases become elongated, and the cells are shaped like rods or tubes. In others, again, the encroachment on the cavity of the cell becomes so pronounced by the thickening of the original walls that the protoplasm and the cavity itself become almost unrecognisable. Again, deposition of certain organic substances resulting from the activity of the same vital principle renders some of the cell-walls stiff and rigid; and others thick, impervious, and tough. When a collection of such cells grows together, their community of origin and development leads to their physiological union, and they then carry out in concert specific physiological functions. Cells thus aggregated together, following a common law of growth, form what are called tissues; and the tissues form the true frame-work of the plant organism.

More than in any other department of Botany, in Histology we are impressed with the fact that development means differentiation. As in Morphology, so here, there is a gradual progression of differentiation as we rise from the simpler to the more complex or higher plants.

It has been shown already that the morphological characters of an organism are connected with its position in the plant-kingdom. The history of the genealogical development of a plant, or its Phyllogeny, can not be studied so thoroughly as Ontogeny, or the history of individual development. In attaining its permanent mature structure, a plant has to pass through successive stages of development. The study of this ontogenetic devlopement shows that in the embryonic stage of a plant, it consists of a number of similar cells each containing an undifferentiated protoplasmic mass. This homogeneous tissue then grows, and with growth differentiation sets in. Different cells grow along different lines, cells become modified variously, the protoplasmic contents of cells manifest an endless variety of heterogeneity, histogenetic elements for carrying different functions take their origin from these altered cells, and lastly the tissues originate. From the origin of the tissues to their final development, the history is a mere repetition of the same laws of growth and differentiation.

Thus the history of individual development repeats in a plant-life the history of the genealogical development. From the embryo to the plant, the history is one of continual change from the simpler to the more complex structures, from the simple cells to the most complex tissues. And this progressive change towards complexity is also recognised as the fundamental principle in the genealogical development of plants, as *evidenced by their gradual ascent in morphological* complexity (p. 7). Hence it is often said that the ontogeny of a plant repeats its phyllogeny.

The two points about which the whole fabric of Histology or rather Phytotomy is woven are (1) the Cell, and (2) the Tissues. The ultimate histological unit of higher plants is the tissue; but the starting point of all phytotomical studies is the cell. But these so-called units are artificial and merely conventional; mere attempts at simplification in the nomenclature of collective ideas. For, it will be shown later on, in the chapter on Ecology, that tissues are nothing more than expressions of adaptations of the protoplasmic masses to requirements called forth by external forces *i.e.* factors peculiar to the particular environment of plants. The internal organisation of each mass of protoplasm is considerably modified by the forces at play about it in Nature. Responsive to the call of the outer world the protoplasm always conforms to, and produces structures and substances in harmony with the forces of the physical part of Nature. A plant exists under such and such circumstances, conditioned mainly by the existence of forces associated with them; it is something like a resultant expression of the interaction of forces within and outside the protoplasm. For instance, a plant living in the deserts will have its members, organs, tissues, cells etc., developed in a way widely different from what we find when it grows in an ordinary soil A submerged water-plant wholly unable ever to see the light of day, and one living in the rich alluvial debris of lowlands will undoubtedly develope their structures along quite divergent lines. The significance of these different laws of development will be studied in a subsequent chapter of this part, but it may be pointed out here that development and differentiation of structures,—Morphological and Anatomical—is regulated by *(a)* the mode of Nutrition of the plant, as determined by its *habitat* or *environment*, and *(b)* by the specific internal constitution of the protoplasm. Thus physiological necessity being the main predisposing factor, histological structures arise in response thereto; and when once the anatomical frame-work of a plant is thus built up, the question of the formation of morphological members is but a step in advance.

the microscope, will show up the living and dead cells and the protoplasm contained in the former. The thick-walled cells forming a ring about the axis of the stem do not contain any protoplasm and are elongated longitudinally; while the thin-walled cells towards the circumference and immediately surrounding the above ring are lined on the inside with a granular substance, the protoplasm, with one or two vacuoles in the centre. Hairs on the surface of stems and leaves of Cucurbita plants (*e.g.* Gourd), peeled off epidermis of many leaves, particularly of the fleshy scales of Onions and other bulbs, also show up very clearly the protoplasm and the vacuoles, within a thin cell-wall. (For directions for mounting see Appendix).

FIG. 258.

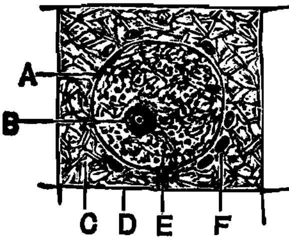


FIG. 259.

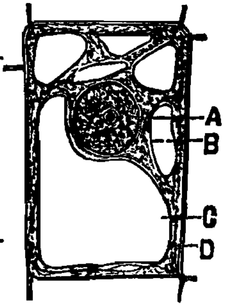


Fig. 258. A vegetable Cell—(Diagrammatic, after Strasburger), A, nucleus; ·B, nucleolus. Shows the nuclear membrane, the *linin* threads and the *chromatin* granules. C, the Cytoplasmic matter; D, the Cell-wall; F, the Chromatophores.

Fig. 259. The same after the formation of vacuoles. A, the nucleus; B, the tonoplast layer lining the vacuolar cavity. C, a big vacuole. D, the Cytoplasm.

The functions of Primordial cells are simply reproductive; those of the living cells are vegetative, and in many cases also reproductive; while those of the dead cells are either

CHAPTER XIV.

The Cell.

The term cell has been indiscriminately applied to a mass of protoplasm, or this substance contained within a chamber walled with cellulose, or simply an empty chamber of cellulose or its modifications. Accordingly there are

(*a*) *Primordial cells*, such as spermatozoids, oospheres, gametes, zoospores etc., each of which is simply a mass of protoplasm without the cellulose protective membrane;

(*b*) *Living cells*, *i.e.* those ordinary cells of plants where protoplasm and cell-wall are both present;

(*c*) *Dead cells*, such as cork-cells, wood-cells, etc., which remain simply as mechanical supports or carry on other subsidiary functions.

It is, however, with the living cells of the second sort that we are more particularly concerned here. In such a typical cell, three parts may be distinguished :—

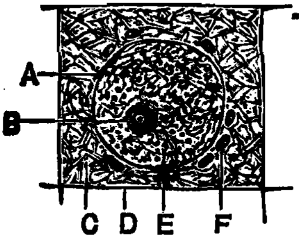
(*a*) the cell-wall ;

(*b*) the protoplasm with its differentiated parts ;

(*c*) the *vacuoles*, or cavities formed within the protoplasm during its growth, and filled with a watery solution, called cell-sap. In an old and large cell these vacuoles coalesce into a single cavity occupying its centre; this is known as the SAP CAVITY.

Such cells normally compose the soft and succulent parts of plants, as the cortex, the growing points of stems and roots, the leaves, the succulent parts of fruits etc. A transverse section through a one year old stem, when examined under the microscope, will show up the living and dead cells and the protoplasm contained in the former. The thick-walled cells forming a ring about the axis of the stem do not contain any protoplasm and are elongated longitudinally; while the thin-walled cells towards the circumference and immediately surrounding the above ring are lined on the inside with a granular substance, the protoplasm, with one or two vacuoles in the centre. Hairs on the surface of stems and leaves of Cucurbita plants (*e.g.* Gourd), peeled off epidermis of many leaves, particularly of the fleshy scales of Onions and other bulbs, also show up very clearly the protoplasm and the vacuoles, within a thin cell-wall. (For directions for mounting see Appendix).

FIG. 258.



[illegible]G. 259.

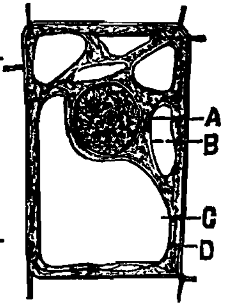


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Fig. 259. The same after the formation of vacuoles. A, the nucleus ; B, the tonoplast layer lining the vacuolar cavity. C, a big vacuole. D, the Cytoplasm.

The functions of Primordial cells are simply reproductive ; those of the living cells are vegetative, and in many cases also reproductive ; while those of the dead cells are either to afford protection, or to act as agents of transport of nutritive materials, or to maintain the rigidity of the plant structure in which they occur.

SECTION I.

The Protoplasm.

The Protoplasm is a generic term applied to the collective aggregate of those substances which form the physical basis of life. It is in its essence the sole building material or living principle of all living organisms. This fundamental material, out of which the st[illegible]ures of plants (in fact of all living organisms) arise, is not a single or simple substance either chemically or physically. As the peculiar living essence of the cell, it is constantly changing its physical and chemical characters, and acting always in response to stimuli from the outer world. This property of *irritability* to external stimuli is one of its main functions consistent with its organisation. But what the specific constitution of the protoplasm is, in different plants, or in the different parts of a plant, is more than what modern science can tell us. All that we know is that

It should be remarked here that at the base of all protoplasmic structures there is a hyaline, colourless, homogeneous substance which alone can claim to be the ultimate basis of life. The minute particles of matter distributed in this hyaline matrix, which makes the cytoplasm appear granular, are really either finely divided food-materials in the process of being assimilated within the protoplasm, or are differentiated parts of its body. Collectively these granules are called ***microsomes***, and the hyaline protoplasmic matter, the ***Hyaloplasm***. The supreme importance of this hyaloplasm is borne out still more clearly by the fact that chromatophores, nucleus, microsomes all lie imbedded in it; even around each Vacuolar cavity there can be found a very thin, but (*a*) physically, it is soft, colorless, tough but plastic, inelastic but susceptible of great extensibility ; (*b*) chemically, it is a combination of various albuminous matters with a considerable amount of water and small quantities of inorganic mineral substances ; and (*c*) physiologically, or more properly speaking vitally, it is capable of carrying on the functions of growth, nutrition, reproduction, and in many cases, of movement, independently. But these can never be taken as the determinating factors ; for in many cases (as in seeds) it is stiff and brittle, in others it is gelatinous : in still others it contains a large amount of oils and carbohydrates, and more often it is granular in appearance.

FIG. 260.

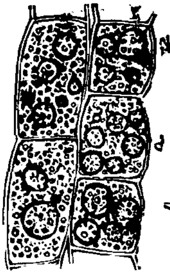


FIG. 261.

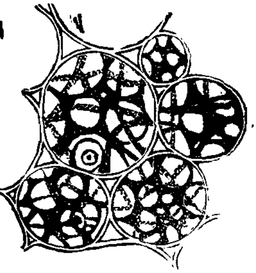


Fig. 260. Very young cells from seedling of Maize, showing the thin Cell-wall and the Protoplasm differentiated into Cytoplasm, Nucleus and Chromatophores.

Fig. 261. Growing cells of same, showing the origin of vacuoles and the cytoplasmic strands.

nevertheless a tough, hyaline and colourless layer of protoplasm which acts as a boundary between the watery fluid inside and the general cytoplasmic mass on the outside. This vacuolar wall may thus be regarded as the undifferentiated protoplasm or hyaloplasm. But since this wall has a greater tenacity of life and regulates the pressure of the cellsap contained in the vacuole, it has been called the *Tonoplast.* **A** similar layer, rather tough, homogeneous and colourless, and apparently serving

Besides the above-noted attributes of the protoplasm—attributes that are to be regarded as merely the outward expression of a too complex set of internal forces at play within it—there is another most important vital property, that of its *differentiation.* In all living parts of plants, the constituent cells contain masses of protoplasm essentially differentiated into three parts. These are :—

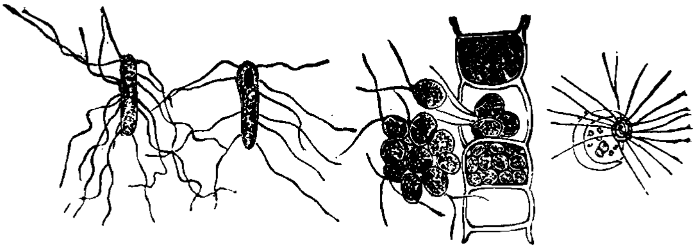
(1) the *Nucleus* :—the organic centre of the protoplasm formed by the accumulation of its more essential particles and their condensation into a globular structure harder, and more refractive than the ground substance, called
(2) the *Cytoplasm* :—which is actually the nutritive field of the protoplasm ; and
(3) the *Chromatophores* or the pigment-bearers. These are coloured or colourless roundish bodies distributed in large numbers in the cytoplasmic layer around the Nucleus, and carry on functions correlated with nutrition.

as a protective skin to the whole protoplasmic structures is also found on the outside of the cytoplasm between it and the cell-wall. This has been designated as the *Ectoplasm.* In origin, form, consistency, and function the ectoplasm and the tonoplasm are related. What the tonoplasm is to the vacuolar cavity, the ectoplasm is to the whole protoplasm. Again, in contrast to the denser hyaline layer of ectoplasm, the less dense, inner, granular layer of the protoplasm is distinguished as the *Endoplasm.*

Thus, leaving aside for a moment the use of the generic term protoplasm, we see that the physical basis of life, the hyaloplasm, is an undifferentiated, hyaline and colourless mass of plasma. It however becomes always differentiated into parts according to the functions that have to be carried out. The ectoplasm, endoplasm and the tonoplasm mark the first stage of its differentiation. The functions that necessitate these differentiations are (1) protection against the outer world being afforded by the rather tough ectoplasm, (2) protection against injurious products of vital actions which are stowed away in the

These three are the constant constituents of all protoplasmic substance. In fact, the term protoplasm is applied to designate all these collectively, with also the other living constituents of the cell. They are characterised by the fact that they never arise *de novo* but always multiply by division. There are other and equally differentiated parts of protoplasm which never originate by division but are produced by one or other of the above three protoplasmic substances.

FIG. 262. FIG. 263. FIG. 264. FIG. 265.



Primordial cells; showing the cilia and the Cytoplasmic masses. The dark spots are the Nuclei.

If a thin longitudinal section through the growing point of a plant be examined with a high magnifying power of the microscope, it will be seen (Fig. 260),

(*a*) that it consists of nearly rectangular cells separated from one another by very delicate and thin layers of cellwall;

(*b*) that each cell is full of a dense protoplasm in which Vacuolar cavities do not occur;

(*c*) that the protoplasm is highly granular and differentiated at about the centre into the more refractive Nucleus;

(*d*) and that distributed in the ground substance (the cytoplasm) and arranged round the Nucleus are a few smaller refractive bodies, the Chromatophores.

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vacuolar cavity lined with the protective layer of the tonoplast, and (3) preparation of plastic formative materials, which goes on in the endo-

A similar examination of a section, taken a little lower down the stem, will show that a large number of cells have become elongated and thick-walled, some have lost the protoplasm, and that in still others the cells have simply increased in size with the cell-wall forming a more prominent boundary line and the protoplasm restricted to a thin layer lining the wall. A big sap-cavity occupying the centre of the cell may be seen in most of these latter cells; or at isolated parts of the protoplasm smaller cavities may be found to have developed. The cytoplasmic layer is thus found to be in actual contact with the whole inner surface of the cell-wall, so long as the cell is living; while in old cells it frequently becomes reduced to a fine coating—sometimes thin enough to elude observation. Huge v. Mohl described such a thin peripheral layer of cytoplasm as the *primordial utricle.* Fig. 226.

From a comparison of the above two cases it will be seen that the protoplasm in the embryonic stage is dense, granular and not very highly differentiated—not, at least, into more parts than the three mentioned already. As it grows, however, and thus leads to the growth of the cell-wall, it becomes less

lasm and its differentiated parts. Now of all these, the function thrown pon the endoplasm being too complex and multifarious, it undergoes nother differentiation into three parts viz. the nucleus, the chromatohores, and the cytoplasm.

As a matter of fact, however, these differentiated parts are present nly in very well-developed cells. In the lower plants, in many fungi, or instance, the essential constituents of the cell are the Nucleus and he Cytoplasm. But in other very low plants as in *Bacteria* and *yanophyceæ*, the protoplasm does not apparently contain any ucleus. In the naked primordial cells alluded to above, the ytoplasm is the real principle while the nucleus may or may ot be present. Still in all these case of undifferentiated protoplasm he two layers of ectoplasm and endoplasm remain as well-marked ut portions. The cell-wall being absent the ectoplasm carries on he protective function.

granular and more clear, less dense and more thin, and watery spaces eventually appear in its very mass. The differentiation advances also *pari passu*, as will be shown presently; the cell wall becomes more and more prominent, and in proportion as the cell grows physically the protoplasm decreases, until at last it is reduced to the lining layer of the primordial utricle, or as in the case of dead cells it may be quite lost.

Fig. 266.

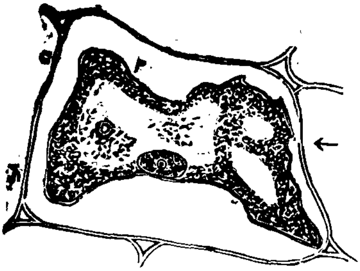


Fig. 267.

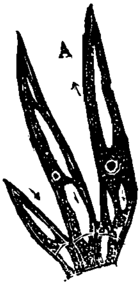


Fig. 266. Showing the *primordial utricle*; the protoplasm being contracted by Glycerine.

Fig. 267. Hairs showing movement of protoplasm. (After Sachs).

The parts of the Protoplasm.

The Cytoplasm.—

1. In appearance, it is granular in young active cells; rather clear and colourless in old ones.

2. In consistency, it is a viscid tenacious matter and though of the nature of a fluid physically it is never a fluid. Cohesion is one of its physical characters; thus on being freed from the cell-wall by artificial means, as by treating the cell with a dilute glycerine or salt solution, it tends to assume the spherical form.

3. In structure, it exhibits, when very highly magnified, a

form more or less like a honey-comb; and sometimes fibrillæ can also be distinguished.

4. In shape, it always conforms to the cell-wall; one, two, or many vacuoles may be present; and in the last case it appears to be broken up in its centre into a number of strands or threads which become woven together as they intersect.

5. It exhibits, also, a peculiar mode of locomotion, which we shall refer to later on.

The Nucleus.—

1. As regards its position, it occupies almost the geometrical centre in young cells, while in old cells it may have any position; either enclosed in one of those networks of cytoplasmic bands alluded to above, or imbedded at one part of the peripheral layer of the cytoplasm. It is always enveloped by a thin and hyaline layer of protoplasm called nuclear membrane.

2. As regards its structure, it is made up of colourless threads (called *Linin* threads) twisted together into an anastomosing net-work in which lie imbedded quite a number of small granules (called *Chromatin* granules). One or two bigger bodies, called Nucleoli, occur in this net work. The nuclear net work lies within the nuclear cavity filled with the nuclear Sap. Thus the differentiated parts of the nucleus correspond with the differentiated parts of the protoplasm. In form and function the linin network may be compared with the cytoplasmic fibrillæ, the chromatin granules with the chromatophores, and the nucleolus with the nucleus of the cell.

3. In external appearance the nucleus looks like a punctated ball with some deeper excavations on its surface. This aspect is due to the formation of small cavities within its body, exactly as the vacuoles are formed in a well developed cell.

4. With regard to the number of nucleus present in a cell,

it is a general rule and one to which no exceptions have yet been known, that the cells of all higher plants (Cormophyta) are uninuclear. In some of the Thallophyta, on the other hand, *e. g.* in all Fungi and in some Algae (*Siphoneæ*), the cells are as a rule multinuclear.

5. As regards its form, the usual shape of the nucleus is spherical. In certain cases, however, it becomes ellipsoidal or flattened or may have irregular shapes. But these are either transitory or abnormal.

The Chromatophores :—

These are the *plant-plastids*, or differentiated parts of the protoplasm charged with various functions connected with nutrition. In the embryonic cell, parts of protoplasm around the nucleus are differentiated into small colourless and highly refractive bodies—these are called *pigment bearers* (chromatophores) on account of their frequently containing colouring matters, when fully developed and differentiated within a rather well-grown cell. Three kinds of Plastids are known. These are :—

(1) The *Leucoplastids* or colourless chromatophores found in parts of plants where light can not penetrate ; their function being the formation of starch grains as a reserve food-material in Bulbs, Tubers, Corms and other underground parts of plants. They often turn green (cf. Chloroplastids) when exposed to light.

(2) The *Chromoplastids* or red, yellow or otherwise coloured chromatophores found in coloured parts of plants, *e. g.*, flowers, fruits etc. They are unlike the other two plastids which are globular or discoid, frequently of a triangular, needle-shaped, or other crystalline form.

(3) The *Chloroplastids* or the green chromatophores found invariably in vegetative parts of plants exposed to light ; it is to their presence in the cells that the green

colour of leaves and stems is due. In shape, these are flattened ellipsoidal granules and occur freely distributed in the cytoplasm. The Chlorophyll-body, as the undeveloped chromatophore of this kind is called, is fundamentally colourless; the green colour is due to the development of drops of oily matters which hold in solution the green pigment called *Chlorophyll* principally. These oleaginous drops are called *Grana*.

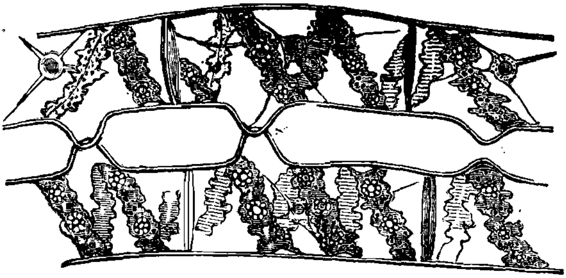
The plastids are also named with the suffix *plasts* in text books; thus we find chloroplasts, leucoplasts and chromoplasts The chloroplastids are also popularly called the chlorophyle-granules or corpuscles.

The pigment present in chloroplastids can be readily dissolved out by alcohol. The solution obtained is green, but the colour is soon discharged owing to the decomposition of the colouring matters thus extracted. The protoplasm of the cells thus freed from them now contains the colourless basis of the chloroplastids. The alcoholic extract of green leaves contains four different kinds of pigments; of these, two are green and are known as *chlorophyll* and *allochlorophyll*, and two yellow known as *chrysophyll* and *xanthophyll*. These two sets of pigments may be qualitatively separated by shaking the alcoholic solution with Benzole; on standing, the latter rises to the surface as a green layer while the lower alcoholic layer is left yellow. The pigment chlorophyll however forms the greater part of the green droplets already referred to as *grana*.

In a few exceptional cases, assimilatory organs, such as leaves, are not green. This is due not to the absence of chlorophyll from the plastids but to its being masked by other pigments related to chlorophyll Such for instance, are *Phycoerythrine*, a red colouring matter present in the chloroplasts of the red seaweeds—a kind of Alga; *Phycophæin*, a brown pigment present in the brown Algae (Phaeophyceae). In Saprophytes, however, chloroplasts are not developed.

As differentiated parts of the protoplasm, the chloroplastids only of all the chromatophores play the most important part in plant nutrition. That is, (1) they can produce organic substances (starch grains) like the leucoplastids and thus function as an amyloplastic organ, and (2) they can under the influence of light absorb and decompose carbon dioxide from the air and thus function as an assimilatory organ.

FIG. 268.



Conjugating filaments of *Spirogyra*, showing the spirally coiled chlorophyll-bands ; the small circles are Pyrenoids. Note also the Nucleus—one in each cell—surrounded by strands of protaplasm which radiate towards the cell-wall.

Chemical Properties and Reactions of Protoplasm.

In microchemical studies a distinction must be made between living and dead protoplasm. Various chemical and mechanical means may be employed to kill the protoplasm ; indeed most chemicals kill it as soon as they are allowed to react. The following, however, is only a summary of some of the various tests and reactions of the protoplasm.

In some of the green Algæ the chromatophores have very peculiar forms. In Spirogyra, they form green spirally-coiled bands or ribbons in which one or more spherical thickenings also occur. These spherical bodies are called *pyrenoids*, and apparently are the only starch-forming corpuscles. Fig. 268.

1. Living and active protoplasm generally gives an alkaline reaction. It is never acid unless indeed it is killed.

2. It coagulates at a temperature between 50°C to 75°C, although in spores or seeds where it is in a state of dormancy it can endure a still higher temperature without coagulating. Coagulation which means death, takes place also when it is treated with alcohol, ether, mineral acids etc. Coagulation sets the protoplasm hard by abstracting the elements of water.

3. Coagulated or otherwise dead protoplasm always gives the ordinary proteid reaction. Thus :—

   (*a*) When incinerated, it gives off fumes of ammonia.

   (*b*) When treated with a dilute watery solution of Iodine, it takes a yellowish-brown colour. (*Iodine reaction*).

   (*c*) When treated with strong Nitric acid and then again with Ammonia, it becomes orange or yellow; (*Xanthoprotein reaction*).

   (*d*) When saturated with a solution of copper sulphate and then treated with potash, it becomes violet. (*Biuret reaction*).

   (*e*) When treated with solution of the acid Nitrate of mercury, it takes a brick-red colour. (*Millons reaction*).

4. It becomes dissolved, or disorganised and ultimately rendered soluble by Potash or Potassium hypochlorite (Eau de Javelle) solution.

The Movements of Protoplasm.

It has already been said that one property of Protoplasm is that it can, *under certain circumstances*, move about. Where the protoplastic body is not provided with a cell-wall, as in the primordial cells of many Fungi and Algæ, it can easily move about in the medium (which is water) in which it lives. In the Amœba and Myxomycetes, protuberances of the protoplasmic mass, which constitutes the whole organism, are thrust out; and these finger-like processes draw after them the rest of the mass, and in this way creep over the substratum. Such movements are called *Amœboid* movements. In many reproductive spores, *e. g.* the swarm spores of Algæ and Fungi, a similar bodily transport of the protoplasm takes place by means of delicate threads or *cilia* which act like whips, or rather propellers, in water, The cilia, or flagella as they are also called, are threads of protoplasm formed as outgrowths

The ciliary movement of swarm-spores and other similar naked masses of potoplasm is really a combination of lashing and rotatory motions. The movement may thus be compared to that of a rifle bullet; in both cases the forward movement is in the direction of the longitudinal axis of the moving body, and round this axis there is also a rotatory movement.

The whole work of the protoplasm in exhibiting all the aforesaid kinds of movements consists in absorbing nutriment, increasing its own activity and vegetative vigour, maturing the offspring, and searching for places where the struggle for existence is less hard, and the environment is in harmony with its organisation. It will be understood that the material disposition of the particles floating in the hyaloplasm, brought about by circulatory and rotatory movements, is directly connected with the origin and growth of the different structures which eventually arise from the protoplasm.

The best material for observing circulation is the epidermal hairs of of the common Cucumber plant. The preparation for microscopical study may be made by scraping a few hairs from the epidermis and placing them in a drop of water on a slide. The "streaming" may be accelerated by placing a drop of warm water on the preparation, or heating gently one end of the glass slide. The large nucleus will appear at the centre enclosed within the cytoplasmic strands that run from the peripheral layer; a few green chloroplasts will also be seen distributed in these strands.

of the ectoplasm ; they lash out in water, and drive the whole mass forward in definite directions which may be altered by the action of stimuli. Such movements are called *Ciliary* or *Flagellary movements*. Again many Bacteria are motile ; and spermatozoids are known exclusively to approach female organs by executing some very remarkable movements.

It is, however, when the protoplasm lives within the cell-wall that the movements become specially attractive. This sort of movement is distinguished as *streaming* and is known in Botanical technique as *cyclosis*. It may be studied in the epidermal cells torn from the inner fleshy leaves of Onion and other bulbes, in the epidermal hairs on stems and leaves of many plants, and particularly in the cells of the water-plant Chara or Vallisneria. These movements become very clear under the microscope when the cells are large, and the cell-wall thin and colourless.. Occasionally they are accelerated or started by external injury or heat, these being the stimulating agents. In very young cells, however, cyclosis apparently does not exist. Indeed not usually after the vacuole has been formed does the protoplasm show any tendency to execute the movements. In fully grown cells of Vallisneria, for instance, the protoplasm is studded with minute dark granules—the microsomes—and also a large number of the green chloroplastids.

The best material for observing Rotation is Vallisneria spiralis, a common water plant inhabiting our ponds and ditches. For observation, a strong leaf is selected ; laid flat on the index-fingure and sections taken from it midway between the two epidermal tissues. Too thin sections should be avoided ; and one having elongated cells should be chosen. The section is laid on a slide, preferably with the epidermis downwards and covered with a drop of water. A very gentle warming of the slide will not only remove some of the air bubbles which always become enclosed when a cover glass is used, but will also enhance the movement. Under the high power green chlorophyll bodies are seen to be trooping past in rapid succession from the field of view of the microscope. Proper focussing will however enable the observer

The movement of the protoplasm which in itself is colourless and hyaline is rendered evident from the fact that the granules move forward in one direction, like particles of mud in turbid water. In this particular case, as well as in water-plants generally, the protoplasm-mass of the mature cells withdraws to the cell-wall, encloses a single vacuolar cavity, exhibits a continuous flow of the granular substance imbedded in it along the endoplastic layer enveloping the vacuole, and keeps the direction of this current constant. This kind of protoplasmic movement is distinguished as Rotation, in contrast to what is called the movement of Circulation. This latter is observed in the epidermal hairs of many land plants. The protoplasm-mass in these hairs encloses a large sap-cavity which, however, is traversed by a number of cytoplasmic strands which again meet at about the centre and may enclose the nucleus. Thus the single vacuolar cavity is divided into a number of separate sacs or chambers. In these strands, thus stretching across the sap-cavity, the granular substances flow in streaming movements which are never constant in direction. Granular currents often run in opposite directions, now uniting, now dividing, or again, at some convenient part the opposing currents may coalesce to form a neutral non-motile zone. In circulation, the nucleus which remains in the centre of the

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to notice that the granules always move in a constant direction, that this translocation takes place in the part of the cytoplasm abutting upon the vacuole in the centre, and that there is always a "neutral band" of protoplasm towards which the motion is less rapid. 'This neutral band" is the immediate lining layer of the protoplasm and is by many regarded as the *ectoplasm*.

The ectoplastic layer or the neutral band in the cells of Vallisneria may be best studied by applying some reagents which will cause a contraction of the protoplasm. Concentrated solution of Sugar or Glycerine when added to the water in the above section, causes the protoplasm to recede from the cell-wall. The contraction is due to the abstraction of the elements of water from the thin protoplasm, and vacuolar net-work, or in the parietal layer of the protoplasm, usually remains stationary: for the cytoplasmic strands are tightly stretched and keep the nucleus pinned at one point. But when there is any considerable movement in these strands, the nucleus is often displaced and looks as if it were "towed about like a ferry-boat by ropes" (Hanstein).

SECTION II.

The Cell-Wall.

It has been mentioned already that the cell-wall is a product of the protoplasm; that at its inception it originates as a thin membranous layer from the secretion of cellulose matter by the protoplasm on its surface; and that during the growth of the

this phenomenon is known as *Plasmolysis*. The receding protoplasm squeezes out water from the vacuole and becomes itself globular in shape. When not too greatly contracted the movement goes on as usual and then it can be demonstrated that the outer layer of the protoplasm takes no part in the movement, remains firm, clear and hyaline. This layer is the *ectoplasm*. If the contraction is too great, cyclosis stops, but the protoplasm can again, in most cases, be revived by washing the dehydrating medium in which it is placed, and remounting the section in water. During this process of revival the contracted ball-like protoplasm expands again by taking up the lost water, and may again show the movements. At this stage the slowly advancing layer of the colourless and hyaline ectoplasm becomes most clear and can be studied with advantage.

It should be remarked that Plasmolysis takes place only in living cells. If sections be treated with alcohol, and the protoplasm thus killed, it not only does not contract (with glycerine and recede from the cell-wall, but on the other hand, takes up readily colouring matters presented to it. Thus living and active protoplasm is usually not stained with watery solutions of eosin, methyl green etc. for the ectoplasmic layer prevents the entrance of these staining fluids; but as soon as it is killed with alcohol or by any other similar agent, it becomes capable of absorbing and retaining a comparatively large amount of the colouring matter.

cell, it becomes gradually differentiated into layers exactly like what happens in the protoplasm, and finally may also be altered considerably in its chemical nature. Hence we have to consider

1. The growth and development of the cell-wall ;
2. Its differentiation and modification in chemical composition.

1. **The Growth of the Cell-Wall.** In the embryonic parts of plants, *e. g.*, the punctum vegetationis (p. 29), the embryo-sac of ovaries, the seedling etc. the component cells are separated by very thin cell-walls. The rapid increase in size which follows immediately after this stage is due to the *growth in surface* of the cells. The growth of the cell is really a vital function of the protoplasm, for the cellulose matter is formed by it. Now this superficial growth may take place in two ways :—

(*a*) by the introduction of cellulose matter, continuously formed by the active protoplasm, into the substance of the cell-wall, *i. e.* what is technically called, by *intussusception* ;

(*b*) by the deposition of layers of cellulose on the surface of the original cell-wall, *i.e.* by *apposition*.

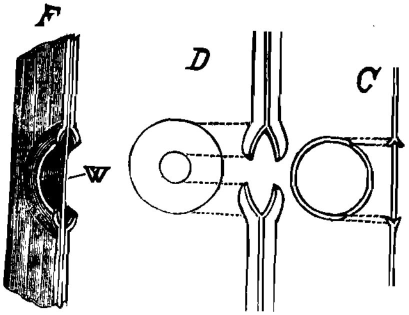
Imagine a rubber bladder fully stretched by pumping air within it and brought to about the bursting-point. The resistance required to be given by it to the increasing force of air within may be best attained by strengthening the material particles already present ; and this strengthening we can have by increasing the component particles, and by giving the bladder additional coatings of rubber-matter. In the cell the constantly growing protoplasm stretches the cell-wall to its full, and it intercalates particles of cellulose within those already existing in the original cell-wall ; simultaneously new layers are added. Thus strengthened the cell wall is enabled to extend further ; and the same processes being then repeated the maximum growth in size is attained. Thus, again, so long as the cell grows in surface the cell-wall remains thin, delicate, colourless and undifferentiated, although, it receives large additions from the protoplasm.

The next step, in the growth of a cell which has attained its maximum size, is the *growth in thickness* and differentiation of the cell-wall. The former takes place by the method of apposition ; new layers of cellulose are laid down on to the surface of the older ones. Thickened cell-walls when examined under the microscope always exhibit a layered appearance. This layering, or *stratification* as it is called, is due to the deposition of successive thickening layers of cellulose. Thicker dense layers alternate with thinner less dense ones, and thus light passing through is transmitted more readily by the latter, while the former—the denser ones—appear as dark lines in contrast.

After the growth of the cell is complete, differentiation of the wall sets in. In strongly thickened cell-walls three distinct layers can frequently be distinguished. In physical and chemical properties, they always differ considerably. The primary layer is that which is towards the outer surface of the thickened wall, and the tertiary that which faces the cavity. The secondary layer, intermediate between these, is the most strongly developed and prominent part.

The growth of the cell-wall is rarely uniform. When secondary, tertiary, etc deposits of lamellæ take place they are applied not on the whole surface of the original membrane, but parts may be left vacant *i. e.* without the apposition of layers. This is obviously connected with the activity of the protoplasm. So long as the protoplasm is in the embryonic state, *i. e.* not well differentiated, the vital activity of the protoplasm in producing cellulose may be supposed to be uniform over its outer surface ; hence a continous cell-wall is the result. But gradually as the protoplasm passes through the stages of differentiation its activity is mainly directed towards is own differentiation, so that the function of producing cellulose is located at but isolated or limited parts of its surface. Thus in old cells, where the protoplasm has to work out functions other than that of producing cellulose, the cell-wall exhibits what are called *pits* or pores or chinks, evidencing that at these points cellulose matter has not been produced and applied. Thus arise the PITTED CELLS, as these are called. Pits may be compared in a way to the cabin port-holes closed by thin plates of glass (which may be taken as the original almost transparent and delicate cell-wall). The part of the thickened wall just surrounding a pore is elevated to form a ring-like border, and sometimes arched over it, so that the upper opening is contracted. Pits with the thickening layers arching over the original unthickened spot of cell-wall are called *Bordered pits* and are functionally the most important.

FIG. 269.



to illustrate Bordered pits. (From Sachs). F. A cell-wall showing the arched thickennings; W, the original membrane (Torus). D, the circles represent the inner and outer openings of the pit. C shews the formation of the borders.

Differentiation of Cell-walls.

Discontinuous surface-growth results in different forms of cells. Thus cells that are round or tabular or polyhedral in their embryonic stage may become subsequently cylindrical, conical, tubular, star-shaped etc. Again, discontinuous growth in thickness results generally in the sculpturing of the surface. What is known as striation often arises as superficial markings, and is due to the alternation of bands of thicker denser cellulose with those of less dense ones. It may be observed in the form of two systems of parallel lines crossing each other at an angle.

The further differentiation and change in the substance of the cell-wall take place in rather old cells. There is always a chemical change, attended also by a change in physical properties, which mark out the thickened cell-wall into concentric layers differing from one another in their behaviour towards chemical re-agents. Three such changes may be noticed here as the most important and common :—

1. *Cutinous change.* This consists in the impregnation of a substance called *cutin* within the particles of cellulose matter. It takes place generally in the outer cellwall of parts of plants exposed to the air, such for instance, as the epidermis of trees and shrubs.

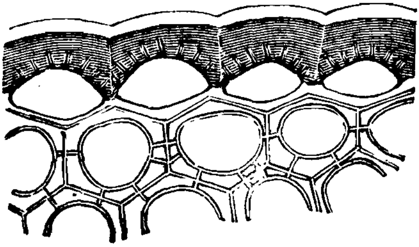
2. *Suberous change.* This consists in a similar deposition of a substance called *suberin* in cell-walls. Corky cells are examples *par excellance.* The outer layers of the thickened walls of pollen grains and spores are similarly *suberised.*

3. *Ligneous change.* Here the impregnated substance is Lignin. It is found in the woody cells of plants.

4. *Mucilaginous change.* This, unlike the above three, is not due to the intercalation of any foreign matter, but a mere conversion of the cellulose into a substance capable of imbibing water to a large extent.

Where *Lignification* or *Suberisation* takes place, it is particularly the secondary layers that receive the lignin or suberin substance ; the tertiary or internal layer as also the primary or outer layer remains of cellulose. In *Cutinisation*, especially in the cuticle of the epidermis, the outer layers are particularly affected. Lignification while increasing the hardness of the cell-wall and thus diminishing its extensibility, renders it more pervious to water. Hence lignified wood cells not only act as mechanical tissues for the support of the plant but also transport water in the plant body. Cutinisation or Suberisation of cell-wall, however, makes it impervious to water but does not affect the extensibility and elasticity—inherent properties of the cell membrane.

FIG 270.



Epidermal cells of a desert plant, showing stratification. The onter layers of the cells of the first row are cutinised. Note the middle lamella in the lower cells.

Forms of Cells.

Primordial cells, as also isolated masses of protoplasm, are spherical ; while where cells are united to form groupings called tissues, the form of the constituent cells varies greatly. Again, young cells, for instance those that are in the growing or multiplying stage (cells of the punctum vegetationis etc), are generally in intimate union and thus are either polygonal or tabular or cubical. The ultimate form of many old cells is also polygonal. These regular forms depend upon the uniform production of cellulose from the protoplasm. But more often the protoplasm is active in producing cellulose at certain points or places only of its surface. The origin of pits has already been referred to as due to this want of uniformity in the growth of the cell-wall. When the protoplasm produces cellulose matter at a few points only, necessarily the growth and further elongation of the cell-wall take place at these points. In this way, star-like and elongated cells arise. Star-like or *stellate* cells are irregular in outline, and unsymmetrical. Elongated cells are those where the cell-wall has grown at two points only in a straight line which is in general vertical, and are of various forms. Thus :—

1. Sclerenchymatous cells are fibre-like pointed cells with the walls much thickened. The mature cells lose their protoplasmic contents and show diagonal pits on their surface. Their function is mainly to act as mechanical supports for maintaining the rigidity of a plant.

2. Tracheids are similar cells but are not pointed, are comparatively more wide, and provided with conspicuous round bordered pits on their surface. They contain no living matter and their chief function is to conduct water. They are, as a rule, lignified and hence hard. According as they are very narrow or very broad, and serve merely as mechanical structures in the former case or as water-carries also in the second, tracheids are called *fibrous* or *vascular* respectively.

3. Latex cells, or milk cells or Laticiferous cells are, as the name denotes, tubes of inordinate length having simple cellulose cell-walls, rather thin and smooth, and containing a milky sap of gums, resins and other matters of plant excretion. They contain a peripheral lining layer of protoplasm. They are found in plants which readily exude a milky juice when injured. Such for example as in the Fig family, the Papaw family, the Euphorbias, Asclepiads etc.

These are the three most important varieties of elongated cells. It will be seen that they differ not only in form but in function as well. Cells that are not elongated may also be referred to the following types when there is a marked variation from the ordinary polyhedral, tabular or cubical form.

4. Stellate or star-like cells occur in the stem of many water-plants. They are provided with simple cellulose walls and contain a rich and active protoplasm.

FIG. 271.

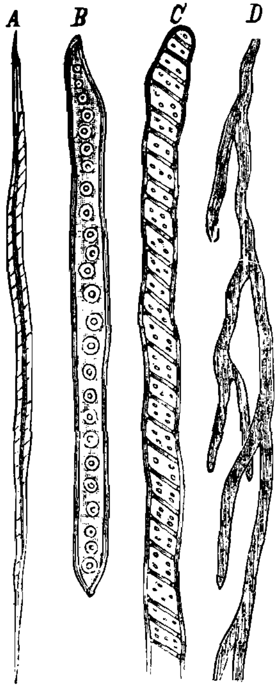


Diagram illustrating the more important elongated cells.

A. Sclerenchyma fibres; note the diagonal pits.

B. Tracheids with bordered-pits.

C. Part of Vasiform tracheid with spiral thickenings, also with small pits.

D. Part of a branched Latex cell containing minute granules in the milky sap.

5. Scleroids or Slerotic cells are strongly thickened, hard and lignified cells (stone cells as they are called), containing ferments and similar substances. They are abundant in the stones of fruits (Date, for instance).

6. Collenchyma or Collenchymatous cells are living cells with the cell-walls thickened considerably at an isolated point, more usually at the corners. They often occur in the sub-epidermal tissues of plants, and contain crystals.

The growth in thickness and the kinds of Pits.

(*a*). Thickening layers are usually formed centripetally. If they are strongest at certain points knobs or spines or ridges project inwardly. In elongated cells specially the ridge-like projections may form reticulate figures, or coiled, or spiral, or annular bands. Thus tracheids, more particularly the vascular tracheids are very often provided with rings or spiral bands widely separated from one another, and with the intermediate portions of the cell-wall remaining thin and almost unchanged. Tracheids with lenticular bordered-pits may be seen in longitudinal sections of almost all woody structures. If a thin longitudinal section of a match stick be examined under the higher power of a microscope, they shew up their structure most beautifully They are more abundant in Conifers than in Dicots or Monocots. But spirally thickened cells or those provided with ring-like or reticulate thickenings are observable more commonly in Angiospermous stems. In Ferns the tracheids have their bordered-pits elongated horizontally ; the large number of such elongated pits arranged closely one above the other gives them the appearance of rungs of a ladder. Such tracheids are called *Scalariform tracheids*.

FIG. 272.

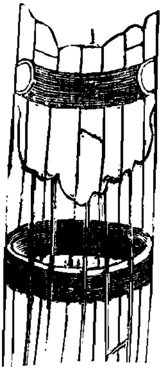


FIG. 273.

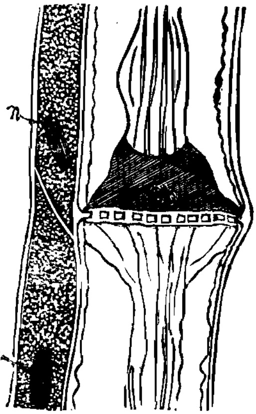


Fig. 272. Vessel with annular thickening-rings (*a*), from the wood of Maize (After Sachs).

Fig. 273. A Sieve-tube from the stem of Cucumber showing the Sieve-pits, in the Sieve-plate (sp) ; to the left is a Companion cell.

Reactions of Cell-walls.

A. Of Cellulose walls.

1. Dilute acids and alkalies have no action upon cellulose cell-walls.
2. Concentrated Sulphuric acid, allowed to react upon a simple unaltered cell-wall for some time, converts it into a kind of sugar (Dextrose), and thus causes first a swelling and then dissolution.
3. Sulphuric acid followed by Iodine solution in water colours cellulose layers a beautiful blue. (Test).
4. Treated with Iodine solution simply, cellulose becomes only faintly yellow.
5. Treated with a solution of cupric hydroxide in ammonia (cuper-ammonium oxide), cellulose swells and is then dissolved.
6. Treated with Chlor-Zinc-Iodine, it turns blue or violet.
7. It is stained by various Aniline and other colours, e.g. Carmine stains it red ; Hæmatoxylin, violet ; Methylene blue, blue etc.

B. Of Lignified walls.

1. Dilute acids and alkalies have no action upon lignified cell walls.

(*b*) Kinds of Pits :—

1. Pits widened towards the primary layer of the cell-wall and found in the epidermal cells of many tendrils have been called by Strasburger TACTILE PITS. They contain protoplasm, and probably receive the stimulus for coiling the tendrils.

2. BORDERED PITS have already been described, as also the elongated bordered-pits of ferns. The original or primary membrane of bordered pits is thickened at the centre to form the TORUS. The latter acts like a valve, for by curving to one side or the other, it may close the opening of the pit *(halo)*.

3. SIEVE PITS are very fine pores which pass perforating the sieve-plates of sieve-tubes. The cell contents of these tubes are thus enabled to pass easily from one cell to another through these pits.

2. Sulphuric acid followed by Iodine causes swelling and turns them brown.
3. Chlor-zinc-Iodine stains lignified membranes yellow; so also does Iodine.
4. Aniline chloride or sulphate solution (acidulated) stains them bright yellow.
5. Acidulated solution of Phloroglucin colours them red or violet.
6. Treated with Phenol and Hydrochloric acid and exposed to light, they take a beautiful green colour.
7. Safranin, Fuchsine, and many aniline colours readily stain them almost permamently, but Carmine or Hæmatoxylin has no lasting action.

C. Of Cutinised or Suberised walls.

1. Dilute acids and alkalies have no dissolving action.
2. Strong Caustic-Potash and similar alkalies impart a strong yellow colour. Boiled with Caustic Potash suberised cell-walls become dissolved, and yellow drops of ceric acid exude; Cutin withstands the action of boiling Caustic Potash better than Suberin.
3. Iodine solution colours cutinised or suberised walls yellow.
4. Chlor-zinc-Iodine gives the same reaction.
5. Strong Sulphuric acid has no action.
6. They are not particularly affected by Carmine or Hæmatoxylin, but are stained a lasting pink or red with Fuchsine.

D. Of Mucilaginous walls.

1. They swell considerably in water, Potash and many other reagents.
2. They are not affected by Iodine solution, or preparations of Iodine (as Chlor-zinc-Iodine).
3. They are stained deep red with Ruthenium red, and pink with Corallin soda.
4. Methylene blue and some other aniline colours also stain them.

SECTION III.

The Cell Contents.

Under this head it is usual to describe all those substances that are found inside various cells, some included in the protoplasmic substance, some left in solution in the cell-sap of the vacuolar cavities, and a few others distributed here and there in the cell. They are not living bodies like the protoplasmatic bodies, neither are they the integral parts of the cell. They may be best classified on the following basis :—

- I. *Solid*
  - Inorganic
  - Organic
    - Carbohydrates.
    - Albuminoids.
- II. Liquids or in solution
  - Inorganic
  - Organic
    - Carbohydrates.
    - Albuminoids.

1. **Solid Inorganic cell contents.**—(*a*). The most important of these is **calcium oxalate** which occurs in the form of crystals. Few plants are devoid of such crystalline bodies. In many Monocots, as in Liliacaæ, Orchidaceæ etc, long needles of Calcium oxalate crystals occur in compact bundles imbedded in mucilaginous sap cavities. These are distinguished as *Raphides*. In other cases, the oxalate crystals are formed in another shape ; thus, quadratic octahedral crystals may often be seen in the sap-cavities of Begonias, Phaseolus (the pulse known as Moonga) and many other Dicots, especially in the cells of the leaves.

Very fine crystals of calcium oxalate can also be observed in the hairs of many species of *cucurbita*.

While the oxalate crystals found in the Angiosperms occur almost exclusively in the cell cavity, in Gymnosperms, on the other hand, they often appear in the mass of the cell wall. Numerous granules of unrecognisable shape can thus be seen in the cell walls of Bast fibres in the Abietineæ and a few other Gymnosperms.

(*b*) Crystals of **calcium carbonate** also occur as the cell contents in many plants, though they are not so extensive as those of the oxalate. Plants of the families Acanthaceæ, Urticaceæ, Cannabinaceæ, abound in such crystals. They are aggregated together into what in appearance may be called bunches of grapes, with the stalks attached to the outer cell wall of the cell. They often occur in the epidermal cells of the plants mentioned and sometimes also in the cortical cells. In a few cases they take up all the space in a sap cavity and thus form its sole occupant. Such stalked collection of calcium carbonate crystals are called **Cystoliths**. The epidermal cells of the leaves of the India rubber or Bat or Aswatha (*Ficus*) plants afford a very good view of these bodies.

Cystoliths arise from the protuberance of the cell-wall into the cavity of the cell ; on the thickening layers that thus protuberate the protoplasmic matter deposits additional layers of cellulose and then the mineral crystals as well. In this way the clustered clubshaped form is attained.

In the cell-walls of many marine Algæ (Acetabularia, Corallina etc) and in Chara, the carbonate crystals are deposited in such a fine state of division and profusion that the structure becomes stony and brittle.

Other inorganic matters are also deposited in the old cell-walls of many plants. Thus, in Gramineæ (Grass family), Equisetums, and Diatoms Silica is abundantly formed in the superficial walls.

2. Solid Organic cell contents,—

(*a*) Carbohydrates :—**Starch grains** are *par excellance* the most important structural constituents of the cell. They arise within the chloroplastic bodies as very minute granules, almost undistinguishable even under the microscope, except with the aid of chemical tests. They are the first visible products of the assimilation of inorganic matter that are carried to the cells of the leaves. As these small granules always arise during assimilation in leaves, they are distinguished as *Assimilation Starch*. In contrast to these, are the bigger granules found as *Reserve Starch* in Bulbs, Tubers and other subterranean and aerial structures which act as reservoirs of reserve food-materials. The assimilation starch has a transitory existence ; for they are continually transformed into soluble sugars as soon as they are formed in the leaves ; the liquid sugar-solution then travels through the conducting strands of the leaves, then through those of the stem and root, and reconverted into the bigger granules of reserve starch by the action of the leucoplasts. They are found in abundance in, and extracted for economic purposes from, the rhizomes and roots of perennials, tubers of Potato and seeds of all cereals.

In form starch grains are oval, elliptical, lenticular, rounded etc. They always exhibit a *stratified* appearance ; for as in the case of cellulose cell-wall so here, thicker denser layers alternate with thinner less dense ones. The organic centre round which these layers are formed is called the *hilum*. The difference in the distribution of water, which is the immediate cause of stratification leads to the growth of the grains by *intussusception* ; that is new particles of starch-substance are intercalated between those already existing in some of the layers ; by which means, again, the difference in densities

FIGS. 274, 275. FIG. 276. FIG. 277.

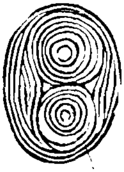


Fig. 274. A cell of Potato showing the elliptical starch grains.

Fig. 275. A single starch grain—showing the stratifications—the small circle at the centre of the narrow end is *hilum*.

Fig. 276. A compound starch grain.

Fig. 277. A half-compound starch grain.

becomes more pronounced. Generally when young and small, the grains are spherical, but as growth proceeds this shape is almost always lost. Thus, the fully developed grains of potato are *eccentric i.e.*, the hilum does not correspond to the centre of the grain. Those of cereals on the other hand are a little flattened and the organic centre corresponds with the geometrical centre.

In chemical composition starch is a carbohydrate similar in percentage composition to cellulose ; but its molecules are comparatively less complex. It is chemically represented by the chemical formula $(C_6 H_{10} O_5)n$ where the value of *n* is still unknown. It is readily detected by the following reactions :—

(*a*) When treated with an aqueous solution of Iodine, it takes up a very beautiful blue colour which however disappears on boiling and reappears on cooling.

Though as a rule starch is formed in all green plants and green parts of plants, in Onions and in the green Alga Vaucheria it is absent. On the other hand, it is absent from all plants that are not provided with the green chloroplasts.

As an organised substance,it should be remembered that a starch grain is not a simple and pure chemical substance,much less as the protoplasm and cell wall are. It really consits of (a) water, (b) mineral substances and (c) starch. But the starch itself occurs in two modifications :— *Amyloid* or *Granulose* which gives the usual blue colouration with Iodine, and *Farinose* or *Amylodextrin* which takes only a wine red colour with Iodine. The latter is more related chemically to cellulose than the former. Although starch grains are specially rich in amyloid, in many cereals, as for instance *Oryza*, *Sorghum* etc, amylodextrin usually predominates.

In structure starch grains are of three principal tvpes :—

1. Simple grains are such as have only one hilum round which the alternating layers are arranged either concentrically as in cereals), or eccentrically (as in potato).

2. Compound grains are those in which there are two or more organic centres (hilum) round which the layers are separately distributed, e. g. in the seedlings of *Phaseolus* and the cortex of *Cucurbita.*

(*b*) When treated with Sulphuric acid, or Potash, or when boiled with water, it swells and ultimately runs into a paste.

(*c*) When treated with chlor-zinc-Iodine, it swells and stains blue at the same time. The stratifications come out with remarkable clearness with this reagent.

(*d*) When roasted *i. e*, heated without addition of water, it is transformed into a kind of sugar (Dextrin), and in this state is more disgestible.

(*e*) When treated with aniline stains, it does not take up the stain and remains colourless.

FIG. 278.

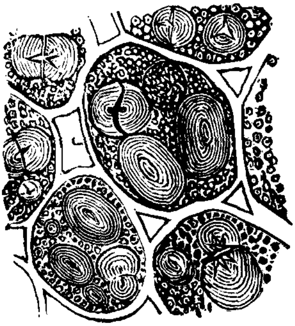


Fig. 278. Section through the cotyledon of common Pea—The large concentrically stratified grains are Starch grains : the smaller granules are aleurone grains ; the triangular spaces are intercelluar spaces. After Sachs. (×320).

3. Half-compound grains are made up of two or three individual grains with a hilum for each, and a few[1] enveloping layers surrounding the whole cluster. The separate grains thus appear to be enclosed within the layers of the mother grain.

In Rice and Oats all the grains are compound ; indeed in some of them the number of individual grains varies from 4 to 100. Both the compound and half-compound grains can however be observed in potato in conjunction with the simple grains.

(*b*) Albuminoids :—Like the starch-grains, Proteid matters are reserved in the cells of seeds and other similar reservoirs of food-substances in the form of solid grains of definite shape. They are known as **Aleurone grains** and originate in vacuoles specially rich in albumen. The grains are formed by a condensation of the albumen which may, during the progress of hardening, enclose crystals of calcium oxalate or small round bodies called **Globoids**. The latter are inorganic salts, and have been shown to consist of a double phosphate of calcium and magnesium. Aleurone grains are present in almost all seeds, but they are particularly rich in oily seeds and sparse in those that contain starch. In Pea they may be seen as very small roundish grains lying in the same cells that contain starch. In Wheat (Fig. 281) the first layer of cells that lie just below the pericarp are particularly rich in small aleurone grains of indefinite shape, while the rest of the tissue forming the major part of the fruit, is stuffed with a large amount of starch.

Crystalloids are really masses of protoplasm adapted for a dormant condition and are rarely found in cells with watery saps. In the cells of potato-tubers they remain imbedded in the protoplasm ; but in oily seeds they are invariably enclosed in the aleurone-grains. The best method to observe them, in the potato, is to take thin sections from the sub-epidermal tissues. They occur as cubical crystals in the parenchymatous tissues just below the skin. The crystalloids of the seeds of the castor-oil plant (*Ricinus*) can also be best seen on mounting thin sections in water when the surrounding granular substances are partly dissolved and the crystalloids become all the more prominent For, all crystalloids, unlike the aleurone grains, are insoluble in water ;. generally they are colourless, but in some cases they occur in petals and other floral parts as vehicles of colouring matter. Like all proteids, they are capable of swelling under the influence of certain chemical substances, as potash.

Aleurone grains occur only in the outer layer of cells of all cereals. In such cases they do not contain any inclusions—either of crystalloid or globoid. They are capable of imbibing water to a great extent ; indeed some are wholly soluble in water. In chemical properties they

Crystalloids are solidified proteid matters either enclosed in the aleurone grains (as in most oily seeds), or remain singly distributed in the matrix of the protoplasm (as in potato). They are so called because they assume the geometrical shape of crystals. Aleurone grains containing enclosed albumin crystals (crystalloids) are seen with very good effect in the seeds of castor-oil (Ricinus) and many other Euphorbiaceous plants.

All these grains and crystals of albumin are proteids, and behave exactly like the protoplasm towards chemical reagents (see reactions of protoplasm).

FIG. 279.

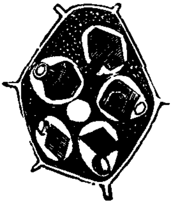


FIG. 280.

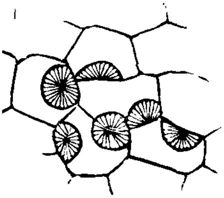


Fig. 279. A cell from the endosperm of the Castor oil plant, showing the crystalline aleurone grains, the roundish globoids and a crystalloid in the grain towards the right. After sachs. (× 300).

Fig. 280. Sphere-Crystals of Inulin.

do not differ from Crystalloids ; thus, with a trace of caustic potash in water, they all swell and dissolve. On account of their very small size and globular shape they may be often confounded with oil-globules. But all proteids are absolutely insoluble in alcohol, ether, benzol or chloroform ; these reagents would always dissolve oil.

In oily seeds the matrix in which aleurone grains are imbedded consists of a mixture of oil and protoplasmic matters. Globoids, when present, may be distinguished from their being dissolved when sections containing the grains are treated with very dilute acids.

If a thin section of a Ricinus or almond seed be treated with benzol, the oily matrix surrounding the aleurone grains is dissolved, while the small grains themselves are left behind. Treated with an alcoholic solution of Alkanet, the oily matrix is stained deep blood-

3. **Liquid cell-contents.**—

The watery fluid which saturates the whole cell and its contents—cell-wall, protoplasm, starch, etc.—is called the *water of organisation.* The function of this water is two-fold: *first,* it enters into the composition of all organised substances, it is indispensable for the growth of the whole cell; and *secondly,* it is the vehicle of transport of food-materials within the cell and is the general solvent of solid food-substances. The cell-sap, however is a concentrated watery solution of various substances formed within the cell—either in the vacuoles or the bigger sap-cavities. The sap usually gives an acid reaction, and holds in solution not only *sugars,* as glucose, cane-sugar, grape sugar etc, *amides,* such as Glutamin, Asparagin etc, but also *acids* such as malic, formic and oxalic acids. Of inorganic salts that are present, nitrates, sulphates, and phosphates are the chief.

In the root-tubers of many compositaeæ plants a peculiar form of carbohydrate allied to starch is found dissolved in the cell-sap. This is *Inulin.* When cells containing *inulin* are treated with alcohol it is precipitated in the form of small granules; so too when they are placed in glycerin. The granules crystallise out and arrange themselves in the form of *sphere-crystals*—*i. e.* the crystalline elements are disposed in a radiate manner. They are not stained by Iodine but are converted, like starch, into glucose when treated with boiling Sulphuric acid.

Besides the above the other liquid cell contents are (*a*) various tannins, alkaloids and glucosides dissolved in the cellsap ; (*b*) fats, oils, resins dispersed in small drops ; and (*c*) certain colouring matters to which the sap sometimes owes its colour, called *anthocianin.* Thus :—

red. If the oil be removed by alcohol and the aleurone grains by potash solution and then the section treated with dilute Iodine solution the matrix that is left behind forms yellowish bands enclosing clear spaces—those previously occupied by the grains.

Fig. 281.

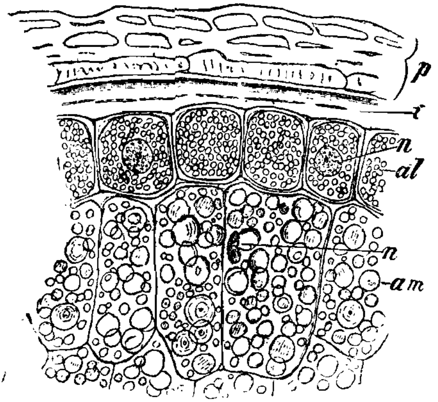


Fig. 281. Part of a section of a wheat-grain. The outer part *(p)* is composed of disorganised dead cells and constitute the Pericarp. In the first row of cells the small granules *(al)* are aleurone grains; in the next row of large cells, the chief cell contents are starch grains. *(am)*. After strasburger.

1. The inorganic contents of cell sap are—salts, *e. g.*, nitrates, phosphates.
2. The carbohydrates are—glucose, grape sugar, cane sugar, inulin etc.,
3. The complex organic substances are—amides such as glutamin, asparagin; tannins, alkaloids and glucosides such as thein, amygdalin, strychnine, nicotine etc; organic acids; fats, oils, and resins.

CHAPTER XV

Cell-Formation.

Before going into the description of tissues, it will be necessary to discuss the different modes of cell-formation. Each cell takes its origin from a pre-existing cell; and as it is broken up into a number of new cells by the subsequent development of partition-walls of cellulose, a tissue is formed

The nucleus being the organic centre of the protoplasm, all sorts of cell-formation are generally preceded by some peculiarities in the nuclear behaviour: again, cell-formation is really dependent upon protoplasmic redistribution. The different ways in which this redistribution takes place may be reduced to the following three important types :—

1. The *Rejuvenescence* of a cell; that is the formation of a new cell from the renewal of constructive activity in a mass of old protoplasm already in existence; in this process only one new cell is formed from an old one.

2. The *Conjugation* of (generally) two cells; that is the fusion of two (or more) protoplasmic masses into a new cell.

3. The *Multiplication* of a cell; that is the formation of two or more cells from the protoplasm of one mother cell.

1. **Rejuvenescence** is connected with reproduction; for in this process no new cells are formed, only the protoplasmic activity being revived. It occurs almost exclusively in the filamentous cells of the simpler Algæ (*e.g.* Œdogonium, Stigeoclonium). The process consists in the contraction of the protoplasm from the cell-wall, elimination of water

m its mass, rupturing of the cell-wall, and finally the ape of the contracted protoplast in a globular and usually otile mass. Fig. 283 shows a rejuvenated swarm-shore.

FIG. 282.

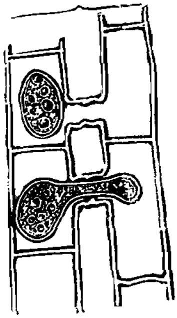


FIG. 283.

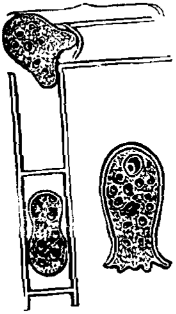


FIG. 284.

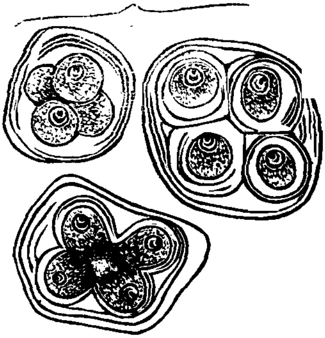


Fig. 282. Conjugation of *spirogyra*

Fig. 283. Rejuvenescence of *Œdogonium* : to the right a resting swarm-spore.

Fig. 284. Formation of pollen grains—cell formation by rounding off of the protoplasm of mother cell-(After Sachs).

2. **Conjugation** is another mode of reproduction. It is by far the most common, and takes place either by the fusion of two similar cells, as in the lower thallophyta, or by the impregnation of a female by a male cell. Where the conjugating cells are sexually undifferentiated, *i.e.* are physically alike, they are called GAMETES, and may be motile or non-motile; in the latter case they are distinguished as PLANOGAMETES. Sexually differentiated, *i.e.* dissimilar conjugating cells are known as the OOSPHERE, or the female. and the SPERMATOZOID, or the male cell. These reproductive cells are generally not provided with cell-walls, and originate by a contraction of the protoplasm of the mother cells which recedes from the walls.

The filamentous green Alga *Spirogyra* offers the best material for the study of conjugation by non-motile gametes. It grows commonly in shallow waters in large flocculent green floating masses which feel slippery to the touch, and have often a frothy appearance. Conjugation can be observed in midsummer ; the following is however a somewhat detailed account of the process. Each filament consists of a row of tubular cells containing a mass of protoplasm with a big sap-cavity in the centre. Preparatory to fusion, two filaments which lie almost side by side, give out short protuberances laterally from two opposite parallel cells; when they eventually touch, the partition wall is absorbed, and then a channel is formed running from one cell to the other. By this time the protoplasmic masses of these cells have receded from the cell-walls, and contracting and squeezing out a part of the sap-water become almost rounded off. One of the masses however, contract more than the other, and then pass over, through the channel already formed, to the other. The coalescence that then results gives rise to an egg-shaped or rounded cell, called the *zygote* ; from this *a zygospore* is formed by the development of a firm and thickened cell-wall, which after undergoing a period of rest, more particularly to tide over the winter, germinates into a new filament. An almost exact mode of reproduction takes place, in the *Desmids*, unicellular microscopic organisms allied to spirogyra.

FIG. 285.

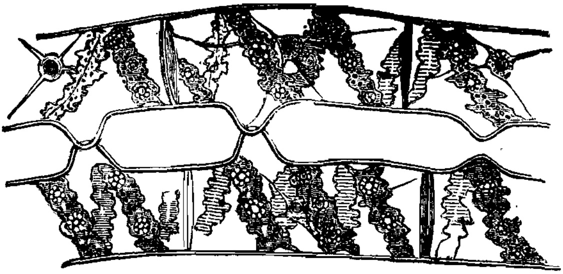


Fig. 285. The process of conjugation in spirogyra ; the lateral walls have bulged out.

In CHLOROPHYCEÆ, another class of green Algæ distinct from the class CONJUGATEÆ to which desmids and spirogyra belong, conjugation takes place in some cases between motile gametes or ***planogametes***.

These are ciliated primordial cells, which move in water for sometime, and in *Ulothrix* specially are provided with cilia. Conjugation takes place in pairs; the resultant Zygotes draw in the cilia, round themselves off, and becoming invested with a thick cell-wall form the zygospores which may germinate into new filaments exactly as in the case of spirogyra.

In Bryophyta, Pteridophyta, and many higher Thallophyta, reproductive cells are formed by the conjugation of sexually differentiated oospheres or egg-cells and spermatozoids. The spermatozoids are mostly coiled or spirally twisted masses of protoplasm provided with a number of cilia which enable them to lash out in water. Impregnation consists, in these cases, essentially in the complete fusion of the nuclei of the conjugating sexual cells and the rest of the cytoplasm.

In all these cases of cell-formation, it should be noted that there is no actual increase in the number of cells formed. It is also important to note that reproductive cells (as in the above cases) are always preceded by a contraction of the protoplasm of the mother cell before they actually are separated from the parent.

3. In the third process, that of **cell-multiplication,** the greatest variations occur. Cells that are destined to be reproductive are always produced by a contraction and rounding off of the protoplasm of the mother-cell. Vegetative cells, however, always originate by a bipartition of the parent-protoplasm, preceded by a very complicated nuclear division, and followed by the deposition of cellulose matter in the median plane of the two daughter protoplasmic masses. This latter process is known as CELL DIVISION; while the phenomena of nuclear bipartition is called KARYOKINESIS. Chief among the various kinds of cell-multiplication coming under the first category is the **Free cell-formation**, so very common in the Fungi and in the embryo-sacs of Phanerogams.

In the *ascus* of the *Ascomocytes* (a group of Fungus), for instance, there is only one nucleus; this together with the cytoplasm of the mother-cell (ascus) becomes disorganised for the time being, and the contents of the cell assume a frothy appearance. Eventually eight daughter-nuclei appear, and round each of these new centres the protoplasm collects and thus forms eight new cells, each being limited by a thin and clear peripheral layer of protoplasm which ultimately forms the cell-wall. The eight daughter cells are not in contact with each other, a part of the original protoplasm is left behind unused and distributed around the new cells. Later on the wall of the ascus ruptures and the eight spores (called ascospores) come out and multiply the species.

Cell division is the most important of all processes of cell-formation. It occurs universally in all growing parts of plants and in all vegetative organs. In the uninuclear cells of cormophytes,the actual division of the cell starts *first*, with the nuclear splitting, and *secondly* with the interposition of a cellulose wall in a plane at right angles to the plane of division of the nucleus. Contraction or rounding off of the protoplasm never happens. The process of nuclear division, or karyokinesis, as it is called, involves the following changes in the nucleus :—

1, It first becomes broader and thus appears to be a little swollen ; at the same time the *linin* thread becomes thicker and shorter and less entangled.

2. The *chromatin* next increases, and the granules then range themselves in parallel discs along the *linin* thread.

3. By this time cytoplasmic strands come to be applied over the nuclear membrane which is raised at two opposite points forming the *polar caps*. The linin thread now divides into a number of segments called *chromosomes*.

4. The chromosomes then arrange themselves in a plane called *nuclear plate*, and each then undergoes a longitudinal splitting—thus originate the daughter chromosomes.

5. The daughter chromosomes then travel in opposite directions towards the two *poles* ; there they fold up like the letter **V** and converge towards a point facing the polar cap.

6. The **V** shaped chromosomes become then entangled, fused, drawn in and thus form two daughter nuclei.

FIG. 286.

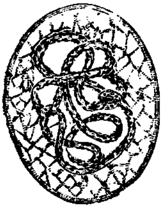


FIG. 287.

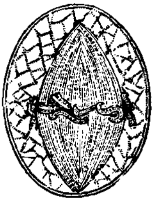


FIG. 288.

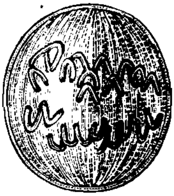
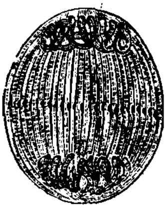


FIG. 289.



Successive stages of Nuclear division.

Fig. 286 Shows the swollen Nucleus and the unravelled *linin* thread. (1).

Fig. 287. Shows formation of Polar Caps and the division of the *linin*. (3).

Fig. 288. Chromosomes travel to the poles. (5).

Fig. 289. Chromosomes reunite to from daughter-nuclei.

(Diagrammatic, after Kerner).

FIG. 290.

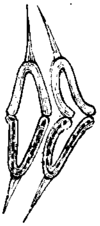


Fig. 290. Shows how each Chromosome split up into the daughter-chromosomes (After Strasburger).

The formation of the cell-wall then takes place by the deposition of cellulose matter at the equitorial plane between the daughter nuclei. See Fig. 289.

CHAPTER XVI.

The Tissues.

It has more than once been pointed out that aggregates of cells following a common law of growth and development form a *tissue.* This aggregation is only a necessary result of cell-division. And the particular law of development followed by a particular group of cells is defined by their position and function in plant-economy. Tissues are really the expression of different physiological wants in different plants and at different parts of plants.

In Algæ and Fungi, a necessity for the physiological division of labour does not arise; hence true tissues are not differentiated. But in the massive Fungi (mushroom—*agarics*) and Lichens, cells are merely juxtaposed and grow *individually* along parallel lines. The resulting structure simulates a tissue in form and function; but it has been distinguished as *false* tissue, though there is no sharp boundary line between the *false* and *true* forms of tissues.

In the plant-kingdom true tissues make their first appearance in the Bryophyta in a very rudimentary state. In this class, groups of cells originate by repeated bipartition of a mother cell, but they are not much altered in the composition of their cell-walls; *i.e.*, the tissues are simply *cellular* and they remain so throughout the life of the plant.

It is, however, when we come to the higher plants, from the Pteridophyta onwards, that the tissues are exhibited in their endless varieties. In these cases, the tissue forming the embryonic part of the plant is called **Meristem**. It should be remembered that, as in all plants and the cells of plants, so in tissues there are several stages of differentiation. Differentiation of tissues into completely developed organs for carrying out distinct plant functions accompanies the development of a part to maturity, and is immediately due to cell division. The repeated division of cells, which goes on always in the embryonic parts of the plants, thus gives rise to a cell-mass—the *meristem*. In the growing point of a Pteridophyta (excepting Lycopodium) there is, for instance, a single cell, of a tetrahedral shape, termed the *apical cell*. From this a series of cells are cut off, which then undergoing a process of repeated and recurring division forms a meristematic tissue. The cells of a meristem can be distinguished as an uniform layer, separated from one another by very delicate and rather homogeneous membranes of cellulose, and contain finely granular protoplasm with nucleus, but with no further evidence of structural differentiation. A similar meristem also occupies the apex of the phanerogamous plants; here, however, the apical cell does not exist, its place being taken up at once by a multicellular meristem.

As growth proceeds, cells or groups of cells forming constituent parts of the meristem begin to grow along different lines, till by subsequent metamorphosis they come to have a stable and permanent form at maturity. Thus, the mature tissues which are derived from the meristem are distinguished as **permanent** or fixed tissues. Intermediate between the main meristem of a growing part and the permanent tissues of the mature part of a plant, occurs what is known as the *primary meristem i.e.*, the first foundation of the fixed tissues where they have already been adumbrated as recognisable forms.

During the growth of cells from the meristematic to the permanent, great increase in volume, and consequently also changes in form and structure take place. In certain cases these are attended with a partial loosening of the cells themselves by a splitting of the original cell-membrane into two parts—each part forming a boundary of a cell. In this way **Intercellular spaces** arise. They are mere cavities filled sometimes with gases, sometimes with secretions (c.f. Glands), left between the component cells of a mature tissue. In land-plants, in general, small angular intercellular spaces occur at the angles of the soft-walled cells (Cortex), and communicate with one another to form a continuous ventilating apparatus for the plant.

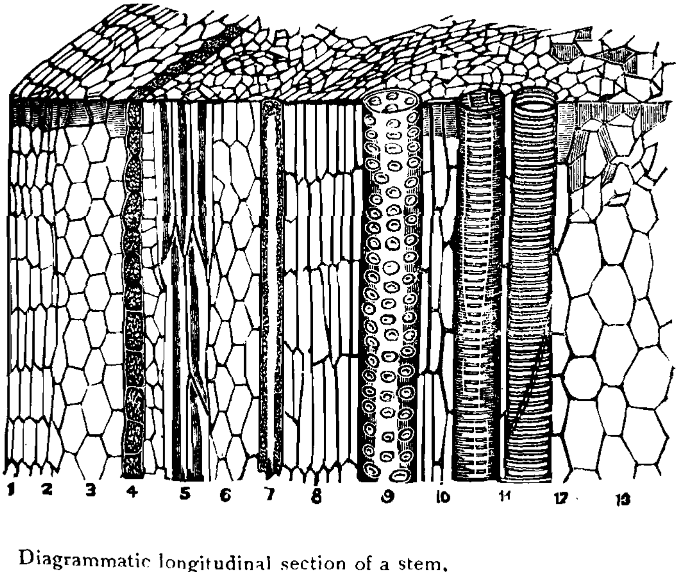
The development of intercellular spaces is **schizogenous**, when they originate by a simple splitting ot the original cell-wall ; or **lysigenous**, when a disorganisation and dissolution of certain *transitory* cells result in their formation. Such lysigenic spaces occur in the stems of Equisetums, Grasses (*Cereals, Bamboo* etc.), Cyperaceæ (*Keysoor*, *mootha*), Umbelliferæ, in the internodes and petioles of Onion, Lily, etc, in the form of large hollow air-containing canals. In a cross section, they can be observed with the naked eye in many of the above cases. In the central wood of the aerial roots of many epiphytes similar air-containing lysigenic spaces may be observed. In all these instances, the wall of the lysigenic space is as a rule covered by the torn remains of those cells from the disorganisation of which the space originates.

Schizogenic air-containing spaces occur in the vegetative members of almost all water and marsh-plants, *e. g.* in Marsilia (*Shooshny shak*) Pontedaria (*Neelotpala*), Lotus family etc Such schizogenic spaces are always bounded by the smooth walls of the cells that surround them.

Though the bigger cavities, whether lysigenic or schizogenic, contain gases, in a large number of cases the smaller spaces serve as resin passages or as reservoirs of secretion. Such passages may form elongated tubular canals extending through the tissues, as for examples, the *resin-passages* of Pines and other Conifers, the *mucilage* and *gum-passages* of many Lycopods, Cycads, Aroids etc. The oil-ducts which form the characteristic elevated markings (Vittæ) on the fruits of Umbellifers (Anise, Dill, Asafæteda etc.) are schizogenic spaces. On the other hand, the small roundish glands that store ethereal oils in the plants of Rutaceæ (Bilva, Lemon, Citron, Orange etc.) are lysigenic in origin. In all such secretory reservoirs the intercellular passage, cavity, or space is generally bounded by a layer of thin walle c

Proceeding with the history of development of the tissues, then, we find that the progenitor of all permanent tissues, the meristem, becomes differentiated into three layers or groups of cells each having a distinct law of development and division. These three layers, called by HANSTEIN *Dermatogen*, *Periblem* and *Plerome* respectively, pass down gradually by differentiation into the three primary permanent tissues—*Epidermis*, *Cortex*, *Stele*. The component cells of all these meristematic tissues, cells which from their soft texture, thin walls, close contact to form a continuous lining layer, and active secretion may be distinguished

FIG. 291.



Diagrammatic longitudinal section of a stem.

1—3, Parenchymatous cells of the cortex (3) and epidermis (1). 4. Endodermis. 5. Prosenchymatous fibres. 7. Sieve tube. 9., Pitted Xylem vessel. 11-12. Spiral and thickened Tracheids. 13. Cells of the Medulla.

hough arranged differently in the different layers, are all young, active, multiplying and growing cells. They always contain a viscid granular protoplasm and a thin, almost transparent, cell-wall of cellulose.

The **Dermatogen layer** originates as a peripheral group of closely packed tabular cells which at their maturity become the cells of the Epidermis. In general, it remains a single layer of cells the division of which takes place by walls at right angles to the surface. The walls, again, of the individual cells show a tendency of special differentiation and growth on the outside, i. e. the side exposed to the atmosphere, particularly in the stems of land plants.

The **Periblem** layer lies immediately surrounded by the Dermatogen; it is a zone of tissue lying between the Dermatogen and the Plerome. The cells though closely packed at first, soon become rather loose, and frequently show irregular transverse or longitudinal divisions. In the permanent form it becomes the cortex.

The **Plerome** layer, or rather cylinder, forms the centre of the system of primary meristems. Even at an early stage the cells of this cylinder are longitudinally elongated, and thus appear in strong contrast to the two other layers. The mode of division in this case is essentially longitudinal, and so also is the growth When mature it forms the Stele or the central cylinder of woody stems and roots.

Before going into the developmental history of these tissues more in detail it will be necessary here to introduce the terms *Parenchyma* and *Prosenchyma*, used with special reference to the forms of permanent tissue.

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from the neighbouring tissues as *Epithelium cells*. They are very neatly seen in almost all the cases cited above.

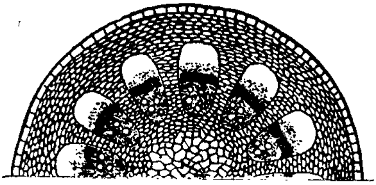
In Compositæ (sunflower and marigold family) oil-passages occur very frequently in the roots; while the large mucilage-passages of many species of Opuntias contain large crystals of calcium oxalate.

A **Parenchymatous** tissue is typically one which is composed of thin-walled cells expanded almost equally in all directions and containing abundant living matter.

A **Prosenchymatous** tissue is one which is composed of usually thick-walled and elongated cells which may or may not contain any living matter. The distinction between these tissues depends upon the *form* of the cells: in the first case, they are *isodiametrical*; in the second, they are *elongated* or *fibrous* with blunt or pointed extremities dovetailing with one another.

Thus, it will be seen, that while prosenchymatous tissue elements preponderate in the Plerome and the Stele, the cells that compose and result from the differentiation of the Dermatogen and the Periblem, are on the whole, parenchymatous. It should not be supposed however that there is any genetic relation subsisting between parenchyma and prosenchyma on the one hand, and the three primary meristems on the other. Both the Periblem and the Plerome, for instance, give rise to elongated and not-elongated tissue-elements, although it may be said with a fair degree of accuracy that parenchyma preponderates in the cortex, and prosenchyma in the stele.

FIG. 292.



Diagrammatic cross section through a Dicot Stem. Note the one layered epidermis. The elliptical or wedge shaped structures are the Bundles. Outside this zone is the Cortex; and inside, the Medulla.

A little lower down the growing point of a plant we find that the cells lose their meristematic properties and become permanent in the form of the epidermis, the cortex, and the stele. The progressive development of these tissues will now be discussed.

The differentiation of the Epidermis from the Dermatogen is a comparatively simple process. During this process, the cells receive thickening layers on the outer walls which thus become strong, and later on also cutinised. Hairs arise from the stronger development of some of the epidermal or underlying cells; and intercellular spaces breaking the continuity of the layer originate at certain points. These spaces, called stomata, thus serve as breathing pores of the plants, establishing, as they do, communication between the gases inside and outside the plants. Thus a fully differentiated epidermis has:—

(*a*) the thickened outer layer called the cuticle.
(*b*) the appendages, called trichomes or hairs.
(*c*) the intercellular spaces, called stomata.

The mature Cortex which results from the differentiation of the Periblem is in most cases (stems and roots) divisible into three distinct parts or layers. When the periblem is traced downwards, the changes met with are these:—the cells which in the meristem were all in contact now become separated at the corners giving rise to the cortical intercellular spaces; the growth in the size of the cells still leads to isodiametrical cells in the greater part; but some of the rows of cells abutting immediately upon the stele or central cylinder or lying just below the epidermis may be developed quite differently from the rest.

In certain cases some of the sub-epidermal cells (belonging to the cortex) become thickened at the corners (collenchyma). In a few other cases, such cells are greatly elongated into fibre like structures. Such differentiated parts of the cortex forming the subepidermal tissue are called **Hypoderma.** Next to this the soft-walled parenchymatous cortex follows. But the inner most layer of the cortex—that which abuts immediately upon the stele,—forms a continuous covering layer of tissue—one cell thick—with the cells in close contact like those of the epidermis. This part is called **Endodermis.** When, as in some cases elongated, lignified, hard, tapering cells occur at the inner parts of the cortex, they form the sclerenchymatous tissue. Thus, besides the ordinary parenchyma the cortex may also contain all, or some of the following as differentiated tissues:—

(*a*) Hypoderma, either as collenchyma or sclerenchyma;
(*b*) Endodermis; and
(*c*) Sclerenchyma sheath.

The Plerome, it will be remembered, consists of longitudinally dividing cells. In attaining maturity, some may be greatly elongated longitudinally, others may remain simple. A meristem or generating tissue which gives rise to prosenchymatous permanent tissues, NAGELI terms a **cambium.** Very early in the development of the Plerome isolated groups of cells belonging to it become differentiated as prosenchyma, forming generating tissues or **Procambium** strands. From each procambium a Bundle results.

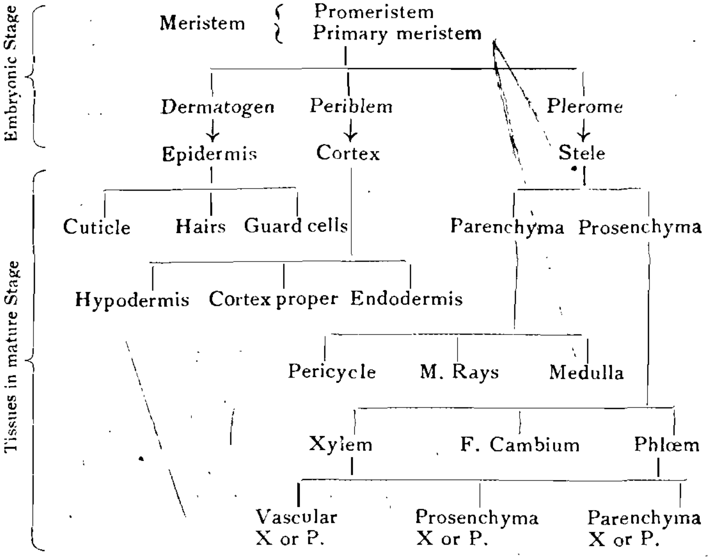
Indeed, we can divide the plerome into two parts—a parenchyma generating tissue, and strands of prosenchyma generating tissue or procambium.

From the first is differentiated the stellar parenchyma, and from the second the bundles or the elongated elements. The stellar parenchyma forms, as it were, the ground substance in which the Bundles are distributed or embedded. In most cases, it is cut off into two or three zones or layers, by the Bundles. That part of it which remains outside the Bundles, just enclosed by the endodermis, is called the **Pericycle,**—it is the outermost part of the stele. Enclosed within a ring of Bundles, again, a part of the stellar parenchyma becomes a separate tissue called the **Medulla** or Pith. When strands or bridges of parenchyma stretch out from the pericycle to the medulla through the intervals between the Bundles, they receive the name of the **Medullary rays.**

The tissues that develop from the procambium strands are typically prosenchymatous, but may be conveniently placed under two distinct categories, *viz.* *Fibrous* and *Vascular*. Fibre-like cells with little or no protoplasmic matter occur for the most part ; while the transverse partition walls of some of the longitudinal rows of cells become absorbed, or pierced by pores. A vessel is such a structure. Bundles are hence also called Fibrovascular Bundles. During the development and maturity of a Bundle one part of it becomes lignified, *i.e.* the cell-walls of one side receive the deposit of lignin. This part is called **Xylem** ; it is very hard and is popularly known as the Wood ; it contains the fibrous and vascular elements which contain no protoplasm, and a little parenchyma. The other softer part of the Bundle is called **Phlœm** ; it is likewise composed of vascular, fibrous and parenchymatous tissues. The vascular Xylem tissue is distinguished as **Tracheæ ;** the vascular Phlœm is **Sieve tissue**. These are the permanent mature tissues of all Bundles. But in many cases they contain a part of the mother procambium left untransformed between the Xylem and the Phlœm—this, then, genetically is a cambium, since it produces more elements of Xylem and Phlœm ; but to distinguish it from the other kinds of meristematic tissues it is called *Fascicular cambium*.

The above is a connected history of the development of all the Primary tissues. Development and differentiation of tissues do not stop here, but proceed with the formation of what are called secondary structures. Before we go on with these it will be instructive to give here the genesis of the primary structures schematically in a table.

NAGELI who first laid the foundation of a systematic classification of the tissues drew a distinction between the generating and the permanent tissues, and divided each into parenchyma and prosenchyma. The parenchymatous generating tissue he called the primary meristem, and the prosenchymatous generating tissue the cambium. Permanent tissues derived from the primary meristem, he called *Protenchyma* ;



The Secondary Tissues.

In parts of plants that grow continuously from year to year (*e.g.* stems and roots) secondary tissues are formed immediately after the differentiation of the primary structures. Groups of cells forming part of the permanent tissues later on revive their multiplying power, and in this way *secondary meristems* originate. They then undergo almost the same process of differentiation as indicated in the foregoing pages and lead to the formation of secondary tissues.

Thus, in a two or three year old stem of a Phanerogam, the epidermis generally gives place to another skin or covering

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those from the cambium, *Epenchyma.* Permanent tissues which lose their protoplasmic cell-contents, as the cork and the tracheal elements, Sachs distinguishes as *Kenenchyma.* These terms are, however not in use.

called *Cork.* A part of the sub-epidermal tissue belonging to the cortex becomes so modified that the component cells begin to divide regularly. The secondary meristem that thus arises is called **Phellogen** or *cork-cambium.* It gives out layers of cells on the outside *i. e.* towards the epidermis; and these form the cork. Cork cells are empty and dead, and are strongly suberised all through their walls. In many cases the phellogen produces layers of cells on the cortical side which behave exactly like those of the ordinary primary cortex. This secondary cortex thus replaces that part of the primary cortex at the expense of which the phellogen was formed, and is distinguished as the **Phelloderm.** The Phellogen however does not remain long active; it soon dies or loses its meristematic character. The dead permanent protective tissues that thus originate from the Phellogen on the outside are called collectively the **Periderm.**

FIG. 293.

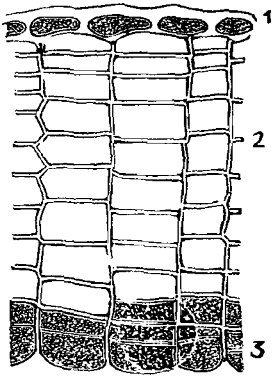
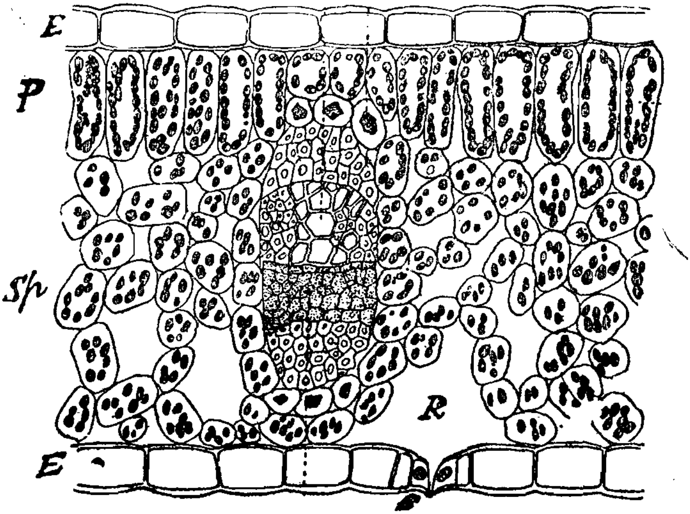


Fig. 293. Formation of Cork—(1) the Epidermis. (2) the Cork cells. (3) the Phellogen.

It is, however, in the stele that secondary tissues become conspicuous by their constant and abundant formation. The structure of a thick and growing stem or root is composed almost entirely of secondary tissues. The characteristic growth in thickness of Dicot plants is to be attributed solely to the origin and development of these. The particular cases will be dealt in detail later on. The following however is a general description of the mode of origin of secondary tissues in the stele.

Fig. 294.



Diagrammatic cross section through a Leaf. E, the epidermis with the cuticle on the outside. P, the pallisade parenchyma. Sp, the spongy parenchyma. The elliptical structure in the centre is a Bundle.

Soon after the complete maturation of the fibrovascular bundles, isolated parts of the stellar parenchyma revive multiplying power—in this way plates or groups of secondary cambium arise. Where these are developed between the primary bundles in the medullary strands (as in Dicots), they receive the name of *interfascicular cambium.* Like the procambial strands these cambium layers throw out new cells on their two sides, which become ultimately permanent in the shape of secondary xylem and phloem. The fascicular cambium also joins hands, and thus a perennially active cambium is left behind in the plant to continue its unceasing activity for tissue formation. It is usually during the initiation of these changes that the phellogen and the tissues genetically connected with it originate. The secondary xylem and the Phloem are the correlate of the primary ones, not only in form, consistency and structure, but in function as well.

It should be noticed here that during all these changes, the true genesis of which we have traced from step to step, there are other cognate but not genetically related changes which give rise to other tissues or groups of cells. A coalescence of thin-walled elongated cells may take place in the form of latex tubes; irregular growth in certain cells differing from their neighbours in form, structure, function and contents may follow; and new anomalous groups, plates, tubes etc of tissues may originate. But all these structures arise very late. In the younger parts of plants a thin-walled, soft-textured parenchyma with abundant protoplasmic contents preponderate. In as much as all the subsequent complex tissues either arise from the cells of this parenchyma or lie embedded in it, it is regarded as the Fundamental or the Ground-tissue sytsem. Again, as strings, vessels, fibres, plates and similar other complicated tissues continually arise, and as the primary structures are gradually replaced by those of the secondary, different groups of tissues ordered out for the performance of some function jointly, become prominent. Thus arise the **Tissue-systems.** These are collections of tissues of whatever sort or rank, which are mutually continuous and run together for long distances. Unions of cells, fusions of cells, or groups of cells calculated to promote a common object form tissues; and similar unions, fusions, groupings etc among the tissues themselves result in the formation of the systems of tissues. The persistent parts of every higher plant will, when examined, show up the structure as being roughly made up of three tissue-systems—viz, the Tegumentary, the Fundamental, and the Fibrovascular. For instance, a stout stem can be dissected out into three layers, or rather regions—the outer dry and dead mass of tissues composed of the torn epidermis, cork, periderm and probably also of bark, forming the protective (Tegumentary) system of tissues; the innermost hard woody part forming the fibro-vascular tissue system; and the intermediate zone with the medulla or pith, forming the soft parenchymatous part, being derived from the Fundamental tissue-system.

Hence for the better description of tissues we shall divide the subject into three parts:—

TISSUE SYSTEMS	A. PRIMARY	B. SECONDARY
1. TEGUMENTARY	Epidermis	Cork, Periderm, Bark.
2. FUNDAMENTAL	Cortex etc	Secondary Cortex Phelloderm etc.
3. FIBROVASCULAR	Primary Bundles	Secondary Bundles Secondary Wood and Bast etc.

SECTION II

The Functions of Tissues

It has more than once been hinted that the differentiation of tissues is dependent upon the Physiological division of labour; that they are to be regarded as groups of cells specialised for distinct purposes. The whole complex physiological question of *living* may be regarded as parcelled out into several parts with each of which a particular tissue is concerned. Hence, it is important to set forth here the different works that the different tissues have to carry out.

The main categories of physiological functions, so far as tissues are concerned are, it will appear, the following :—

1. Nutrition.
2. Protection.
3. Secretion and excretion.
4. Maintenance of rigidity.

Of these the process of nutrition is most complicated and includes the following cognate processes :—

- (*a*) That of absorption of raw food.
- (*b*) That of transmission of the raw food matters to the leaves.
- (*c*) That of preparation of complex organic matters by the assimilation of the raw matters.
- (*d*) That of distribution of the prepared and assimilated food to the different parts.
- (*e*) That of storing the same for future use.

Each of these tasks is thrown upon a tissue or tissue system. Before we enumerate these tissue-organs it will be instructive to give concise accounts of the physiology of nutrition, of protection etc.

1. **Process of Nutrition.**—Plants derive their food from the media in which they live. A water plant gets all its food dissolved in the water. A land plant has to depend partly upon the atmosphere, partly upon the soil. The essential plant-foods (in green plants only) are (*a*) water, which as we have seen, forms an organic part of protoplasm, cellwall, starch etc, (*b*) certain inorganic salts, such as phosphates, nitrates of certain metals *e. g.* Potassium, Magnesium, Iron and Calcium, and (*c*) Carbon Dioxide from the atmosphere. The inorganic salts are to be found abundantly in ordinary soil. Now plants cannot absorb solid food; hence roots have to absorb the crude salts dissolved in the water present in the soil. The epidermis of the younger parts of all roots produce very fine *root-hairs.* By the combined chemical activity of these hairs and the atmospheric oxygen entangled between the minute grains of the soil, the latter are to a great measure dissolved in the water by which they are enveloped. The very active and young hairs are especially adapted to absorb this nutrient salt and send it away to the interior of the root whence it is distributed to the different parts. Thus, the epidermal tissue of roots carry on the function of absorbing raw food from the soil. All the food-elements excepting only carbon are thus absorbed from the soil. The element carbon which forms the bulk of all green plants is obtained from the carbon dioxide of the air. Only the green parts of plants can absorb the carbon dioxide, and the leaves are eminently fitted for this function. The dilute nutrient water drawn up from the soil is then brought up to the cells of the leaves which alone, from their containing chlorophyll, are enabed to prepare complex organic food. The leaves, or better the chlorophyll-containing cells of leaves, are the assimilatory organs, and so also is the green Cortex. These cells have, by virtue of their chloroplast, the inherent property of absorbing a part of the solar energy when sunlight falls upon them, and thus may be compared to a furnace in

which raw matters thrown in are welded up into complex products. In fact, they are the organs in which complex organic matters are synthetically prepared. But in order that these matters may be formed, the raw food substances must be brought in first. This is done by the xylem part of the Bundles. The function of the xylem is to pump up the nutrient sap sucked up from the soil, and distribute it to the parenchymatous chlorophyll-containing cells of the leaves by its ultimate branches—the small veinlets. Thus it is a tissue for the transport of crude food. But the assimilated substance *i. e.* the synthetically prepared organic compounds formed in the leaves must be transferred to those parts of the plants that are growing, and hence are in need of plastic material; for instance, the growing points of stems and roots. This transference is effected through the Phloem or the seive-tissue. In short, the Bundles form the conducting strands—the conduit pipes for the plant.

The products of assimilation are chiefly two, namely starch and albumens. Starch is a carbohydrate having the same percentage composition as cellulose; and albumen is a nitrogenous substance allied to protoplasm. During the process of transportation, however, oth starch and albumen are converted into soluble compounds such as sugars, acids, glucosides etc.

In periods of strong assimilatory activity, spring for instance, more substances are formed than can be used up by the growing structures. Again, growth is almost at a stand-still in severe winter. Hence the influx of unused assimilated food must be removed from the conducting strands lest they choke them up entirely, to certain reservoirs for reserve material. The tissues that thus function are the parenchymatous elements of the Fibrovascular system and the cortex *i.e.*, the endodermis, the pericycle, the medullary rays etc. The assimilated sap which descends from the leaf-cells—the 'little laboratories of the plant—are retransformed into starch, albumen etc when they come to be thus stored for a certain period.

Now, it may be asked what happens to the large amount of water which is sucked up by the roots? Is it all used up in the synthetic process? No ; a large part of it is evaporated through the pores of the epidermis called *stomata.* The function of the absorbed water is twofold ; first, to enter into the assimilalory activity and form part of the organised structures—being then called the *water of organisation* ; and secondly, to act as the mere vehicle of the soil-constituents—the crude plant-food.

2. **The Function of Protection.** The tegumentary system is *par excellance* the protective tissue-organ. The Epidermis, the Cork, the Periderm and the Bark are best adapted for this purpose; for not only are they mostly dead cells in the latter three cases, but they are also impervious to air or water on account of their thickened and suberised or cutinised cell-walls. The epidermal cells undoubtedly contain protoplasm in most cases ; but then this protoplasm shows the least nutritive activity in aerial parts. When hairs and other trichome structures are developed, the living epidermal cells show that they are rather adapted to produce structures that would afford protection. For the cuticle and hairs formed on the aerial epidermis of land plants are contrivances for giving additional protection against the injurious influences of the almosphere. That the endodermis is also partly a protective tissue (the protection in this case being afforded to the young stele) is borne out by the fact that like the epidermis, it is a single layer of cells in uninterrupted lateral contact having the radial walls thickened and impregnated with cutin.

3. **The Function of Secretion.** As in the animal so in the vegetable kingdom, nutrition is inevitably followed by the formation of waste matters. Not that these matters in plants are waste in the same sense as in the animals, but

they are best stowed away to specialised tissues removed from the immediate vicinity of the nutritive tissues. They are known as *Glandular tissues*, and may occur at any part of the three fundamental ones. Substances of the nature of gums, resins, mucilage, or milky emulsious of these and a host of similar matters—all more or less degenerated products of plastic materials—are stored either in Sacs, Glands, Laticiferous vessels or similar tissues, or in the intercellular spaces, (see p. 278). The structures in which such storage takes place are accordingly designated *secretory-reservoirs*. Perhaps the most important of these are the *resin-passages* of Conifers (Deodar pine, for instance), *gum-passages of* Cycads and Umbellifers. They consist essentially of hollow tubular spaces surrounded by small, well fitting secreting cells known as *Epithelium cells*. In all Pines, it is well-known, how copious the resin is. Similar too is the abundant mucilage found in the mucilage-containing sacs in the parenchyma of the Malvaceæ, Tiliaceæ and Cactaceæ, and in the tubers of Orchids. It will be quite out of place, here to mention all the minute points, and we may safely dismiss the subject with the remark that in almost all the families of higher plants, glands, glandular tissues, or some forms of secretory reservoirs are liberally distributed. But two particular cases must be touched upon here on account of the overwhelming importance they bear to the formation of tissues.

1. Laticiferous vessels deserve first mention. They attain maturity as vascular tissues by the rupture or disorganisation or dissolution of the transverse walls of a longitudinal row of much elongated cells. (See Latex cells, p. 254). In many cases they also fuse laterally, and thus form what are called *syncytes*. Their contents are usually milky but may also be watery. In Banana and other Musaceæ such syncytes containing a watery sap often run parallel to the Bundles. The milky opaque fluid, called *latex*, consists partly of water

and partly of numerous small bodies suspended as in an emulsion. The latex is yellowish in the Papaviraceæ, milky or white in Papayaceæ, watery in Musaceæ and Aroideæ, and in the latter two cases specially tannin has been detected. The walls of these tubes are always soft; and though sometimes thickened, always give the cellulose reaction. Protoplasmic matter there is none, and when it does occur it forms a dead and disorganised mass of small granules. These vessels and the laticiferous cells often permeate the whole body of the plant and thus act as the drainage system.

Closely allied to these vessels or syncytes, both in form and function, are the Latex or Laticiferous cells. These are merely much branched cells with similar cell-walls and contents. They occur in the Euphorbiaceæ (Croton family), Urticaceæ (Fig family), Apocynaceæ and Asclepiadaceæ. The latex, for instance, which oozes out from the cut surface of the India-rubber plants, *Hevea brasiliensis* and *Manihot Glaziovii*, dry up when exposed to the sun and form a sticky substance—the crude rubber. The latex cells are formed from initial cells of the meristem, which grow so as to form long-branched sacs, passing between the other tissue elements. It is with regard to this point about origin and development that the two latex-containing structures differ.

2 Glandular tissue. A Gland is a sharply differentiated set of cells, the intervening septa of which become absorbed so that a single cavity is formed filled with matters of secretion. It is a tissue, since it is a product of a group of cells, and hence must be distinguished from secreting cells, latex cells etc. Examples are in the large transparent dots in the fruits of the Orange and Lemon and in the leaves of the Myrtle (Myrtaceæ—guava, jambolin) and Citrus families. The dots are large cavities filled with drops of oil.

4. **The Function of Maintaining Rigidity** by the mechanical tissues for plant-support. One of the physiological necessities of a plant is to maintain its structure—upright or

otherwise—permanently. The great weight of the foliage, which has to be borne by the slender stems of Palms, that of the infructescence of the delicate culms of Grasses, Umbellifers etc, will necessarily demand a great deal of strength and elasticity on the part of the erect structures. Common observation shows us that grasses and reeds, thinner stems and branches of shrubs, bushes, and also of trees, and palm caudices, are constantly bent down a considerable distance, or at least far away from their centres of gravity, but are never permanently displaced, much less are fractured. The tissues that give resistance to bending, strain, pressure etc, and thus secure for the plant the requisite amount of rigidity with elasticity are called *mechanical tissues* or *stereome.* Chief among these are:—

(*a*) The lignified elements of the Bundles or the xylem. Lignification, it should be remembered, sets the cells hard. The resistance offered to the knife when a section is cut is proof enough of the hardness and rigidity of the xylem. But as an additional protection, the elements of the secondary phloem become long thickwalled empty cells which are extraordinarily elastic. These *Bast fibres*, when they are present, run always parallel to the xylem, and hence are eminently adapted to strengthen it. They are not lignified and hence cannot transport water; they contain no living matter and hence cannot carry on nutrition; they are empty elongated pointed cells, and hence do not carry on the work of the phloem. Thus they appear to form a tissues which has only an architectural value, viz. to act as a stereome.

Again, the disposition of the fibro-vascular bundles and their subsequent development are also contrivances. For the hard structures always grow centrifugally; and they seldom occupy the central axis of the plant.

(*b*) The sclerenchymatous tissue is another kind of stereome. It consists essentially of thick-walled and pointed cells which may or may not be lignified. It is generally formed towards the periphery of an erect stem either as separate strands, or as a complete ring of hypoderma,or as a sheath to the bundles. Where hard bast is absent, as in the bundles of Monocots they occupy its place. The bundles of Grasses, Palms etc are generally protected by a thick sheath of lignified sclerenchyma.

(*c*) The thickened and permanent stereome tissues are to be found in mature parts of plants only. In an actively growing young part, such strutures are not formed. Consequently some of the living parenchymatous, and probably also nutritive cells are adapted to meet this demand. Such cells form the Collenchymatous tissue. It is characterised by being composed of young cells that are irregularly thickened at the corners and are capable of further growth. This latter property prevents them from being broken or torn, for they are extensible. Thus they have a distinct advantage over the other forms of mechanical tissues.

The subjoined table gives a birds-eye view of the tissues, and the work they have to perform *i.e.* their functional significance.

Tissues that act as organs of—

1. Absorption of food—Young epidermis of water plants; Epidermal root-hairs of land plants.
2 Transport of nutrient water—Xylem tissue (lignified) of the Bundles.
3. Assimilation of raw food—Parenchyma of leaf and cortex.
4. Transport of assimilated (elaborated) food—Phloem tissue of the Bundles.

5. Storage of reserve food—Parenchymatous tissues of the stele (pericyle etc), and those of the inner cortex (endodermis etc).
6. Storage of secretion—Hairs, epidermal glands, epithelium tissue, latex tissue etc.
7. Protection—Cuticle of epidermis, Cork, Bark, Periderm.
8. Mechanical support—Xylem, hard Bast, Sclerenchyma, Collenchyma, Scleroids.

CHAPTER XVII

The Tissue System

TEGUMENTARY SYSTEMS

A PRIMARY

1. **The Epidermis** can be divided, for the sake of convenience of description, into the following three parts :—

1. The *epidermis proper.*
2. *Hairs* and other similar appendages.
3. The *stomata* and the *guard-cells.*

In all higher plants, from the Pteridophyta onwards, the whole body of the plant is covered by a protective mantle of tissue which (in its younger stage) is the epidermis. The term however, is more strictly applied to the part pertaining to the shoot ; that belonging to the region of the root being called *epiblem.* It persists as the surface of plants till the beginning of the formation of cork, when it is ruptured and displaced by the latter. As a tissue its characteristic structural peculiarities are :—

(1) that it is a continuous layer one cell deep;

(2) that the external cell-walls of this layer are always thickened, and wholly or partly cutinised ; while the internal and lateral walls remain of unthickened cellulose.

(3) that though typically parenchymatous, its cells do not contain chloroplasts ; the protoplasm is not nutritive but is adapted to produce protective structures.

(4) that hairs and stomata are found only in this system.

These are only the general characters, in fact those that are bound up with the environment of plants. For the great majority of them are land plants, and hence the aerial parts are so developed that the tissues may act in harmony with the natural forces working around them. Thus, in plants that are not ærial, e.g. water-plants, and in parts of plants that are underground, e.g. roots, the epidermis varies widely from the above. In such cases the outer cells are neither thickened nor cutinised, stomata do not develop, and the cells themselves are positively nutritive. Again, the epidermal cells of water plants, most Ferns and Selaginellas do contain the chloroplasts. So also, in a few exceptional cases the epidermis is *many-layered* such, for instance as in Ficus and Begonia, the velamen of Orchids and Aroids.

The cells of the epidermis are in close contact on all sides; the only intercelluler spaces are those of the stomata between the guard-cells. These latter are specialised cells of the epidermis, and unlike its component cells are nutritive and contain a rich protoplasm with chloroplasts. The epidermal cells have, as a rule, undulating cell-walls, and thus the adjoining cells are firmly interlocked.

In roots, long internodes,and leaves of Monocots, the epidermal cells are usually elongated and hence the sinuous contour of the side walls is more or less lost. In Dicots, generally, the cells are isodiametrical and rectangular; in leaves they are broadly tabular.

The outer thickened and cutinised layer can be easily peeled off in most cases, and is known as the *Cuticle.* In aerial parts of land plants the cuticle extends over the whole surface and is strongly contrasted with the underlying layers of cell. So strong is the resisting power of this cuticle that even strong sulphuric acid can not dissolve it ; but in boiling potash it gradually undergoes dissolution. Iodine, with or without the addition of sulphuric acid, turns it yellow or yellowish-brown, and the same colouration is given by chlor-zinc-iodine.

In some of the Gramineæ, Equisetums, in Magnolia grandiflora, Tectona grandis (teak tree) and many other plants, the epidermal cells are highly silicified on the outside. In Equisetums the impregnation of silica is so great that the surfaces can be used for polishing like sand-paper. In Palms and a few other plants, however, the leaf-epidermis is very hard but not silicified.

Of inorganic matters that are deposited in the epidermal walls, carbonate and oxalate of calcium are important. (See p 260). On the submerged parts of water plants, Chara, for instance, calcium carbonate is deposited in rather thick layers.

An epidermis more than one layer of cells thick arises by the division of the epidermal cells by tangential walls In most of the instances in which such structures have been witnessed, they occur in the leaves In a few Piperaceæ and Bigonias the number of epidermal layers varies from 4-16. In many of our native Ficus trees *e.g.* F. Carica (Fig), Ficus bengalensis (Indian Banyan), F. elastica etc, there is an additional peculiarity in the development of the epidermis ; for while most of the original epidermal cells divide into a number of cells so as to form a many layered tissue, a few original cells remain undivided, but nevertheless grow into large sacs projecting inwards into the lower epidermal layers ; soon after, the outerwall of such an intruding cell sends down perpendicularly a peg-shaped process the blunt end of which swells into a knob. This projection is nothing but the substance of the cell-wall, on which are deposited very fine grains of calcium carbonate. They are called Cystoliths. They occur quite frequently in the families Urticaceæ and Acanthaceæ. (See p. 260.)

In cases where the epidermis is many layered, the lower layers are composed generally of large thin-walled cells with contents as clear as water. Hence they are known as *Aqueous tissue.*

The many layered epidermis of the ærial roots of epiphytes is thus described by SCHIMPER —

"The cells of this tissue (velamen) which is usually composed of several layers, resemble tracheids, are provided with spiral bands, and in dry weather contain air. They are bounded within by an endodermis (exodermis), some of whose cells are differentiated as passage-cells. If water reaches the root it is sucked up by the velamen as if by blotting paper and fills the cell-cavities. Thence it passes more slowly through the passage-cells into the interior of the root."

2. **Hairs** or **Trichomes** are epidermal outgrowths arising either from single or groups of epidermal cells. EMERGENCES a.e mere appendages of the epidermis. They originate mainly as transversely growing parts of the cortical tissue and receive a clothing of the epidermal cells. Examples of emergences are afforded by the prickles and glandular hairs of Roses, sticky tentacles of Drosera (p. 87), tubercules and knobs on many fruits, *e.g* Datura, Ricinus etc. All these structures are not strictly epidermal and though they simulate, are not Trichomes morphologically.

Hairs arise is most cases from single epidermal cells. In almost all higher plants they are present in one form or other ; the root-hairs form a constant feature of young root-structures. In ærial parts of plants hairs occur in the most diverse manner ; and when they are entirely wanting, as for instance, in the whole families of Equisetums, Conifers, and Lemnaceæ (small floating water plants of ponds, ditches etc) and from the leaves and stems of a few other plants, the hairless structures are termed *glabrous*. According to their form and function the following is a classification :—

(1). *Papillæ*, the simplest form of epidermal outgrowth, are merely cells that have bulged out externally in a conical form. They occur often on showy parts of a flower—the velvety touch of petals etc, is due to their presence.

(2). *Fibrous hairs* are long unicellular structures ; *e.g.*, the cotton fibres, which are very long single cells containing only air.

(3). *Stinging hairs*, are similarly unicellular ; they arise as protuberances of single epidermal cells and are protective organs, for as the name denotes, they give a very unpleasant burning sensation when touched or brushed past. They contain poisonous cell contents which are irritating to the skin. Examples in many species of URTICA *(U. interrupta* or Bœhmeria interrupta—Lal Bichute ; *U. heterophylla)*.

(4). *Glandular hairs* are stalked glands They are multicellular bodies with the terminal part forming a swollen vescicle in which resin or ethereal oils collect as secretions. They occur abundantly in the Labiatæ family and in the Primulaceæ. The aromatic odour given out by the leaves and stems of these plants, more particularly when they are gently crushed between the fingures, is due to the presence of aromatic oils in the hairs.

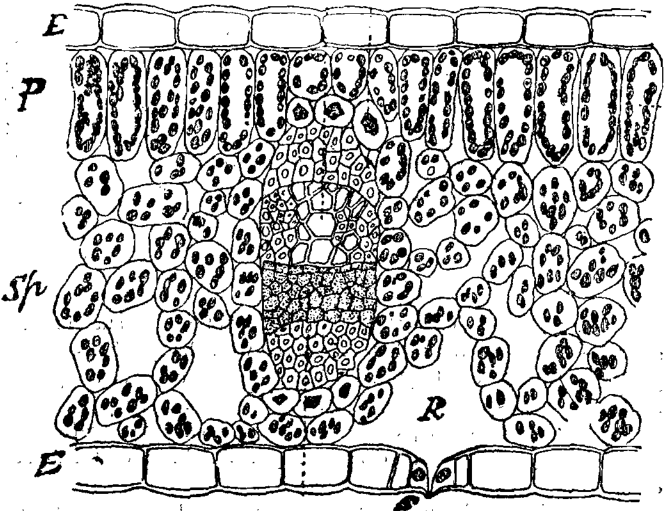
(5). *Scaly hairs* are flattened leaf-like out-growths. They are best seen on the rhizome of Ferns.

(6). *Covering hairs*, as they are called for want of a suitable technical term, form a thick protective clothing on the surface of many plants. Instances are in the downy leaves of many species of Gnaphalium (a high-land genus of Compositæ), of Cruciferæ and Malvaceæ, of Elæagnus (Beng: Guara—the Oleaster), in those of Akanda *(Calotropis gigantea)* and other Asclepiads, in Til *(Sesamum indicum)* etc.

Such covering hairs form sometimes peltate scales on the upper surface of leaves, and in this way act as shields against too much loss of heat and moisture on the part of the leaves. They characterise the flora of hot, dry, sandy, or highland places.

3. The **Stomata** form the only intercellular spaces in the epidermal tissue and occur chiefly in the leaves and stems that are aerial. As a rule they are found in green parts only but are sometimes also found on floral leaves.

FIG. 295.



Section of a Leaf, showing the epidermis (E) with the Cuticle on the outside, the stoma (S) with the guard-cells, and the Respiratory cavity below the stoma.

Each stoma forms a slit between two special epidermal cells called *guard-cells*. The guard-cells, unlike the common epidermal cells, are functionally nutritive and contain fully developed chromatophores in the protoplasmic cell contents. In surface view the stomatal opening is elliptical, like an open human eye. In particular cases, however, they may have other forms, such as circular, narrow, cornered etc. The guard-cells are so articulated to the adjoining cells that they can move as if on a hinge. They open out widely, leaving the passage free, when sunlight falls upon them ; and in darkness or night they close up the orifice. In form, the guard-cells are peculiarly different from the other epidermal cells ; the cell-walls are not thickened in the usual manner ; for ridge-like protuberances jut out above and below each stomatal passage ; midway between these ridges the lateral walls remain generally unthickened.

The function of the guard cells is to keep the stoma open or closed alternately with day and night. Through this *air-passage* as it is also called, atmospheric gases come within the plant and carbon dioxide is thus secured. Immediately below each passage is a wide intercellular space belonging to the cortex, in which gases are for the time being stored ; this is termed the RESPIRATORY CAVITY. The thin walled parenchyma which surrounds this cavity is the actual laboratory of the plant, and interchange of gases regularly takes place between this tissue and the respiratory cavity.

As a rule, in herbacious thin-skinned plants the stomata lie on the surface ; and in thick-skinned, leathery or hairy plants they are generally depressed. Depression of the guard-cells is a protective adaptation against injurious climatic factors, such as too great heat, dry air etc. In desert plants, or those living on sea-shore, and mountain heights, the guard-cells are considerably sunk in the thick-cuticled epidermis.

Besides the guard-cells, a few epidermal cells abutting upon the stoma and surrounding the former are peculiarly developed in a way intermediate between the ordinary cells of the epidermis and the guard-cells; not unfrequently they resemble the latter closely. Such cases characterise the epidermis of many leaves. These peculiar neighbouring cells of the stoma are termed the *Subsidiary cells.*

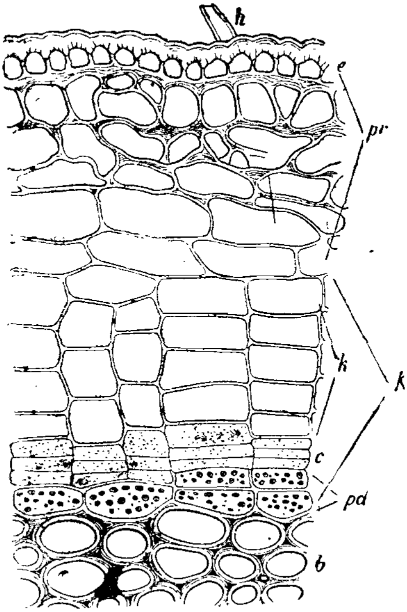
As to the distribution and number of the stomata, they are most abundant on leaves; and more so on the under than on the upper surface. In leaves that are alike on the two surfaces the stomata are equally distributed. In floating aquatic leaves, as in water lily, marsilia (shooshny shak), they occupy the upper surface only. Stomata are, as a rule, absent from roots and underground or submerged parts, though exceptions occur. They are absent from just above the veins of leaves; and where strands of sclerenchyma occur as hypoderma in the cortex, they are absent from the ridges corresponding to these. Firm, horizontal, shiny leaves as those of Ficus, Begonias etc, have their stomata distributed almost entirely on the lower surface.

In contrast to these air-pores which form the characteristic mechanism of gaseous exchange in plants, there are in a few flowering plants WATER STOMATA or PORES which serve as points of exit for drops of water. The cells that abut upon these passages, (corresponding to the guard cells) are immovable, and the opening is really many times larger than a stoma. Being immovable, the guard cells in this case keep the opening always open. The water-pores are always situated over the ends of the vascular bundles, near the margin of the leaf, on the teeth. In the indigenous *Colocasia* (kutchoo), drops of water ejected from the apices of the leaves are a matter of common observation. Similarly, in many other Aroids (to which colocasia belongs) large water pores give outlet to the water within the plant in drops. In some Fuchsias, Umbellifers, Primulas, in Nelumbium speciosum, Papaver somniferum (opium poppy) and generally in Saxifragas and Crassulas one, two or many water pores occur in the leaf-epidermis.

B. SECONDARY.

1. **Formation of Cork.**—When the soft and succulent parts of plants are injured, and the epidermis thus torn from the surface, the wound which brings the softer inner parts of the plant in contact with the atmosphere, is gradually healed up by the formation of a layer of cells having the same physical properties as the epidermis, and is known as CORK. It thus takes the place of the epidermis as a protective tissue.

FIG. 296.



Formation of Cork in an one year old stem. (*p*), hair ; (*e*), epidermis ; (*pr*), cortical parenchyma ; (*k*), cork-cells ; (*c*), the phellogen ; (*pd*),the phelloderm. Part only of a transverse section. After Sachs.

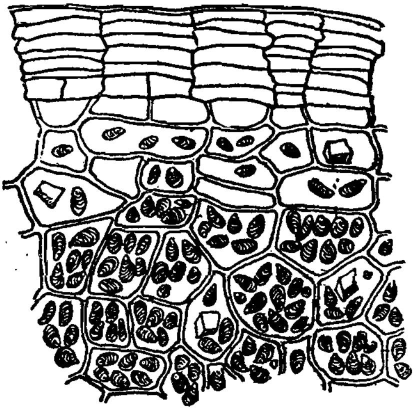
Cork-formation always originates from the continued division of the epidermal (rarely), or more generally, of the sub-epidermal parenchymatous cells. The rupture of the epidermis may take place from external causes, as physical wounds, or from internal causes, as continued internal growth of tissues resulting in a continuous stretching of the epidermis and in its final rupture. Cork tissue thus appears specially on stems and roots of most Dicots and Conifers and a few Monocots which have a long-continued growth in thickness. And though in such cases it arises when the thickening members are several years old, it is formed even before the destruction of the epidermis. As simplest examples we may mention the light yellow scale of Potato tubers and the scales of the common Guava tree.

The history of development of cork is in short this : The stimulus of a wound or the strain put upon by the increasing internal growth in thickness initiates cell multiplication in some of the layers forming the outermost zone of the cortex. This multiplication gives rise to radial rows of cells which now become meristematic. By their lateral union and similarity of development, a layer of cells capable of division, or a meristematic tissue, is formed parallel to the surface of the organ in question. This is the *Phellogen* or *Cork-cambium*. Exposed to the injurious dessicating action of the atmosphere, the row of cells that are cut off from this phellogen externally, die and the cell walls are wholly suberised. This dead suberised layer of cells is cork, By progressive development ultimately the phellogen encircles the whole organ (stem, say) throwing out externally cork and internally other cells that are like those of the cortex. Thus the development of cork is in great measure centrifugal ; and as the older outer layers die off and peel away, new and fresh layers are renewed from behind by the zone of phellogen.

Like the epidermal cells, cork cells always remain in uninterrupted contact with one another. In shape, the cells are hollow parallelopipeds ; the walls are generally thin or at least homogeneously delicate, strongly impregnated with suberin, and the cell content in the mature stage is only air ; treated with Iodine, and Sulphuric acid the characteristic cellulose blue colour does not appear. The reactions of the cuticle however may to some extent be repeated.

2. **The Periderm.**—A mass of dead cork consisting of several layers of cork cells resulting from the continued activity of the phellogen together with the latter tissue when it has stopped its meristematic power is designated Periderm. Some writers use this term in a different sense ; but all the same, it is essentially a complex cork tissue affording protection to the plant. Perhaps its most striking character is that it exhibits differentiated layers,one consisting of large rectangular cells alternating with another of small tabular cells and so on.

FIG. 297.



Part of a transverse section of Potato tuber, showing the **cork cells** (at the upper part) forming the periderm.

In some cases, with the centrifugal formation of cork there goes on also a centripetal development of the cortex by the formation of living cells on the inner side of the Phellogen. The secondary cortex that thus arises is called *Phelloderm.*

3. **Formation of Bark.**—In most stems, branches, and roots of Dicots and Conifers the outer protective system of tissues undergo profound anatomical changes which lead to the formation of what is called the *Bark.* In such cases, new periderm layers originate in the interior of the members deep down in the cortical tissues, and thus cut off all the outlying part from the nutrient solution of food-matters travelling in the centre. Consequently all tissues that lie outside this inner periderm die and form the Bark.

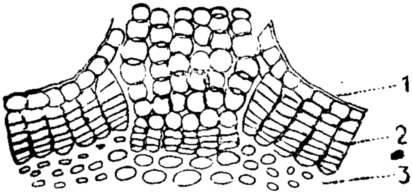
As the epidermis is replaced by the periderm, so later on, when growth in thickness becomes excessive, this is replaced by the bark. In the first one or two years a stem is covered by the epidermis; in the next few years probably by the periderm; while when it has attained the dimensions of a stout trunk the bark forms the tegumentary system. It must not be thought, however, that these tissues always follow one another through the successive years; there are cases, where no bark is formed even in stout tree trunks, and others too where the stem though comparatively slender develops bark.

The formation of bark is thus described by SACHS in his Text Book. "Layers of cells which can extend through the most different tissues of the cortex are changed into cork-cambium, which ceases to be active after the production of thicker or thinner layers of cork. These layers of cork cut out, so to speak, from the cortex, scaly or annular pieces of the surface; everything which lies outside them becomes dried up; and since this process is constantly repeated on the outside of the stem, and new layers of cork continually intrench further on the growing cortical tissue, a mass of dried up portions of tissue, constantly increasing in thickness bocomes separated from the living part of the cortex; and this is *Bark.*"

The Indian plant Melaleuca leucadendron (or Callicarpa Incana—Bhurja patra—the cajeputy-oil tree) is well-known for its thin and smooth bark which in former times was used as a substitute for paper; and so also is Ficus Balkala where the bark is good enough to be made up into a rough cloth.

Lenticels.—As the epidermis is gradually replaced by the periderm, so the stomata or the epidermal pores are replaced by **Lenticels** or **Cortical pores**. They mark the points at which the cork cells are interrupted. In function, they form loose cellular passages for gases (Cf. stomata). In almost all cork-forming Dicots, they appear as yellowish specks on the still green epidermis of branches that are not yet one year old. The appearance of these roundish yellow spots indicates the first formation of cork or phellogen; for lenticels precede the phellogen layers. Each lenticel takes its origin from a few parenchymatous cells below each stoma generally. These cells divide into rows of cells which on the outside become corky; in fact, a phellogen arises in this way below each stoma, and while growth goes on loose cork are cells given out towards the stretched stomatal opening which is thus plugged before the epidermis next splits at this point. And when the epidermis is ruptured, these loose dead cells bulge out. The phellogen layer thus produces not only a periderm of cork but intercellular passages as well, through which exchange of gases can take place. The

FIG. 298.



Formation of Lenticel. 1, the ruptured epidermis; 2, the phellogen giving rise to the loose cells that pack up the opening; 3, cortical cells.

phellogen which gives rise to the lenticel may be just below the epidermis or far down in the cortical tissue ; consequently, the form and depth of the lenticel will depend upon the depth at which the phellogen originates. In some plants (as in Apple, Pear, Jasmine etc) the lenticels arise in the epidermis itself, as in these cases it is the epidermis that initiates the division for phellogen-formation. But in the Grape-vine, in the genus Rubus etc, the phellogen is situated in the pericyclic layer—rather too deep for lenticel-formation, and hence lenticels are not formed in these instances.

SECTION II.

The Fundamental System.

The Fundamental system of tissues is essentially parenchymatous. In lower plants (cellular), it forms the sole tissue. Even in higher plants there are cases where the distinction between the different tissues is forced and far-fetched, for instance, in the leaves of the water-plant Hydrilla.* But in the majority of higher plants the tissues surounded by the epidermal system form the ground structure of the whole plant, through which the bundles run. Thus the fundamental tissue is of supreme importance, in as much as its component parts can be adapted into new structures in accordance with functional requirements. Thus also the different secondary structures originate mainly from this tissue. The development of phellogen and the formation of the bark has been shown to take place at the expense of a part of the fundamental tissue. Where new and secondary bundles arise they do so almost entirely from the cells of this system. Further examples of new groups of cells forming tissues adapted to certain physiological necessities are in the epithelium cells of resin-passages, laticiferous tissues, hypoderma, scle renchyma, secondary wood, medullary ray etc, almost all of which owe their origin to this system of tissues.

Genetically considered, the fundamental tissue consists of two parts—corresponding to two primary meristems. That part which is differentiated from the periblem is commonly called the cortex. But in view of the fact that the cortex itself is not usually a homogeneous tissue, it is

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* Hydrilla verticillata is a submerged water-plant, common in ponds with small verticillate leaves and axillary unisexual flowers.

better called the *extra-stellar* ground or fundamental tissue—the more so as it forms a zone surrounding the stellar tissues. The other part, that which belongs to the stele and is differentiated from the plerome is, for a similar reason, called *intra-stellar* ground tissue.

Hence for the convenience of description, we shall divide the fundamental tissue into,

1. The extra-stellar ground tissue.—
   (*a*) the hypoderma,
   (*b*) the cortex proper,
   (*c*) the endodermis.
2. The intra-stellar ground tissue.—
   (*a*) the pericycle
   (*b*) the medullary rays
   (*c*) the medulla or pith.

It should be noted here that the distinction between intra-stellar and extra-stellar tissues is possible only in the roots and stems of Dicots and Conifers and the Equisetums of the Pteridophyta, where the fibrovascular bundles are arranged in a ring. In all other plants, *e.g.* in Monocots, and Pteridophyta, and in all leaves generally, this distinction can not be made out. In these cases the fundamental tissue, however, admits of sub-division into the hypoderma, the general ground-tissue being the preponderating mass, and a sheathing tissue immediately enveloping the bundles. In ordinary leaves particularly, the fundamental tissue (*mesophyll.*) is generally divisible into two parts; one immediately under the epidermis, ormed of rather close rectangular cells, called the *pallisade parenchyma,* and the other filling up the rest in the form of loose cells with abundant intercellular spaces forms the *spongy parenchyma.* See fig. 295.

Cortex.—This is the general name given to the parenchymatous tissue lying outside the system of bundles. The most constant character of the cortex (of the aerial stem) and one that differentiates it from the rest is the presence of chlorophyll in its cells and consequently also of starch. It forms the organ of assimilation, and is the store-house of elaborated food-matters. The cells are always living *i.e.*, contain protoplasm which is nutritively active. When, as in many stems, it forms a thick zone, the outer part, (*i.e.*, a depth to which sun light can penetrate) only is green, the rest being colourless. In this colourless part leucoplastids occur in abundance. Cortical cells are always thin-walled and made up only of cellulose. The characteristic blue colouration with Iodine and Sulphuric acid come out best here

Hypoderma.—In cases where the stem bears well developed foliage leaves, the outer cortex generally consists of thickwalled closely united elements which add supporting strength to the other tissues. The elements may form either elongated fibre-like *sclerenchymatous tissue*, or thin walled angular cells with the angles strongly thickened with cellulose or *collenchyma tissue*. In the angular stems of Umbellifers, Malvaceæ, Labiatæ and many other families, the collenchymatous hypoderma is massively developed at the corners only, while between them lies the ordinary parenchyma of the cortex. It is, as a rule, absent just below the stomata.

In Pteridophyta, stems of Cyperaceæ and many Palms, the hypoderma generally forms a continuous layer of scherenchyma.

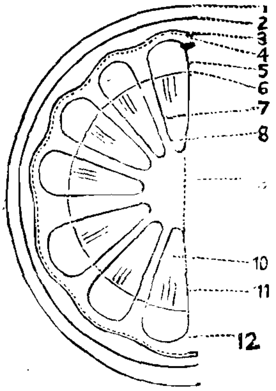
In many Monocot roots, the hypoderma is but feebly developed—being only of one layer of cells cutinised but partly. This layer is the *exodermis*, and characterises the ærial roots of Orchids and Aroids particularly. (See Velamen).

In herbaceous Dicots, collenchyma frequently appears in thick bands just under the epidermis extending a little way into the cortex, in stems, petioles, and veins or ribs of the leaf. The collenchymatous cells are angular, contain protoplasmic matter with chloroplasts, and may, unlike the other hypodermal elements, divide under certain conditions.

Endodermis.—It is a protective sheath formed of one layer of closely united cells. It forms the innermost limiting layer of the cortex and surrounds the vascular bundles. Intercellular spaces are never developed between the component cells. It is a typical parenchyma being made up of active live cells. In stems of Dicots and in all roots generally, where there is but a single stele, the endodermis forms the single vascular-bundle-sheath. But in Ferns and other Pteridophyta where there are more than one stele, each stele gets a separate sheath of endodermis.

The cells of the endodermis generally remain thin walled, but the radial walls are often suberised. In the rhizomes of Cyperaceæ, in palms, and in many other cases, the cells are more strongly thickened on the inner side; and cases are not wanting in which they are thickened all round. However in all cases they are living cells and on account of their frequently containing a very large amount of starch, the endodermis is sometimes called the starch-sheath. They

FIG. 299.



Diagrammatic Cross section of a Dicot stem (Gulancha—*Tinsporoa cordifolia*).

1 Epidermis
2 Outer green Cortex
3 Endodermis
4 Pericycle
5 Bundle
6 Fascicular Cambium
7 Xylem
8 Protoxylem
9 Pith
10 Xylem rays
11 Medullary rays
12 Phloem.

Note the wedge-shaped bundles; the complete ring of cambium passing through that of the bundles, being composed of fascicular (in the bundles) and interfascicular(between the bundles) cambium.

contain leucoplastids in plenty and in some Equisetums they even contain chlorophyll.

The Pericycle.—The intra-stellar ground tissue is differentiated from the plerome in conjunction with the bundles; hence it is also called the CONJUNCTIVE TISSUE. The peripheral layer of this conjunctive tissue, investing the vascular cylinder, is the PERICYCLE. In general, it forms a continuous layer of varying thickness. In the roots of most Angiosperms it consists of only one layer of cells. In the roots of Gymnosperms and of some Dicots it is more than one cell deep. In a few water-plants it is entirely absent. In the stems and petioles of land plants, the pericycle is most conspicuous; in such cases it generally consists of thin-walled slightly elongated cells which in special cases become fibres.

The Medulla.—In plants provided with a ring of bundles the centre of the vascular cylinder is filled up with a soft parenchymatous tissue—this is the central conjunctive tissue in contrast to the pericyle which is the peripheral. This part is called the MEDULLA or PITH. In many plants the cells of the pith become disorganised or torn: consequently they die and leave a hollow space. The hollow stems of Labiatæ, Umbelliferæ, Grasses are examples. In the polystellic Pteridophyta, in Lycopodium, and also in the Monocots, the pith does not form a differentiated tissue; in the first two, it is entirely absent. In Palms (Monocot) there sometimes exists a central parenchymatous tissue which is better called the fundamental tissue; for, the three conjunctive tissues, the pericycle, the medulla and the medullary rays pertain specially to Dicots, where as a rule, the bundles are arranged to form a closed ring.

SECTION III.

The Fibro-Vascular System

A PRIMARY.

The Stele.—The stellar tissue traverses the fundamental tissue in solid strands. It differs from similar solid strands (sclerenchyma) in being fibro-vascular in composition. Its components are the bundles and the intrastellar ground tissue. The stele is the permanently differentiated tissue of the plerome. According to the different ways in which this primary meristem is differentiated, we get the following cases :—

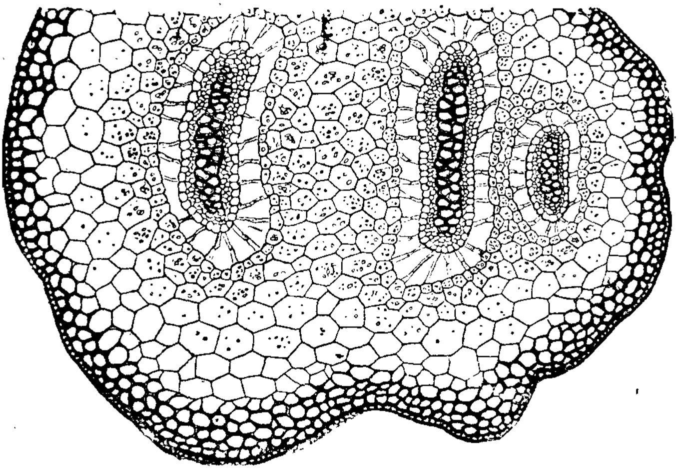
1. In Dicots, Monocots and Conifers the shoot is traversed by a single axial strand—the stele. Hence it is called a monostellic stem. In such cases the stele is composed of a number of bundles forming a compact structure surrounded by a soft parenchymatous stellar tissue called the Pericycle. In Dicot and Conifers, the bundles of the stele are arranged in a ring ; the fundamental tissue bounded by the bundles is divided into two parts—the axial tissue known as the Medulla and the strands or plates of tissues interposed between the primary bundles, known as the medullary rays (primary). In Monocots however, any line between the medulla and the rays can not be drawn.

2. In Pteridophyta generally, the bundles do not originate by differentiation of the plerome at the same time. The stem is traversed by two or more steles which in the period of development have very likely followed one another. Such stems are hence called polystellic. The steles that are thus formed do not contain any intrastellar ground tissue, because they can not enclose any. In Ferns polystely is common.

3. In certain Pteridophyta ,the plerome tissue gives

rise to separate steles by splitting into separate parts. Thus the steles are genetically different here. This state is called

FIG. 300.



Cross section of stem of Selaginella, showing the polystellic character and the concentric arrangement of the bundles. Note the thick walled hypoderma and the cell contents in the inner cortex. In each stele the central dark part is xylem, surrounding which is the Phloem. (After Sachs.)

schizostelly. Examples are in some of the **schizostellic stems** of a few equisetums.

4. When separate steles, as in the above case, again fuse later on to form a single stele the structure is called gamostellic. It occurs in Marsilia (shooshny shak).

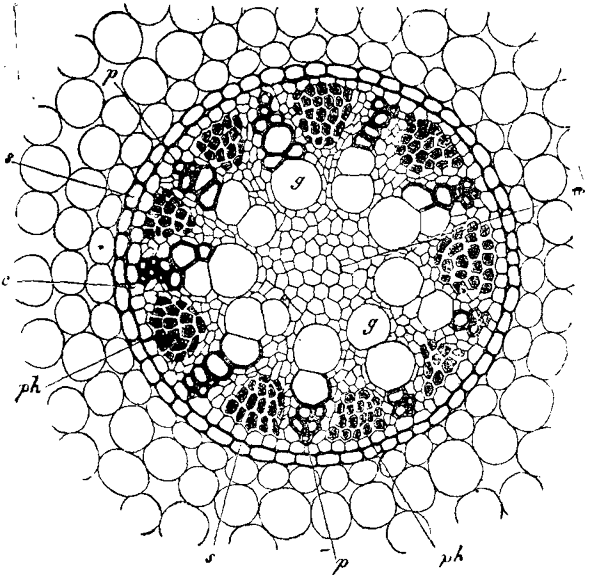
Each stele is delimited from the cortical tissue by a layer of endodermis, and consists typically of.—

(*a*) a few layers of soft-walled parenchymatous cells enveloping the whole, called pericycle;

(*b*) the hard traversing strands of bundles;

(*c*) and another soft-walled parenchyma which may be variously developed.

FIG. 301.



Cross Section of a Root (Acorus calamus) showing the stele bounded by the dark endodermis (*s*). The Bundles are radial—*ph*, phloem ; *g*, the bigger vessels of the xylem ; *m*, the medulla. Surroundidg the stele are roundish cortical cells. (After Sachs).

The individual strands of bundles that pass out to the leaves are called *meristeles*.

The Bundles The two constant elements of a bundle are (*a*) the lignified xylem, and (*b*) the non-lignified phloem. The way in which the different parts of a bundle are disposed, as also its relative position in the stem, varies greatly in different plants.

(1) As to the disposition of bundles in the stem :—In

Dicots and Conifers, they are as a rule arranged in a ring round the medulla. In Monocots, they are scattered. (Fig 303). In Pteridophyta, they are merged into the stele (see ante).

(2) As to their shape:—The Bundles of Dicots are as a rule wedge-shaped. Those of Monocots are elliptical or round. In Ferns they have no very strict outline.

(3) As to their composition:—Bundles are said to be (*a*) open i. e. containing a layer of undifferentiated meristem—the cambium, as in all Dicots and Conifers generally; and (*b*) closed i.e. containing no such cambium layer, as in all Monocots and Pteridophyta.

(4) As to the relative disposition of the xylem and phloem bundles are:—

(*a*) *collateral* i. e. with the xylem and phloem side by side in a radial line, the xylem facing the inner axis of the plant structure, as in all Dicots, Conifers and Monocots;

(*b*) *concentric*, with the phloem entirely surrounding the xylem; or *viceversa*, the xylem surrounding the phloem. In Ferns, Selaginellas and Lycopods, each stele is generally formed by the fusion of two or more bundles; and the fusion takes place in such a way that the xylem forms the centre, and the phloem an encircling layer investing the former. A concentric bundle with the xylem in the centre is rare in phanerogams; but the other kind, *i.e*,. a concentric bundle with the phloem surrounded by the xylem, characterise quite a number of our higher plants. For instances, in the stem of Dracena (the Dragon's blood tree—Beng: *Khun kharapi Lidar*), in the rhizome of Cyperus, Carex and a few other Monocots in the central bundles of Ricinus, Piperaceæ.

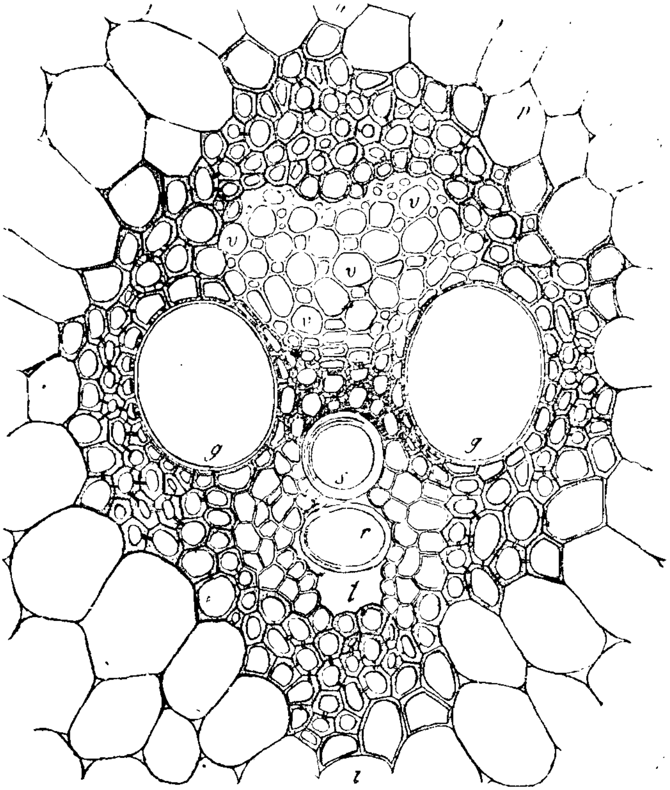
(*c*) *Bicollateral*, *i.e.*, with the phloem on the two sides of xylem in a radial line. Plants of the families Cucurbitaceæ, Solanaceæ (Potato family), Asclepiadaceæ (madar family), Apocynaceæ, Cichoriaceæ and a few other Dicot plants are characterised by such bundles. In a cross section of the stem, they appear as irregularly elliptical bodies with a layer of phloem on the inner (medullar) as well as on the outer (pericyclic) side of a central layer of xylem.

(*d*) *Radial*, *i.e.*, with the xylem and phloem layers forming separate strands alternating with each other. This arrangement obtains generally in all roots and is connected with monostellic development. In a cross section of any root, if radii be drawn from the centre towards the circumference, each radius will pass through either a xylem or a phloem layer, and not through both, as will be the case in a stem. In contrast to this kind of bundle the foregoing ones are termed *conjoint* bundles. The latter always consist of xylem *and* phloem; the former exclusively of xylem *or* phloem.

The differentiation of the procambium into a permanent bundle starts from two places in opposite directions—one facing the centre of the stem and the other at the opposite end towards the cortex. From these two points the differentiation starts, successive procambial cells being transformed into the permanent elements of the bundle. The Phloem first originates as bast cells (prosenchymatous) at the part of the procambium next the pericycle and thence the differentiation proceeds towards the centre; the xylem, similarly, is first differentiated as a lignified tissue at the medullar face of the procambium and thence proceeds towards the phloem. Thus in collateral bundles the development of the xylem is *centrifugal*, that of the phloem is *centripetal.* The first formed elements of the xylem are termed PROTOXYLEM; those of the phloem, PROTOPHLOEM.

Elements of the Bundles.—Each bundle consists of two parts; a hard lignified part, and a soft non-lignified part. The former is distinguished as WOOD, or XYLEM, or HADROME, and the latter as BAST, or PHLOEM, or LEPTOME. Each of these tissues consists (generally, in the case of higher plants) of three kinds of elements, viz., the vascular, the prosenchymatous and the parenchymatous. Thus:—

FIG. 302.



Cross Section of a Monocot bundle (Closed). Highly magnified. The bundle consists of Xylem (*g. g. s. r l.*), Phloem (*v. v. v*), and the Sclerenchymatous bundle-sheath (the thick-walled cells forming a dark layer) surrounding the Xylem and Phloem, p, thin walled parenchyma of fundamental tissue. The Xylem consists of *g. g.* two large pitted vessels; *s*, spirally thickened vessel; *r*, annular vessel; *l*, an air containing cavity, and the smaller xylem parenchyma. The Phloem consists of *v*, *v*, the Sieve tubes, and the smaller companion-cells. After Sachs.

(1) Xylem.—

- (*a*) *Tracheæ* or *Vessels* are the largest xylem structures; they are cell-fusions and have spiral, annular, reticulate, or other kinds of thickening layers.
- (*b*) *Tracheids* are elongated wood cells, and like the above, contain only air and water.
- (*c*) *Wood parenchyma* are living wood cells.

(2) Phloem.—

- (*a*) *Sieve-tubes* are the phloem vessels. They conduct nitrogenous food matter.
- (*b*) *Companion cells*, or elongated phloem cells, often accompany the sieve-tubes. The companion cells are the sister cells of the sieve-tubes, for both arise from the division of the same mother cell. In most Monocots the phloem is almost exclusively composed of sieve-tubes and companion cells.
- (*c*) *Phloem parenchyma* often occur besides the above two phloem-elements in most Dicots.

Of these the most important are the tracheæ and the sieve-tubes. According to the nature of the thickening, there may be :—

(1) Spirally thickened tracheæ, or *spiral vessels.*
(2) Annularly thickened tracheæ, or *annular vessels.*
(3) Reticulately (irregularly) thickened tracheæ or *reticulate vessels.*
(4) Tracheæ with simple bordered pits, or smaller pits, *Pitted vessels.*
(5) Tracheæ with elongated pits, or *Scalariform vessels.*

The Course of the Bundles. The fibro-vascular bundles run in solid strands in the stem and the root, and ultimately ramify in the leaves. We have seen already that the arrangement of the bundles differ in the stem and the root (p. 321); we have now to see the relation or connection between the bundles in the leaves, stems, and roots.

Bundles that pertain strictly to the stem, being differentiated in the terminal bud, and grow acropetally with it are called *Cauline* bundles. And bundles that originate at the nodes, and grow out horizontally or obliquely to the leaves and vertically down to the stem, are called *leaf-trace bundles* or *Common bundles*, because they are common to the stem and the leaf. The bundle-system of a stem may consist of only common, or only cauline bundles, or both.

It is possible, under certain conditions, to obtain evidence of the course followed by the bundles by separating them from the soft cellular tissues of a plant. By macerating, i. e. by treating stems, or leaves, or twigs with certain chemicals, (e. g. Nitric acid) a skeleton of the more refractory bundle system may be easily obtained. Examined in this state, most plants show themselves up as being composed almost entirely of *leaf-traces* or *common* bundles ; the latter appear to curve down as isolated strands for considerable distances in the stem after quitting the leaves, and then coalesce with other leaf traces (or cauline bundles) to form the units of the stele.

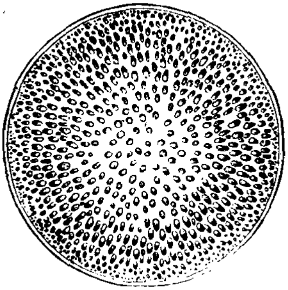
The course of the bundles—whether cauline, common, or both—differs in different plants, and in the different classes of plants.

(*a*) In the great majority of Dicots and Conifers, as also in a few Monocots (Dioscorea) and Equisetums, all the primary bundles are common bundles. From each node they bulge towards the centre of the stem, pursue a direction downwards parallel to the sides of the stem, pass down through more than one internode, and are so arranged that they are equidistant from the centre of the stem : in cross section the characteristic *ring-like* arrangement is thus observed. The bundles that proceed from the leaves next above insert themselves to those that run from the lower ones, and in this way the form of the ring is maintained.

(*b*) In a few Dicots and Cycads, sometimes in whole families, the bundles follow a course different from what obtains in their relatives (an in the above cases). Thus, in the climbing *Cucurbitas*, the bundles, though all common, are arranged in *two rings* ; some of them form the ordinary typical ring (of the Dicot), while a few others bend more towards the centre, and form a second irregular ring. Again, in many plants of the family Piperaceæ, besides the ordinary ring of bundles, a second ring is present in the medulla of the former. Further, many species of Begonia, Melastomaceæ, Umbellifers and Nelumbium (Lotus) contain a few isolated and solitary bundles scattered in the medulla formed by other bundles arranged in the usual ring-like manner. In such cases the common bundles form the ring, and the other scattered bundles are really cauline. All such bundles passing through the medulla are accordingly termed *medullary bundles*.

In Nyctaginaceæ (*Krishna-kali*), the ring of bundles in the stem is composed of cauline bundles which form the usual cambium-ring and increase the wood; but a few isolated bundles are also scattered in the central fundamental tissue—these are the thick leaf-traces.

FIG. 303.



Diagrammatic cross section through a Palm-stem (Monocot). Note the scattered bundles crowded more towards the periphery than at the centre.

(*c*) In a few exceptional Dicots, as the Nymphæaceæ, the vascular bundles appear to be scattered like those of the typical Monocot. In such cases, the leaf-trace bundles as soon as they emerge from the leaves anastomose to form a net-work, and hence the scattered appearance.

(*d*) In Monocots generally the bundles are never in a ring (as in Dicots) but scattered. In Grasses the bundles occupy only the peripheral part of the fundamental tissue, the central part (corresponding to the medulla) of which becomes hollow.

In Palms, on the other hand, the bundles are scattered over the whole fundamental tissue even in the centre. The bundles of Palms are common. From the insertion of each leaf a number of bundles pass down into the stem bending considerably inwards towards the centre, descend through many internodes, and finally curve out towards the periphery, there to unite with other leaf-traces. Thus in a transverse section of a palm stem, the outer part of the ground tissue is crowded with the bundles which become lesser in number towards the centre.

(*e*) In Pteridophyta the bundles are continued as cauline bundles in the stem ; the bundles that pass in from the leaves are not common, for they have no independent existence in the stem. From each leaf a *foliar bundle* passes inwards and at once coalesces with a bundle of the stem. In Lycopodium and Selaginella the cauline bundles arise sympodially.

(*f*) In Roots, the xylem and phloem form separate strands (see Radial bundles p. 321). A bundle passing through the stem to the root becomes not only split up into its elements xylem and phloem as soon as it enters into the region of the root, but each xylem strand becomes at the same time twisted through an angle of 180°, so that what was the inner side of the xylem in the stem becomes now the outer. Hence in roots, the protoxylem is nearer the cortex than the newer xylem vessels.

B. Secondary.

Generally in all roots and stems of Dicots and Conifers, and in the stems of some Monocots, the completion of the primary bundle-tissues is followed by the formation of new bundles, or additional elements of the bundles, in the pre-existing primary ground-tissue. The secondary generating tissue which thus arises, and later on produces the secondary permanent tissues is comprehensively designated the *cambium*, or the cambium-ring. The growth in thickness results as a consequence of this cambial activity ; in fact, a continuous increase in thickness of roots and stems is due to the formation of secondary elements of the bundles. It must not be supposed however that *all* kinds of growth are due to secondary structures. Most Monocot stems do not produce them. Again, the increase in girth of the very young parts of a plant is really due to the distention of the component cells. In certain cases this distention is so pronounced that as a result, the pith-cells become ruptured ; such for instance as in Equisetums, Grasses, and Umbellifers where the pith is hollow. In Dicots and Conifers, in general, the stem or the root forms an *erect* cone : the upper part comparatively more slender, while the lower regions grow continuously. In Monocots and Pteridophyta, on the other hand, the apex of the stem is somewhat like an *inverted* cone, with the broader end towards the top and the narrower towards the base. In the latter cases, every internode retains the thickness it received at the close of the maturity of its tissues ; for growth takes place mainly during the unfolding of the bud, and hence there is an almost localised apical growth.

Secondary Growth in Stems of Dicots and Conifers. In general, in all such stems the fibro-vascular bundles run in parallel strands arranged in a ring round the medulla. The successive secondary changes that follow from the activity of the cambium are these :—

1. Between each pair of fascicular cambium of the adjoining bundles, a plate of the primary medullary rays becomes a meristem—the inter-fascicular cambium (secondary). It arises from the multiplication of the ray-cells abutting upon the fascicular cambium.

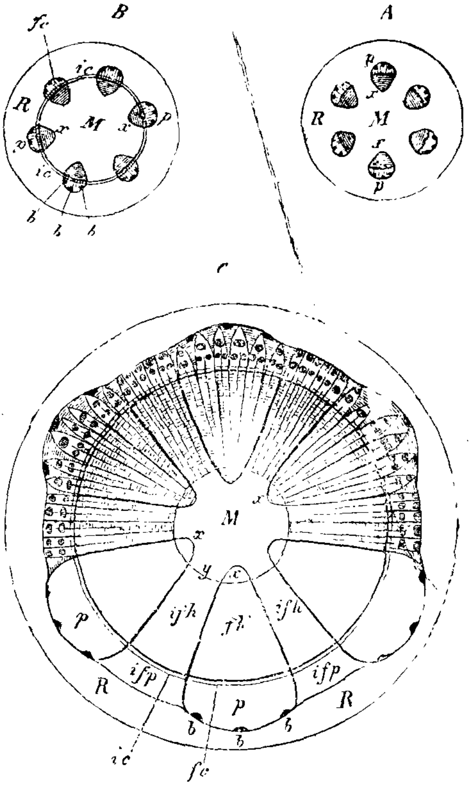
2. The primary and secondary cambium layers thus unite their activity and form a complete cambium ring. This continuous ring consists of rows of cells arranged radially.

3. The activity of this cambium consists in the formation of wood on the inside and bast on the outside, and takes place in the direction of the radii of the cross section of the stem. Each radial row of cells gives rise to secondary xylem cells on the inner side, secondary bast cells on the outer side, while a middle layer always remains capable of division. and thus maintains the cambial activity for a long period.

4. Through the activity of the *fascicular* part of the cambium-ring the original wedge-like shape of the bundles is maintained, while through the activity of the *interfascicular* part new, thin, wedge-like structures originate between the primary bundles. As shown in fig. 304,c, the dark radial lines between two bundles represent the primary medullary rays. They run from the medulla through the cambium to the outer cortex, and result from the activity of the inter-fascicular cambium. By the activity of the fascicular cambium, again, new *secondary medullary rays* are formed within the wedge of each bundle, which terminate bluntly in the wood on one side and phloem on the other. In fig. 304,c these are represented by the shorter dark lines within the bundles. Thus, it will be seen, that with increase in the thickness, the bundles are more and more split up into smaller and thinner wedges all converging to the proto-xylem. The original xylem parts of the bundles, which were formed before the increase in thickness set in, at this stage forms intruding layers of wood and are collectively comprised under the term *Medullary sheath* (*x.x.x.*). The

xylem part of the secondary rays is called the *xylem-rays,* while that traversing the bast is *Phloem-ray.*

FIG. 304.



Diagrammatic Cross section through a Dicot stem to show the activity of the cambium.

A. Before the formation of cambium ring. M, the Medulla ; R, the Cortex ; x, the Xylem ; p, the Phloem

B. Formation of cambium. *fc*, fascicular cambium ; *ic*, interfascicular cambium ; *b*,*b*,*b*, protophloem elements.

C. The upper half shows the secondary tissues formed from the cambium-ring. *x*,*x*,*x*, the proto-xylem elements forming the medullary sheath. Note the continuation of the primary medullary rays through the secondary elements formed from the inter-fascicular cambium. After Sachs.

5. In almost all cases the amount of the xylem is considerably greater than the phloem, or bast. But later on, with the appearance of the phellogen and bark, a large part of the secondary phloem may be lost by the constant formation of layers of bark on the outside. Hence in a woody stem which is several years old, while it is possible to find out all the parts of the wood from the proto-xylem to the secondary rays, the parts of the bast may not be traced out clearly.

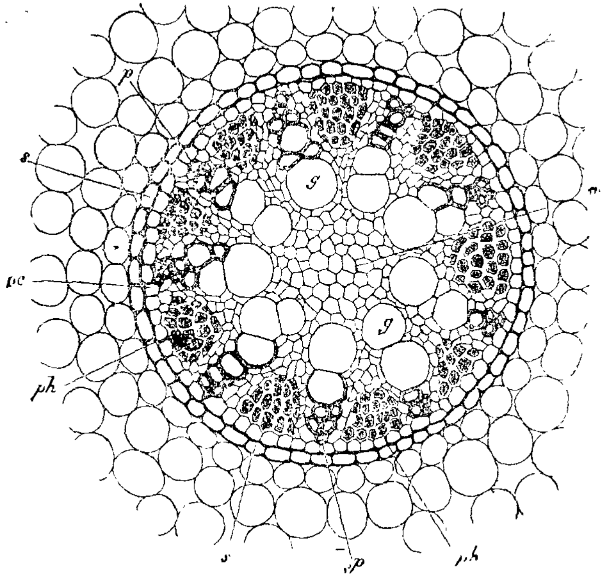
6. Except in tropical countries where there is no well-defined vegetative season, in all other countries cambial-activity becomes more or less pronounced in the different seasons. For while vegetative activity is strong in spring, it is almost wanting in winter. As a result, the cambium layer shows periodic activity which is very clearly manifested by the presence of concentric layers of wood, called *annual rings*, in a cross section of an old woody stem. In spring the elements that are added to the wood are bigger, and more loose than those that are added later on in autumn. Hence, in each year, the wood is clearly marked out in two layers—one consisting of larger and looser elements, called *Spring or Early wood*, and the other more compact and consisting of narrow elements, called the *Late* or *Autumn wood*. In a cross section these layers alternate, and may thus serve as a means of computing the age of the stem or the plant.

7. When a stem becomes very thick and consequently its wood becomes bulky, the inner older part of the wood generally dies and ceases functioning as an organ for transporting the nutrient sap; it becomes more hard and firm than the outer part, and more usually becomes distinctly coloured yellow, red, and even black, due to the impregnation of tannins, gums etc. It is known as the *Duramen* or *Heart wood*, in contrast to the *Alburnum* or the *Sap-wood*—the still living part consisting of the rather soft and light-coloured later annual additions. The inner layers of the alburnum gradually

ransform into those of the Duramen as years pass on, and the cells of the latter are protected by the resinous matters that are formed later on. It is the presence of these coloured and esinous substances that imparts to the wood its 'timber value.' In some Dicot plants, however, the Duramen though dead is not coloured or filled up with any gummy matters. Such wood is necessarily more prone to decay, and has really no imber value; while again, in others there is no formation of he Duramen, the whole wood being living—being then known as *splint wood.*

Secondary Growth in Thickness of Roots—In the oots of Dicots and Conifers, where secondary thickening takes

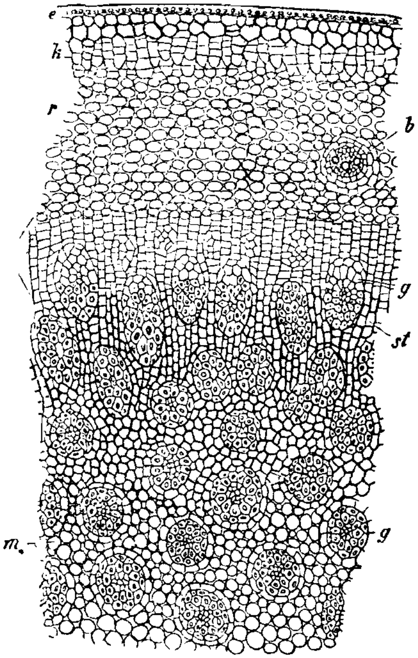
FIG. 305.



place, the process is almost similar to that described above. Due to the orientation of the xylem, the bundles of roots are radial; hence the cambium ring that arises here does not pass through the xylem and pholem as in conjoint bundles. Layers of fundamental tissue on the inside of the phloem strands begin to divide, and dividing form areas of meristem. They produce wood and bast on the two sides (inner and outer), much as the cambium of the stem produces them. Their strong activity, however, soon leads them to curve outwards flanking the two sides of each primary phloem, and thus later on the separate cambium layers join in the pericycle behind the xylem and form a continuous wavy layer of cambium. It is wavy only at first, for at its first formation it may be likened to a string that curves over the phloem and behind the xylem strands. As however growth proceeds and wood and bast are continually thrown up on the two sides, and the young cambium becomes advanced in years, the sinuous contour is soon lost. At this stage the cambium forms a complete ring in no way different from that in the stem. Thus a hasty examination of a cross section of such a root and a similar stem, where growth had been in progress for a few years, will show no difference. Careful examination, however, will reveal the presence of isolated strands of xylem in the centre, unconnected or but partially connected with the rest of the wood, and phloem towards the circumference. These isolated strands represent the first formed elements of the radial bundles which have been thrust further and further apart by the stretching of the sinuous cambium and its continued activity for the formation of secondary wood and bast. The wood of old roots is rarely differentiated into layers, and is of a nature more homogeneous and soft than that of the stem. Hence in roots there is rarely any duramen, or 'annual rings.'

Secondary Growth in Thickness of Monocots. Except in only a few cases, the great majority of Monocot stems and roots shows no secondary anatomical changes in the formation of new wood and bast. A superficial periderm may often be formed in many instances, but generally the growth *in thickness of Monocots, such as Palms, is due solely to the* extension and superficial growth of the individual cells of the primary tissues. But in Dracæna, Yucca and a few other

FIG. 306.



Part of a transverse section of the stem of Dracæna. *e*, Epidermis; *k*, phellogen; *p*, cortical parenchyma; *x*, the secondary cambium from which the secondary bundles (*g*) arise. *m*, the central fundamental tissue. Note the bundles which are being formed in the zone of secondary meristem.

arborescent Liliaceous plants the fundamental tissue of the primary cortex outside the central fibro-vascular system, becomes meristematic, and gives rise to new secondary bundles. Fig. 306 shows part of a transverse section of Dracæna. The isolated roundish bodies in the centre (*g*) are the primary bundles which form the central woody substance of the stem. And the closely crowded, slightly elliptical bundles which form a woody layer enveloping the central mass consists of secondary fibro-vascular bundles. Outside this layer is a zone of secondary meristem represented by the tabular dividing cells (*x*) arranged in a radial manner. In this zone groups of cells become elongated longitudinally, and finally form the secondary bundles. The meristem in this way passes over once more into permanent tissue, and then new cortical layers become meristematic. Thus, again, the thickening ring moves continually centrifugally towards the cortex with the increase in diameter of the stem, and leaves behind secondary bundles and parenchyma to be added to those of the primary.

As to the composition of these bundles, it should be noted, that the central primary bundles are all leaf-traces, and hence are of the typical collateral type with the sheath of sclerenchyma usual for Monocots ; the peripheral secondary bundles are concentric, being composed of a little phloem in the centre surrounded by two or three layers of tracheids. The tracheids are elongated spindle-shaped bodies with their pointed ends dove-tailing with one another, and are provided with oblique slit-like bordered pits on their thick lignified walls.

Elements of the Secondary Wood.—In *Conifers*, the whole mass of the secondary wood with the exception of the medullary rays consists of tracheids with bordered pits only. Annular, spiral, or reticulate vessels are not formed. The tracheids of the spring wood have larger lumen than those formed later. A little wood parenchyma may also be formed ; and when resin ducts arise in the wood, they are formed from the disorganisation of these parenchymatous cells.

True vessels, *i. e*, rows of tracheids with their transverse partition walls broken through, do not occur in the wood of the

Conifers or Gymnosperms generally—either in the primary xylem or in the secondary wood.

In *Dicots*, generally, besides the simple tracheids with bordered pits there occur wood parenchyma, true vessels or tracheæ, fibrous tracheids, and simple sclerenchymatous fibres, in the secondary wood. The vessels are chiefly formed in spring, while later on, the wood parenchyma and the fibrous wood cells are formed in abundance. Hence, the spring-wood of normal Dicots having 'annual rings' consists mostly of tracheæ and vasiform tracheids, and the late-wood or autumn-wood consists of fibrous and parenchymatous wood cells.' The parenchymatous wood cells usually retain their living contents and have rarely bordered-pits on their walls. Specially large vessels with wide lumina are characteristic of Dicot climbing plants (Lianes of forests).

In *Roots*, where secondary thickening takes place, the wood (secondary) frequently consists of succulent wood parenchyma with a few vessels. Lignification is generally not very complete in the secondary elements of the wood; and what for this character and for the abundant formation of parenchyma, the structure of thickened roots and stems become easily distinguishable. (See p. 332).

Elements of the Secondary Bast.—In *Dicots* and *Gymnosperms*, the secondary bast which is continuous with the primary phloem strands, consists almost without exception of *sieve-tubes* and *bast-parenchyma*. Besides these constant elements, there also occur very frequently elongated fibrous thick-walled cells known as *bast-fibres*. The latter are in their nature sclerenchymatous. The term *soft-bast* includes all those portions of the bast which are not sclerenchymatous. What are called *companion cells*, *i. e.*, sister-cells of the sieve-tubes, are rarely found in Gymnosperms, but are the constant feature of most Dicots. All the elements of the soft-bast are always soft-walled, while the sclerenchymatous bast-cells may be lignified.

In function, the bast-fibres correspond to the fibrous woody cells, and both act as mechanical tissues ; the parenchyma of the bast similarly corresponds to the wood parenchyma, and both act as tissues for the storage and conduction of carbohydrates. The sieve-tubes, the vascular elements of the soft bast, correspond to the wood vessels, tracheæ and tracheids ; both serve to conduct food materials,—the sieve-tubes conduct the elaborated proteid or albuminous matter, and the wood-vessels only the crude inorganic matters.

The Medullary rays.—The secondary medullary rays, or the *silver-grains* that appear as glistening bands extending through the prosenchymatous elements of the wood and bast, in a cross section of a stem, consist essentially of parenchymatous cells. They arise from rows of cambial cells elongated radially, while the cambial mother-cells of the wood and bast are elongated longitudinally. Each ray runs uninterruptedly from the wood through the cambium into the secondary bast ; that part of it which runs through the wood has its cells lignified, and is know as the *xylem-ray*, while the corresponding *phloem-ray* consists of simple, thin-walled parenchymatous cells. In Pines and other Conifers besides these parenchymatous elements the medullary rays often contain *tracheids* with bordered pits, or irregular thickening layers. In some Umbellifers and Begonias *fibrous cells* also occur either along with the ordinary parenchymatous type, or exclusively, in the xylem-rays.

In function, the rays, as they connect the phloem with the xylem and each with the cambium, serve to supply all those tissues through which they traverse with the food matters prepared in the leaves and cortex and conducted away by the bast They serve, again, in many cases, to give outlet to waste matters formed within the plant. They are often accompanied by intercellular passages or spaces which thus keep the living elements of the hard woody mass as also the other elements within the plant in communication with the atmosphere.

CHAPTER XVIII⁽¹⁾

Anatomy of Plants.

SECTION I

DICOTS.

Helianthus (The sunflower : *surjamukhi*).—

1. Cut transverse sections of the internode of a young green stem ; mount one in water or dilute glycerine, others in chlorzinc-Iodine, and in acidulated solution of aniline chloride, on separate slides. Observe first with the low power of the microscope, and next with the higher powers⁽²⁾.—

1. The *Epidermis*, a single layer of cells extending over the whole surface, not very well defined from the sub-epidermal cells, but provided with multicellular hairs on the outside.

With chlor-zinc-iodine the outer cell-walls are coloured faintly yellow. Chloroplasts may also be noticed in the epidermal cells. This is an exception to the general rule that chloroplasts are not formed in the epidermal cells.

2. The *Cortex*, occupying the zone between the epidermis and the ring of vascular bundles forming the central woody cylinder. It consists of, (*a*) a zone of sub-epidermal tissue of roundish thick-walled cells, the *Collenchyma*, (*b*) a zone of thin-walled irregularly arranged cells with intercellular spaces

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(1) Materials for this chapter have been ~~collected~~ collected mainly from the Notes of senior B. Sc. and B.A Students working in the Botanical Laboratory, Bangabasi College.

(2) For instructions on section-cutting, mounting, etc., students should take the help of teachers ; it is quite outside the scope of this book to give them here ; see, however, Appendix.

between them, the *Cortex proper*, and (*c*) a wavy zone, one cell thick, with the cells in close contact, the *Endodermis*.

Note the green chloroplasts present in the collenchyma cells and in those of the cortex proper. With chlor-zinc-iodine all the cortical cells show up rather dark spots within; these are the starch grains which have become dark blue with the reagent. The dark spots are specially prominent in the endodermis. Note also the dark dots in the radial walls of the endodermal cells. (See p. 315).

All the cortical cells, except probably those of the endodermis, are stained violet with chlor-zinc-iodine. In the thin-walled cortex *Resin-passages* occur at isolated points. Each passage is surrounded by a ring of small round cells—the epithelium cells.

The protoplasm which is present in almost all the cells of the cortex becomes slightly brownish with chlor-zinc-iodine. Aniline chloride gives no particular colour-reaction.

3. The *Stele*, or the central cylinder, lies enclosed within the endodermis. It consists of, (*a*) the soft parenchymatous central part—the *Medulla* or *Pith*, (*b*) the longitudinal strings of the *Vascular Bundles* arranged in a ring, and (*c*) the thick walled bands of *Sclerenchyma* opposite each of the bundles in the pericycle. Besides these there are the *medullary rays*, and the layer of *pericycle* just below the endodermis.

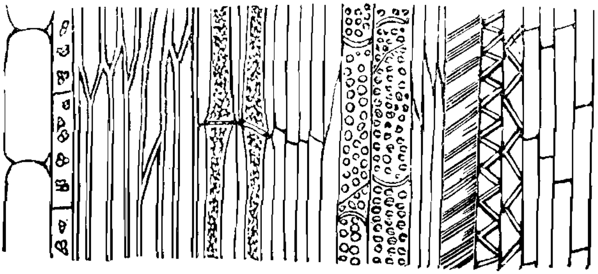
With chlor-zinc-iodine the parts that are very prominently stained are the semilunar bands of sclerenchyma outside the bundles, and the xylem. Both these tissues stain brownish yellow. With acidulated solution of aniline chloride these tissues become bright yellow. Treated with these reagents, they can thus be picked up readily from the rest of the tissues. The peculiar colour-reaction is due to the presence of lignin in the cells. The rest of the stellar tissue is but feebly, if at all, stained by the reagents. In the phloem, some dark deeply stained spots may be noticed; these are the transverse sieve-pits. The phloem cells being composed of cellulose, will very likely take the characteristic violet, or bluish colour with chlor-zinc-iodine.

Note the absence of chloroplasts from all the cells of the stele, and also that of protoplasmic matters from the medulla, the xylem vessels, and the sclerenchyma.

The Pericycle consists of a few layers of cells which are generally parenchymatous except at the places opposite the bundles, where they become elongated, thick-walled and lignified (sclerenchyma).

Each Bundle forms a wedge-shaped mass, and consists of the xylem internally, the phloem externally, and the cambium in the middle The wide cavities found in the xylem are the vessels or tracheæ. The widest are the Pitted vessels. The spirally or annularly thickened vessels are specially found adjoining the medulla. These are the first formed elements of the xylem and consequently represent the proto-xylem. The wider elements of the phloem are sieve-tubes. The

FIG. 307



Longitudinal section of a part of Helianthus Stem. Beginning from the left :—(The cortex is not shown). The Endodermis containing roundish starch grains ; Sclerenchyma, Hard bast, pointed, dovetailed cells ; then two Sieve-tubes with granular contents : next a few sieve-parenchyma ; next the elements of the Xylem, consisting of wide pitted vessels (two), three pointed wood cells, next annular and spiral vessels, and then wood parenchyma.

cambium is formed of thin-walled radial rows of cells in which cell-division goes on actively. The elements of the xylem and phloem are not readily distinguishable in transverse section; they are best studied in a longitudinal section of the stem.

The medullary rays are broad bands of parenchymatous cells which extend from the pith to the pericycle through the bundles. They are crossed by bridges of inter-fascicular cambium which join the fascicular cambiums of the adjoining bundles.

Note that the bundles are leaf-traces. By dissecting and teasing a small leafy twig, it is possible to follow the course of the bundles. In each node the foliar bundles, as they meet, anastomose and some of them fuse laterally, and they run down the stem in company with other bundles descending from the higher nodes. Lateral fusion may then take place in the internodes also.

II. Cut Longitudinal sections passing through one or other of the bundles. Select those that are fine, treat as directed under the first head, and observe :—

1. The *Epidermis* with the multicellular hairs.

2. The *Collenchyma* with abundant protoplasmic cell contents and chloroplasts, merging gradually into the thin-walled parenchyma of the cortex.

3. The *Endodermis* with its closely packed rectangular, starch-containing cells and the radial walls thickened.

4. The *Sclerenchyma* of the pricycle, just outside each bundle, formed of elongated, pointed, thick-walled, lignified (yellow with aniline chloride, brownish with chlor-zinc-iodine), closely dove-tailed cells.

5. The *Phloem* consisting of thin-walled cells of varying lengths containing abundant food matters. With chlor-zinc-iodine the cell-walls stain at least faintly violet, while the contents of the sieve-tubes, and more specially the *callus*, take a deep orange-brown colouration. Running side by side and parallel with the sieve-tubes are the elongated companion cells; in each a nucleus may be observed. The other parts

of the phloem consist of thin-walled parenchyma. Take a section; keep it in Alcohol for 10-15 minutes; wash and then place it on a drop of strong sulphuric acid for 1 minute; remove it, and mount in Iodine solution. The contents of the sieve-tubes are found to form yellowish or brownish strings.

6. The *Xylem* consisting of the spiral and annular vessels bordering on the medulla, the pitted vessels, being the largest, a little behind, the long and pointed tracheids, and the xylem parenchyma. All these are thick-walled and lignified, and take the characteristic yellow colour with chlor-zinc-iodine and aniline chloride solution.

The best material for the study and observation of sieve-tubes is the stem of Cucumber, or Gourd, or Water-melon, or the Pumpkin.

Cucumber :—

I. Cut transverse sections; select some very thin sections; mount some in chlor-zinc-iodine, others in aniline chloride solution; stain one specially fine with Eosin, wash in water, and mount in Glycerine. Observe successively with the low and the high powers.—

Note first the hollow (usually) five-edged, hairy stem which is rather soft and succulent; the bundles arranged in *two rings*—the *outer with* bundles just below the ridges, and the inner with bundles corresponding to the furrows.

1. The *Epidermis* consisting of one layer of cells with the stomatal openings and the hairs.

2. The *Collenchyma* immediately below (1) consisting of cells with their angles thickened, so that they appear to have rounded cell cavities, interrupted just below the stomata, but otherwise with no intercellular spaces.

3. The *Cortex* immediately below this, consisting of a few layers of cells, being thickest opposite the ridges and thinnest in the furrows. The collenchyma is found generally under the ridges.

4. The *Endodermis* a continuous layer of cells, being the inner limiting layer of the cortex, full of starch grains.

5. The *Sclerenchyma* which is very well developed as a continuous thick zone surrounding the bundles and the conjunctive tissues (p. 316). It consists of lignified cells and forms the outer differentiated part of

6. The *Pericycle*, the rest of which forms the bulky parenchymatous tissue in which the bundles are embedded.

7. The *Bundles* in two series, as noted above. The outer bundles are smaller and correspond to the ridges, the inner bundles are larger and correspond to the furrows.

8. The central *cavity* of the torn or disorganised pith.

The Bundles are *bicollateral* (p. 320). The xylem is coloured yellow by aniline chloride or chlor-zinc-iodine; not so the phloem. The widest cavities in the xylem are the vessels. In sections treated with Eosin or chlor-zinc-iodine the sieve-tubes come out very sharply as deep red patches, with violet or blue (cellulose reaction of cell-walls) lining in the latter reagent. The stained patches are the sieve-plates.* The constituents of the bundles appear more clearly in the longitudinal section.

II Cut longitudinal sections passing through the bundles; treat as directed under the first head.

Starting from the periphery we have successively the epidermis, the collenchyma, the soft cortex, the endodermis, the thick-walled, much elongated lignified, pointed dove-tailed cells of the pericyclic sclerenchyma, the soft parenchyma, and finally the bundles. In a bundle, note the phloem on the two sides of the central xylem. Between the outer phloem and the xylem is a layer of elongated thin-walled dividing cells—this is the cambium. Between the inner phloem and the xylem an almost similar but much smaller layer may be seen—this is *not* cambium, but has become permanent, separating the two

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* The best reagent for staining the callus of sieve-tubes is Russow's callus-reagent which is prepared by mixing equal parts of Chlor-zinc-iodine and Iodine in Potassium-Iodide solution.

adjoining tissues. The sieve-tubes stand out very prominently on account of their transverse sieve-plates. With chlor-zinc iodine the callus becomes deep brown; treated with potash, it swells and shows up the sieve-plate with its pores. To observe the sieve-pits more clearly, longitudinal sections should be treated with iodine throughly and then mounted in a drop of slightly dilute sulphuric acid, covered with cover-glass and then examined under the high power. The sieve-plates, being of cellulose, swell up and become blue, while fine yellow proteid threads may be seen passing through the pores.

Tinospora cordifolia (*Gulancha*, the climber).—

Cut transverse sections of a stem ¼ inch or less thick. Proceed as before.

1. The *Epidermis* consists of broken shreds of dead cells. A two-layered Periderm is in evidence. The cork cells are right rectangular and yellowish.

2. Next comes the many-layered *Phellogen*. The cells are very delicate, have very thin walls, and are arranged in very beautiful radial rows. The outer walls of some of the cork-forming cells on the outside are somewhat wavy or bulged.

Chlor-zinc-iodine turns the cork cells yellow, but has no effect on those of the Phellogen.

3. Below this is a layer of rectangular cells containing chlorophyll. Then follows a mass of loose parenchymatous cells with big intercellular spaces. The cells are filled with granular contents. This part is the *Cortex*.

4. Arranged in a ring, then comes the very fine wedge-shaped bundles. On the outside of each bundle is a pad of very thick-walled *Sclerenchyma* in 4 or 5 layers. Note the fine bore, and the thick walls, the absence of any granular contents from these cells. The sclerenchyma forms a semilunar pad, so that the whole ring of bundles is surrounded by it as a thick sheath except at the places corresponding to the medullary rays; the latter thus run directly from the medulla to the

cortex. The sclerenchymatous cells are yellowish, but take a more deep yellow colour with iodine or chlor-zinc iodine.

5. The *Bundles* are very beautifully shown up, as also the broad medullary rays running between them. The Phloem and cambium parts appear to be crushed, or at least not very clear. But note the sinuous *Endodermis* clearly marked out for their starchy contents in preparations in Iodine, from the sclerenchyma and partly enclosed by it. The cambium though ill-defined may still be traced as a layer between the xylem and the phloem. The xylem consists of radial rows of large ducts—these are pitted vessels; and in some the pits on the lateral walls may be seen clearly with the high power. With these ducts also run in parallel rows the thick-walled, rather round, and small xylem parenchyma.

6. In the *Medulla* the protoxylem elements can be easily traced at its periphery. The cells of the medulla are irregular, large, thin and show no further peculiarities.

This is one of the finest specimens for observing phellogen-formation. The phellogen occupies a comparatively wide zone, there being some 5 to 15 layers of cells The radial rows appear like so many ladders, placed side by side with the inner rungs rather wide apart, and the outer almost over-lapping. There is also a very thin layer—with cell-walls thin beyond measure—which is the initial layer of the phellogenetic tissue.

Mango (Mangifera indica).—

Cut sections from the youngest part of the shoot; wash well in alcohol; wash again in dilute sulphuric acid and mount in Iodine solution.

1. The *Epidermis* is clearly differentiated as a layer of very thick-walled, rectangular cells. The cuticle also is well developed. The thick walls of the cells appear yellow; in Iodine they are deep brown or reddish.

2. The *Cortex*, a narrow green zone, consists of small packed cells with not much inter-cellular space between. They are full of granular contents and chlorophyll grains.

3. Then comes the *Endodermis*, as a very well-marked

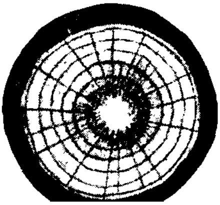
out deep yellow layer (in Iodine) with dense contents. The cells are in close lateral contact and have their radial walls thickened.

4. Below this is a bulky parenchyma with rather loose cells and intercellular spaces. This is the *Pericycle.* There are a few very large cavities or resin-passages arranged in a ring outside the ring of the bundles. Note that each passage is surrounded by annular layers of very small cells in uninterrupted contact. Surrounding these layers, again, are incomplete rings of very thick-walled cells which stain deep yellow or brown with Iodine.

5. The *Bundles* are very large in number, and form a complete closed ring. The medullary rays, even at this young stage, are very narrow, not broad as in the previous case (Gulancha). The fascicular and interfascicular cambiums are combined to form a complete ring, from which a dense mass of wood is formed. The xylem consists of radial rows of very wide ducts, the pits on the lateral walls being in evidence at many points. In Iodine the xylem elements stain deep brown or deep yellow, while the ill-defined cambium and phloem are not much coloured.

6. The cells of the *Medulla* are small and contain very fine starch grains in large numbers. That part of it which abuts on the xylem contains resin-passages similar to those found in the cortex. The primary elements of the xylem—the protoxylem—may be seen to form the *medullary sheath.*

FIG. 308.



Transverse section of Mango Stem, showing the annual rings and the thick Bark.

Sections taken from the older parts of the stem show the formation of the annual rings of growth, the layers of periderm, and bark. Such sections need not be examined under the microscope. A simple hand lens will enable the student to see the annual rings which may be apparent to the unaided eye even; but the lens will reveal the presence of wider wood-cells in one ring and smaller ones in the next adjoining it. It will also be noticed that enclosed by the impervious periderm layer is a layer of *bast*, or the secondary phloem prosenchyma, and inside this are the concentric layers of wood. In stout stems the central woody layers become coloured—the *Duramen*.

Guyava (Psidium Guyava).—

Lenticels, cork, periderm and phellogen can be very neatly seen in the stems of this plant. Note that the young stem is 4-angled and gradually becomes round as it becomes older. Cut transverse sections of the young green stem, and also of the mature stem the surface of which has become rather greyish or yellowish.

In the young stem, observe :—

1. The *Epidermis* of one layer of small roundish cells, not very well differentiated; the unicellular long hairs that arise from the epidermal cells. The cuticle is not much marked out.

2. The cortical cells have no very marked peculiarity, except that they are interrupted here and there to form the intercellular spaces.

3. Next is a zone of three or four layers of closely packed thick-walled cells which envelope the stele. This is composed of the cortical *sclerenchyma* and the *Endodermis*.

4. The *Bundles* forming a very close zone—rather 4-sided and wavy in outline—appear next. The protoxylem elements forming the medullary sheath may be clearly traced out. In the xylem the pitted ducts become apparent.

In the mature stem, observe :—

A layer of radially dividing brick-shaped cells, having very thin walls just below the ruptured epidermal cells—this is phellogen. Every thing outside this is yellowish, being composed of typical cork cells and a few scattered groups of very thick-walled sclerenchymatous cells. At some points a bulging of the cork cells through an opening may be noticed. These are the Lenticels. The ruptured shreds of the epidermis and a few cork cells will be found hanging loose at these points.

The outline of the stele is round here ; in all other particulars the tissues correspond to those examined in the section of the mango.

Rukta Drono

Here, as in many other Labiateæ plants, the stem is hollow and angular. Collenchyma will be found in plenty at the ridges, scarcely at all at the intervals. At some points on the epidermis, multicellular hairs on swollen bases will be observed. These are emergences ; they hold secretions of ethereal oils which give the attractive odour peculiar to these plants. Stomata will be found in the intervals between the ridges. The cortical parenchyma is rather loose at these intervals. These loose cells, as well as those of the collenchyma, contain chloroplasts and other granular cell-contents.

The Endodermis forms a very well-marked out sinuous layer comporting to the sinuous stele. It is well differentiated from the neighbouring tissues. The pericycle just below it forms only a single layer and is not prominent. In the xylem, the wider vessels are arranged in 2 or 3 rows—the rest being filled up with narrower and smaller elements. The pits on these vessels do not come out here so well as in the foregoing cases (in a tranverse section). The medulla is not entirely lost—only the central part being hollowed out ; the protoxylem elements intruding into the medulla may be noticed

Structure of Leaves.—

To study the structure of Dicot leaves :—(1) Cut transverse sections of the limina holding it between two pieces of smooth cork or pith, or (2) separate the tissues by macerating pieces of the limina in boiling Potash solution.

Most leaves are soft and succulent, so that they are readily crushed out of shape when held between pieces of cork for sectioning Hence they should better be hardened in alcohol for a few days. Alcohol secures the additional advantage of removing the green colouring matters which are normally present in such enormous quantities as to make it difficult to distinguish the cells and their contents. Many leaves are stiff enough to escape injury by crushing. They can be folded over many times to form a thick cushon-like mass from which sections may be taken *in the* transverse *direction. In this way very fine sections* may be obtained from the Banyan leaves or from those of similar plants By tearing leaves obliquely and sharply a little epidermal or cuticular part may be isolated and examined immediately in water with the microscope.

The structure of all leaves consists typically of the parts represented in fig. 295. That is in each leaf there are the following parts.—

1. The *Epidermis* of the upper surface with a more or less developed cuticle, and hairs and stoma.

2. Immediately below, the subepidermal tissue forms the *pallisade parenchyma*, with its right rectangular cells containing chlorophyll and other granular contents.

3. Next is the *spongy parenchyma* with roundish or irregular cells and intercellular spaces between, and contents similar to above.

4. The lower *pallisade* tissue, not much developed in ordinary cases, and may be altogether wanting.

5. The lower *Epidermis* with comparatively more stomata.

The parenchymatous leaf-tissue enclosed by the epidermis is designated *mesophyll*; through it, more particularly through the spongy mesophyll, the vascular bundles—the veins—run.

Sections from leaves which have not been decolourised by alcohol or potash show the presence of green chlorophyll corr chloroplasts in the protoplasm of the mesophyll-hese green corpuscles absorb a part of the solar nd give the necessary energy for the preparation of d. In some leaves, e. g., in the young leaves of Cinnamon, Asoka etc, the chlorophyll is partially or the time being by a reddish or bluish colouring lled *cyanophyll*.

es the above general characters, there may be found lual cases the following deviations from the type.—

Thick cuticle, as in Agave and succulent and fleshy leaves.

Sunken Stoma, as in the India rubber plant.

Cystoliths in the epidermal cells, as in the Ficus (Banyan) plants.

Hairs—multicellular or unicellular.

Pallisade tissue two or more layers deep.

Wax layers, as in the poppy leaves.

cture of Roots.—Examine any common young Dicot bserve, in general.—

he *Epidermis*, composed of rather loose cells some grow out as root hairs (a little below the apex of the ots). On account of its bearning these root hairs called the Piliferous layer.

he *Cortex*, composed of thin-walled round cells with lar spaces between. There are granular contents, starch grains, in these cells.

he *Endodermis*, very clearly developed and differen-om the rest as a single layer of closely packed cells. enings in the radial walls are clearly noticeable.

he *Stele* immediately enclosed by the endodermis. consists of :—

he *Pericycle* of one layer of cells. Note the origin rootlets from the division of some of the pericyclic

he primary *Xylem* bundles running in radial manner.

The smaller protoxylem elements are towards the pericycle ; the bigger and later formed xylem vessels are towards the centre. The youngest, softest and the widest vessel is at xtreme limit of the xylem strand in the axis of the root.

(*c*) The Primary ***Phloem*** bundles alternating with the xylem. The hard bast is readily distinguished from the rest as all the ther parenchymatous tissues in the neighbourhood contain bundant starch grains.

For the secondary growth of Dicot roots see p. 332. The ylem strands consist of spiral and annular vessels in the rotoxylem, and scalariform and pitted vessels in the rest.

Generally in roots, the piliferous layer is soon lost by rupture r other causes. A layer of the outer cortex becomes then ifferentiated as the outer endodermis or *Exodermis* which is ceptionally clearly marked out in the aerial roots of epiphytic onocots. In underground roots the exodermis or hypoderal root-tissue persists after the loss of the epidermis and function replaces it.

SECTION II

MONOCOTS.

Common Grass.—Cut transverse sections from the rhizome of common grass. Mount some in glycerine; others in chlor-zinc-iodine. and aniline chloride solution respectively, Examine first with the low power, and finally with the higher powers, to study the tissue-elements in detail. Observe.—

1. The *Epidermis*, formed of only one layer of cells, which is not much differentiated from the sub-epidermal tissue.

2. The bundles of *Sclerenchyma* which occur in large numbers studded in the sub-epidermal tissue at regular small intervals The bundles are wedge-shaped, with the pointed ends facing the centre. The component cells are very thick-walled, have very fine bore, and no living contents. Unstained by chemical agents, they appear as yellowish masses. They function as mechanical tissues.

In chlorzinc-iodine, the sclerenchyma becomes deep yellow or brownish, and is thus brought into more prominence than the adjoining cells. The epidermal cells are not much affected. Aniline chloride gives almost an identical reaction.

3. Between the strands of sclerenchyma, the outer part of the fundamental tissue differentiated as layers of *Collenchymatous cells*; these are small, thick-walled, roundish, and contain chloroplasts and other living contents. The rest of the ground tissue is rather loose, the cells in the centre being bigger than those in the peripheral parts. The vascular bundles are scattered irregularly in this ground tissue.

4. The *Vascular bundles* occurring in pretty large numbers, traversing the ground tissue. A few bundles—smaller than the others—run parallel to the sclerenchyma a little behind the intervals left between the adjoining sclerenchyma strands. These are the peripheral bundles; those that are found in the

central part of the ground tissue are larger. In other respects the structure of the bundles does not differ in the two kinds.

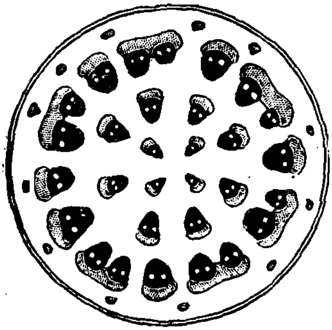
5. Each *Bundle* being of the typical Monocot type *viz* closed and collateral. The whole bundle proper consisting of xylem and phloem is encased in a thick sheath of very thick-walled sclerenchyma which thus froms the vascular bundle-sheath in Monocots See Fig 302. This sclerenchymatous sheath is very thick on the side of the xylem, which is easily recognised from the presence of 3 or 4 very large vessels or ducts.

The Sclerenchyma sheath acts as the mechanical tissue and consists of elongated lignified cells. It may closely invest the whole bundle, or may be interrepted just on the two flanks (as in many other Monocot stems). The cells rarely contain any living matter, and are generally empty. Chlor-zinc-iodine and aniline chloride give the ordinary yellow colour as with lignified cells.

The *Xylem* is that half of the bundle which faces the central axis. It consists of 2 or 4 vessels arranged like the limbs of the letter V, and a number of smaller tracheids and wood-cells. The biggest two cavities on the flanks are the pitted vessels, and are formed comparatively later than the spiral and annular vessels which occupy the narrow end of the xylem. Very often, specially in the larger central bundles, there occurs a wide irregular cavity (*L.* fig 302) which arises from the disorganisation or rupture of the first formed xylem elments; hence this is really an intercellular (lysigenic, see p 278) space. The torn annular bands that may be occasionally found in this cavity are the torn remains of the first formed annular xylem vessel. Each of the other vessels will be found, under closer examination, to be surrounded by layers of thick walled parenchymatous cells of the xylem--the xylem parenchyma. All these xylem elements are strongly lignified, and hence take the characteristic yellow or brownish colouration with chlor-zinc-iodine or aniline chloride solution.

The *Phloem* occupies the outer part of the bundle. It consists of sieve-tubes as the widest cavities, and the companion cells following closely, regularly alternating. Surrounding these phloem-elements is phloem-parenchyma which abuts on the inside upon the xylem parenchyma and on the outside upon the sclerenchyma sheath. The protophloem elements are crushed and remain just below the sclerenchyma on the phloem-side. The phloem cell-walls will very likely take a shade of violet with chlor-zinc-iodine, and the contents of the companion cells will be distinctly yellow or dark. Aniline chloride will give no colour-reaction at this part.

FIG. 309



Transverse Section of the stem of Date Palm. The shaded parts are the sclerenchyma strands; the black parts are the bundles.

In longitudinal sections, passing some through the bundles, others through different parts of the fundamental tissue, all the above elements may be examined with better advantage, and their relative position may also be studied with more clearness of detail. The epidermal cells will be found to have oblong shapes; those of the ground tissue, irregular and roundish. The hypodermal elements will appear as long fibres in some sections (sclerenchyma), thick-walled and roundish in others (collenchyma). The elements of the bundle and those of its sheath, will show up their cell forms, contents etc. Thus the sclerenchymatous cells of the sheath are not pointed, but have blunt extremities. The sieve-plates may be brought into view by following the directions given in p 342.

Cyperas Rotundas.—*(Mootha).* Take transverse section from the 3-sided culm. The epidermis is not very well differentiated except that the cells are very small and form a thin layer interrupted at certain points (stomata). Strings of sclerenchyma occur at many points in the sub epidermal tissue, and are specially developed at the angles. The peripheral fundamental tissue only is green and full of granular contents. It is at this part only that small bundles are scattered. The central part is composed of loose and comparatively big parenchymatous cells. The bundles are almost similar to those described in the previous case. In the central fundamental tissue there are some special groups of cells—one large cell in the centre surrounded by a ring of smaller ones.

In **Palms** the bundles though distributed almost uniformly over the whole fundamental tissue are specially crowded towards the periphery as in the grasses. But unlike the latter, Palms generally have the larger bundles arranged in a ring on the outside ; while the smaller bundles are similarly arranged in other rings towards the inside. Fig. 309 shows the structure of the Date Palm (*Phœnix dactylifera)* diagrammatically. It will be observed that the sclerenchyma of the bundles forms pads supporting them from the outside Hence in a cross-section the sclerenchyma appears as a specially thick and bulky tissue on the outer side of the phloem of the bundles.

In **Bamboos** (*Bambusa)* on the otherhand, though the bundles are disposed in a manner similar to the above, the mechanical tissues appear as massive plates on the inner and outer side of each bundle—that on the inner being by far the bulkiest. As in all Monocots generally, collenchymatous and sclerenchymatous tissues also occur in the subepidermal part. Again, in **Sugar-cane** *(Saccharum officinarum)*, there is a thick zone of thick-walled cells at the periphery just below the epidermis. At isolated parts of this zone big air cavities and sheath-less vascular bundles alternate regularly. And imbedded in the soft parenchyma of the axis lie a few scattered bundles arranged in a ring, with the usual sclerenchyma sheath.

Root of Monocots.—The structure of roots of Moncots does not differ in material points from that of Dicot roots. The adventitious roots of Onion, Wheat or Maize may be examined. In Monocot roots secondary thickening does not take place. The stele is composed of a limited number of xylem bundles. In Onion for instance the xylem parts radiate from the axis in the form of six-rayed star; hence the stele is described as *hexarch*. Thick Dicot roots have generally *polyarch* steles and so also have many Monocot roots

The structure of aerial roots of Orchids (*Rasna*: Vanda) and epiphytic Aroids is peculiar. In place of the loose parenchymatous cells of cortex there is developed a mass of porous tissue (the velamen) which consists of oblong tracheids with ladder-like thckenings. In a cross-section of the aerial root of Vanda, observe :—

1. The Epidermis and the sub-epidermal tissue containing chlorophyll. The third or fourth layer from the outstde is the exodermis which divides the cortex into two parts,—the outer chlorophyll-containing part from the inner air- (or water) containing tracheids (velamen).

2. The irregularly oblong cells of the velamen which show up their very fine scalariform rungs.

3. The Endodermis is very well differentiated as a strongly marked layer. The cells are rectangular, in close contact, and are thickened strongly all round. At isolated parts of the endodermis there are a few special cells these are unthickened, soft, and contain protoplasmic matter unlike the other endodermal cells. The thickened endodermal cells stain very deeply with safranin or chlorzinc-iodine; the unthickened cells are not much affected. These cells are called *Passagecells*, because they give passage to water from he outside to the stele.

4. The stele is like that of ordinary roots.

SECTION III

PTERIDOPHYTA.

Structure of Fern Stem :—Several specimens of Ferns commonly growing wild in this country may be examined. They are typically polystellic in the stems, but the separate steles may as well be considered as schizosteles, for there are many cases in which a gamostely results from their fusion. The following is a case in point.

Cut transverse sections of the leaf-stalk of the common Asplenium. Mount one section in chorzinc-iodine, another unstained in glycerine, and a third in aniline chloride solution. Observe under the microscope:—

1. The *epidermis* composed of narrow cells in one row with thick dark-brown outer walls. These become still more deeply brown with chlorzinc-iodine.

2. Immediately below this a zone of tissue with very thick-walled, compact, yellow, lignified cells. This is the outer *sclerenchyma.* It forms some 8-12 layers of cells which contain but little granular matters. In chlorzinc-iodine or aniline chloride it takes a very beautiful golden yellow colour, and in the former black or deep blue spots may be found in the cavity of the cells

3. Encircled by this ring of sclerenchyma is the soft-walled parenchymatous cells of the fundamental tissue traversing which in an irregular horse-shoe form is the *stele.* The outline of the stele is very peculiar in appearance, but note that there is a well defined endodermis separating the stellar tissues from the ground tissue. For a detailed study of the stele, select the widest part at the angles and focus the high power. The most prominent things to attract attention are the great vessels,—that these are *scalariform vessels* is evident from the ladder-like thickenings that

appear on their oblique walls. The vessels occupy the central part of each stele. Surrounding them is a layer or two of thick-walled *wood parenchyma* with abundant granular contents. These granules are chiefly *starch grains*, as evidenced by their turning deep blue or even black with chlorzinc-iodine. At some parts of the layer of vessels, (more commonly at the ends of the plates) may be found groups of wood cells with scalariform or spiral thickenings. These are the *Protoxylem* elements. The scalariform vessels and the starch containing wood cells form the only mature elements of the xylem-part of the stele. Surrounding these is another layer of wide cells which are thin-walled. These are the *sieve-tubes*, following which externally are the narrower phloem-elements—the bast parenchyma. Like the wood-cells, the bast-cells are rich in granular contents; but these are not starch but proteids and stain yellow with chlorzinc-iodine. The pericycle comes next; its contents are starch grains. Surrounding again all these stele-elements is a layer of almost rectangular cells in close lateral contact, which contain starch grains. This is the endodermis. The walls of these cells are thickened and stain yellow with chorzinc-iodine.

4. Between the endodermis and the sub-epidermal sclarenchyma is the thick layer of the parenchymatous ground tissue. That part of it which abuts upon the outer sclarenchyma is more compact, while the rest is rather loose and spongy.

In longitudinal sections the scalariform vessels, the pointed thick-walled sclerenchyma cells, and the other elements of the stele become more prominent. Under the high power the sieve-tubes are seen with very good effect. On the walls of the sclerenchyma fibres diagonal pits, as very fine lines, may also be detected.

Equisetums.—These are the only Pteridophytes in which the vascular bundles are arranged in a ring as in Dicots and Conifers. In a cross section of an Equisetum stem observe :—

1. The superficial furrows and ridges.
2. The central large air-cavity making the stem hollow.
3. Similar though smaller air-cavities in the cortex.
4. The vascular bundles arranged in a ring forming the Stele.

Observe more minutely with the high power :--

1. The *Epidermis* (with its cell-walls impregnated with silica) provided with stomata at the furrows.

2. The *Cortex* differentiated just below the ridges as strings of sclerenchyma fibres, and as ordinary chlorophyll containing cells just below the furrows.

3. The cortical air-passages corresponding to the furrows, and hence called *Vallecular cavities*.

4. The central cylinder bounded on the outside by a ring of *Endodermis* with the radial cell-walls thickened and cutinised.

5. The Vascular bundles closed, collateral and common ; the xylem towards the interior, the phloem towards the exterior. The *Xylem* consists of annularly and spirally thickened tracheids, and at the inner side there is a small cavity or air-passage arising from the tearing of the protoxylem elements. These air cavities lie under and correspond to the superficial ridges and hence are called *Carinal* cavities. The *Phloem* consists of almost similar cells (in the cross section) which have abundant cell-contents.

6. The bundle-system is bounded externally by a layer of cells rich in starch ; this is the *Pericycle*.

Lycopodium.—Here the stem is *gamostellic*. In a cross section the following parts may be observed :—

1. The *Epidermis* with cutinised outer walls.
2. The *Cortex* with wide and thin-walled cells, forming a rather wide zone.
3. The more internal parts of the cortex developed as a thick-walled compact mass of *sclerenchyma*, forming a zone of varying number of layers.

4. The *Endodermis,* the innermost lining layer of the sclerenchymatous cortex.
5. The *Stele* (gamo) which occupies the centre. The xylem strands occur as plates of very thick-walled wide cells separated (wholly or partially) from one another by plates of the soft phloem. The xylem consists of broad scalariform tracheids (true vessels are as a rule not formed), and surrounding these on the two sides of each plate are small wood-cells. The phloem plates consist of sieve-tubes and bast-cells. The seive-tubes can with difficulty be picked up, even in longitudinal sections. The protoxylem elements can be found at the thin edges of the xylem or phloem-plates.

Selaginella.—These Pteridophytes are generally polystellic ; but in some cases only one stele may is formed. In a cross section of the stem, observe :—

1. The *Epidermis,* a layer of thick-walled cutinised cells.

2. The *Cortex,* differentiated at the outer part into a zone or ring of thick-walled, elongated, lignified cells, forming the *sclerenchyma.* Next to this is the soft parenchymatous chlorophyll-containing cells of the ground tissue in which are two (or three)

3 *Steles.* Surrounding each stele is a ring of air-space bridged by rows of cells—the *trabeculæ*—which represent the *Endodermis.* Each stele consists of concentric elliptical rings of, (*a*) *pericycle,* (*b*) *phloem,* and (*c*) a central solid plate of xylem. The stele is suspended by the trabeculæ in the middle of the large air cavity, and hence in cutting sections the steles are often displaced or lost as the thin cell-walls of these bridges are ruptured. The xylem consists mostly of large scalariform tracheids surrounded by rings of smaller wood-cells. The phloem consists of sieve-tubes and phloem-parenchyma. At the extremities of the plates the protoxylem and the protophloem elements may be observed.

SECTION IV.

CONIFERS.

Stem of Pine.—Here the annual rings are very distinctly seen, as also the periderm or cork and the cambium. The wood consists almost exclusively of tracheids, excepting a few spiral or annular vessels in the protoxylem. The abundant resin passages are also characteristic of this plant.

In sectioning take the very young shoots, preferably the axis of the buds preserved in alcohol; cut transverse sections and proceed as directed in the previous cases. Observe:—

1. The *Epidermis* with the cuticle in the very young stem, or the periderm which replaces it in mature stems.

2. The *Phellogen* layer, which is formed very early, consisting of radial rows of cells.

3. The many-layered *Cortex* consisting of rounded cells with cellulose cell-walls. Some of the cells contain starch, others tannin.

4. The *Resin passages* in the cortex, arranged in a ring. Each passage is surrounded by a ring of small delicate cells, the epithelium cells, which secrete resinous matter.

5. The wide zone of *Vascular bundles.* The phloem part is separated from the xylem by a very fine but distinct layer of cambium. The xylem part is made up of parabolic masses, the narrower ends of which project into the central pith These are the protoxylem elements, and consist mostly of narrow elements and spiral and annular vessels. In a longitudinal section these come out to the best advantage. The rest of the woody mass is composed entirely of *tracheids* with bordered-pits on their surface and blunt extremities. The Phloem consists of thin-walled sieve-tubes, and thick-walled dull-white bast cells. Companion cells are not formed.

6. At some parts of the older wood *Resin passages* occur.

The epithelium cells which line each passage contain yellowish cell-contents and are bounded on the outside by starch-containing wood parenchyma.

By mounting sections of very young pine stems in tincture of alkanet the contents of the resin-passages and epithelium cells can be stained, and thus differentiated from other cell contents. Cells containing resinous matter take up a very fine dark-red colour while all other parts of the section remain entirely uncoloured.

In chlorzinc-iodine the lignified tracheids take up a yellowish brown colour; the later woody cells bordering upon the cambium show up their protoplasmic contents by being stained yellow. The older wood parenchyma, the outer cortical cells, and the bast cells show up the dark blue spots of starch. The walls of the epithelium cells take a dirty violet colour showing that they are of cellulose.

In unstained preparations the white radial rows of cells that traverse the yellowish wood and the colourless bast, are the 'silver grains' or medullary rays. In older parts of the stem the annual rings are very beautifully shown np. The tracheids are ordinarily four sided, but become regularly and alternatingly wide and narrow in summer and winter or autumn respectively·

CHAPTER XIX.

Influence of Environment on Plants.

Ecological Classes of Plants.—

It is a matter of common observation that the vegetations of different regions of the earth, where the prevalent climatic and other physical conditions are different, show well-marked differences in their common peculiarities. Thus water plants are soft and delicate, land plants are hard and woody, desert plants still more so, high-land plants are dwarfy or naked, low-land plants are bushy and dense, forest plants are often climbers or tall, and so on. The study of the relation of plants to their environment, that is, the influence which the latter brings upon plants in shaping their structure, is known as **Plant Ecology**.

The structure of plants, as has been mentioned on p. 231, depends upon two comprehensive causes:—First, upon the internal organisation of the protoplasm which it derives from its ancestors; and secondly upon the responsive power of the protoplasm to so adapt itself as to remain in harmony with the external world, or the environment. No doubt, it is still a debatable point how far one or the other of these causes, is responsible for plant-structure, and whether any line can really be drawn between them. But the weight of evidence that has been collected from direct experimentation, and still widely from close observation, is on the side of proving environment to be a proximate cause of structural variation. It is not possible, in many instances of course, to make a water-plant live in sandy or desert tracts, or a sturdy land-plant to live immersed in water; still instances are not wanting to make it experimentally demonstrable that a plant removed from its natural medium and carefully reared up in a foreign and quite different medium, shows unmistakeable signs of variation, the significance of which can only be explained as being adaptive. Similarly, if seeds of the same parent be allowed to germinate and grow in different soils having different physical and climatic associations, the colonies of plants that originate, though showing common characters so long as those associations are almost common, manifest some very significant structural changes when they are not so.

Nothing, however, is more certain than that the surface of earth is divisible into zones or belts or regions where the conditions offered to life vary greatly. Thus, attempting at classification, we can divide the terrestrial surface as under.—

(1) the region or sphere of the gases,—the Atmosphere :
(2) the region or sphere of water,—the Hydrosphere ;
(3) the region of the sandy, salty and porous sea-shore ;
(4) the region of the ordinary soil or land ;
(5) the region of the dry, hot, arid lands or Deserts ;
(6) the region of the stones or Rocks.

We begin with the lightest region and proceed successively through those that are more and more hard. Omitting minor details, it will be apparent that the prevailing characters of these regions are fundamentally different from one another. Hence it is but natural to conclude that the flora of each of these regions will show some common characters, and that the difference between the flora of one region and another will be as great as that between the corresponding physical characters. But as environment is not built up solely of the hardness of soil, but is dependent also upon temperature, humidity, altitude etc, any attempt to classify plants in accordance with the above divisions of the globe would be unscientific. Notwithstanding this defect the following classification, according to the above plan, merits simplicity and will be easily understood.

1. Plants that live suspended in air, though supported by other structures—*Epiphytes.*

2. Water-plants or those that remain partially or wholly submerged—*Hydrophytes.*
3. Sea-shore-loving plants, or those that live on saline soil—*Halophytes.*
4. Land plants—*Mesophytes.*
5. Desert-plants—*Xerophytes.*
6. Rock or stone-plants—*Lithophytes.*

Mode of Nutrition and Plant-Structure.—The habitat of a plant, as defined by the above divisions of the earth, is responsible for its structure. But no factor in plant-life is more important than nutrition, and this latter process depends upon the habitat, or the environment. When we say that environment influences plant-structure, what we really mean is that the nature of the locality in which a plant lives determines in what way food-absorption and other cognate plant-functions are to be carried on; that is, what particular tissues, what organs, what cells—in short, what *structures*—are to be developed in order that those functions may be best carried on. No matter whether a plant is composed of a single cell, or a vast collection of cells, it depends for its food upon its environment. For the amount of water which is not only the common vehicle of all plant-food but is also the organic essence of all plant-structures (see water of organisation), varies in different soils, and is adulterated with various soil-constituents injurious to active vegetation. Sea-shore, for instance, abounds in saline water, and common salt is not one of the essential food-substances. Again the water of ponds is rich in plant food; in deserts, water is scarce; in peat-bogs and marshes, water though abundant, contains a large amount of organic matters, acids etc. Thus plants are required to adapt themselves in order that they may cope successfully with these adverse circumstances, and consequently this adaptation is with regard to the tissues. Hence we may as well say, that *mode of nutrition determines plant structures.* To illustrate this proposition we shall take some of the great Ecological classes of

Plants. Besides those that have been named there are a few more 'classes,' and of these the *saprophytes* rank foremost. These are plants that live entirely upon decaying organic matters. Their mode of nutrition, thus, differs infinitely from that in green plants. For, while in the latter the sun is the sole driving power, so to say, of the whole mechanism of nutrition—it being remembered that transpiration or the ascent of the nutrient sap takes place only in light—in saprophytic food-absorption, sun-light is not a necessary factor. Hence the total absence of chlorophyll-tissue, of lignified tissue—in fact, of any proper tissue—from all saprophytes is significant enough. Equally significant is the fact that those plants that are entirely parasitic do not develop leaves or the green cortex. Ecologically leaves are little more than expansions of the green and porous cortex; they are adaptive mechanisms for gaseous exchange.

Xerophytes.—These are plants which live usually in dry, sandy localities, or deserts, or places in which the supply of water is small. They are characterised by having adopted contrivances to keep down loss of water by transpiration, and to enhance absorption and retention of water.

The conditions of the environment against which these plants have to struggle, and consequently to adopt protective expediencies, are.—

(1) *want of free water in the soil.* This may depend on (a) want of rain, as in deserts, and (b) porous nature of soil, where the particles are so much sandy and loose that water passes out by percolation soon after the soil is wet.

(2) *frozen nature of the soil.* Water in the form of ice can never be utilised by plants, and besides very low temperature has a decided injurious action upon protoplasm.

(3) *high temperature and dryness of the atmosphere.* Under this circumstance, it is well known, how water evaporates rapidly. When there is very little water in the soil and too

much evaparation, necessarily there is very little left for the plant to subsist upon.

(4) *reduction in the pressure of the atmosphere.* This is another factor which favours loss of water by transpiration.

Accordingly the more important habitats of xerophytes are :—

1. *Deserts and Steppes*, where there are dry soil, dry air and great heat.

2. *Barks of trees*, which being porous very soon dry up.

3. *Sandy soil* and *Sea-shore*, where the soil is not only porous but is also rich in saline matters which impede absorptive process.

4. *Polar Zones*, which are mostly frozen and intensely cold.

5. *Mountain highlands*, where the air is under reduced pressure, and other climatic and edaphic factors are prevalent.

Adaptations in Xerophytes.—As contrivances for absorbing what little water they may find in the places where they grow, for retaining this water within their body, and for diminishing the loss of water by transpiration through leaves, xerophytes, in general, exhibit the following main characters :—

1. Morphological.—

1. The Root is very long ; indeed desert-loving plants develop very complex and stout root systems. The physiological significance of such elongated roots is no doubt the responsive power of the root apices to move towards moisture. This *hydrotropism* as it is called, constantly sends the roots more and more downwards in sandy soils, where the subsoil water is rather deep. Schimper mentions cases of desert plants which develop two systems of roots ; one, that which goes downwards and is by far the strongest, penetrates the dry soil and seeks the deep-lying subsoil water, and the other merely trailing or burrowing in the soil, formed during the rains to absorb the surface water.

2. The Stem is often of stunted growth. The great intensity of light coupled with the other hard climatic factors, impe-

des the upward elongation of the stem. It is commonly known that plants elongate very rapidly in darkness, so much indeed that roughly speaking it may be said that they assimilate during day and grow during night. It must not be supposed, however, that plants will continue to grow if kept in darkness indefinitely; indeed prolonged darkness acts fatally on them. Again many plants tide over the hot periods by assuming tuberous, bulbous, and rhizomous forms; and thus remain underground during these periods, sprouting up with foliage and flowers in the rains.

3. The Foliage of desert plants is but poorly developed; in many places it is not developed at all; in many others it is spinous. This reduction in surface, though a means of checking transpiration, is in many instances compensated for by an increase in volume. Thus the vegetation of some African deserts consists of succulent plants. In our country, instances of such succulent plants are, in the Agaves, the Bryophyllum (Pathurkuchy), many Spurges, the Cactii (Phani-mansa) etc., The climber Hoya carnosa so very common on Palm trees has succulent leaves. Succulence of leaves is really due to the very strong development of the tegumentary tissue, which thus not only reduces to a great extent the heat of the sun but also prevents the actual removal of water from the leaf-tissue.

4. Extreme hairiness of the aerial parts is another xerophytic peculiarity. The hairs often contain only air, and thus act as a non-conducting cushion, cutting off a part of the intense heat. Where hairs are not present, their work is carried on by a thick layer of wax which takes their place.

Desert plants are mostly thorny, some are succulent, and some are almost like ordinary land plants. But the form of the plant varies at different xerophytic habitats. Some of the semi-desert tracts of Mexico, for instance, contain only globose aphyllous stems, with spines on their surface to represent the leaves. Some tracts in Sahara contain only thorny but branched woody plants with no actual leaves which, however, may appear only during the rains. Oasis tracts of the Arabian deserts on the other hand, abound in Palms. The arid sandy plains of the Cape are rich in small herbacious but succulent plants.

2. Histological.—

1. The Epidermis is very strongly developed in almost all desert plants ; correspondingly the cuticle becomes thickened and impregnated with cutin. There generally occur outgrowths of hairs or layers of wax on the cuticle. These are no doubt additional protections against too much loss of water.

2. The palisade parenchyma of leaves is also very strongly developed. And as leaves of many xerophytes point their edges, instead of their surfaces, to the earth and the sky, the palisade tissue is formed on both sides in them. As a rule, the palisade cells are elongated.

3. The intercellular spaces and other larger air cavities are extremely reduced. Hence succulence of leaves, where it occurs, is not really due to the presence of cavities as water-reservoirs, but to the succulent cells themselves.

4. The stomata are sunk in the sub-epidermal tissue.

5. The sclerenchymatous elements and other mechanical tissues are strongly developed. The spinose character of many leaves is due to this predisposition for sclerenchyma formation. Similarly thorny stems are so formed because of the lignification of the terminal cells. The general tendency of pronounced desert plants is to augment the hard lignified structures and cells, and to minimise the soft parenchymatous cells.

6. The Wood and Bast are very fully developed and go on forming centrifugally in Dicots. In many instances, the pericycle also is lignified. More usually a thickened band of sclerenchyma immediately invests the ring of wood. All these contrivances for the lavish development of lignified tissues, of vessels etc, lend weight to the inference that they are adaptations for enhancing absorption of water from the soil.

The reduction in surface of leaves, of the intercellular spaces of the transpiring surface, the augmentation of the cuticle and the layers of palissade, the formation of hairs or wax, the sinking of the stomata, the strong lignification, the poor parenchyma—all clearly point to the adaptation for increasing absorption and retarding transpiration of water.

Tropophytes.—There are climates and soils that are alternately dry and wet. Plants that inhabit these regions have accordingly adapted themselves to the various conditions as regards the supply of water during the different seasons of the year, and are called tropophytes. In times of scarcity of water, for instance, they are xerophytic, and in times of a plentiful supply of water they are hygrophytic. Hence tropophytes adopt alternately xerophytic and hygrophytic contrivances to fall in with their environment. The regions which they inhabit are either alternately hot and cold, or dry and moist. The Teak tree (*Tectona grandis*), for instance, produces a luxuriant foliage during the monsoon but in dry season the leaves are shed and the pointed naked stumps of the branches thus reduce transpiration or loss of water to a minimum. Similar is the case with many other Indian trees—the Banyan, the Bombax (Shimul Cotton) the common Plumeria acutifolia (Katchampa, of temples), the Ægle marmelos (Bilva or Bel) etc. And while woody plants shed their leaves many herbacious plants lose their ærial parts periodically. In the cooler regions of Europe, where the ground is frozen in winter, herbacious tropophytes adopt the xerophytic contrivance of remaining dormant as underground bulbs and rhizomes during this period, and they sprout up again in spring with an abundant foliage. As Schimper says "periodic foliation and defoliation is indeed particularly characteristic of tropophytic districts, for the defoliation is very complete and foliation very luxuriant."

Halophytes—These are plants that thrive best in saline soils. They are not capable of struggling successfully with other plants in non-saline regions ; but in their own soil they would soon crowd much too luxuriantly to allow non-halophytes to have a footing. Most of our edible vegetables are halophytes; for instance, cabbages, turnips, radishes and other cruciferous plants. It is common knowledge that these plants require careful cultivation, and that they flourish most in soils comparatively rich in saline or alkaline salts. Experiments on plant-nutrition have shown that concentrated saline solutions impede the osmotic absorption of water through the root-hairs, and hence halophytes are provided with contrivances for lessening transpiration. Thus halophytic characters agree with some of those that are found in xerophytes. Of these the following are the most common. Reduction of the transpiring surface by diminishing the superficial extension of leaves and rendering them succulent and fleshy; thick outer walls of the epidermal cells; sunken stomata; abundance of mucilage as cell-contents; water-storing cells; in some cases abundant production of hairs; reduction of intercellular spaces; and reduction in the comparative amount of chlorophyll.

Further examples of Indian halophytes are in:—*Cocos nucifera* (cocoanut), the natural habitat of which is in the saline soil of the sea-shore of Madras and Ceylon; *Terminalia Catappa* (the country almond); *Erythrina indica* (Palitamandar), growing wild in the salty sundribans; *Beta vulgaris* (or *benghalensis*), the common cultivated Beet (palung shak); *Basella* the common succulent herb, and other Chenopods; some Plumbaginaceæ; Calophyllum Inophyllum (Sultana Champa) of the Orissa Coast and many others.

Though they have their native seat in saline soils, halophytes can thrive well on ordinary non-saline soils. Indeed most plants that are themselves halophytic, or trace their descent from halophytes, are cultivated in our gardens; but in a wild state, when there is a competition between halophytes and non-halophytes on a common non-saline soil, the former are driven out of the field. By long and careful cultivation, however, many halophytic plants are gradually losing some of their peculiarities—their succulence, for instance—and reverting to the type of the ordinary landplant.

Hygrophytes.—The structural modifications of aquatic plants bear a close resemblance to those mesophytes which ordinarily thrive in shady, moist places. These water-loving mesophytes, termed Hygrophytes, form a link between the typical land plants and the typical water-plants. The structural peculiarities which they exhibit are no doubt due to the watery environment; and the very pronounced way in which these peculiarities are developed in water-plants makes the conclusion irresistable that water is a determinating factor of plant-structures. In typical hygrophytes—such as Banana, Ferns, small Palms, many Aroids, Balsams (Dopaty), Canna and many other shade-loving plants—the roots are poorly developed, the stems are elongated, and the leaves are large, thin and plentifully supplied with stomata. In short, the adaptation is such that the greatest facility is given for *loss* of water by transpiration. The danger to which hygrophytes are exposed arise from a stagnation of the transpiration current; for if the large amount of water which is taken up by these plants be not given a ready outlet, obsession will follow, and circulation of food matters within the body of the plant will stop. This is obviated by the development of very large and thin leaves. And where such plants periodically receive heavy showers, an additional contrivance in the shape of a long drawn out leaf apex to effect a speedy drain of the rain-water, or of a silky coating on the surface which (as in the colocasia) makes the water run into drops without wetting the epidermal tissue, is most commonly adopted. In very damp situations, such as ditches, banks of ponds etc, there is still another adaptation for expediting loss of water. Drops of water falling like dew-drops from the leaf-apices of many Aroids (such as colocasia), Grasses, Bamboos etc are common phenomena. The epidermal pores or passages which thus press out water are called *Hydathodes* It is also said that the variegated coloured spots found so commonly on the leaf surfaces of many garden Aroids are some how connected with this exit of water.

Typical hygrophytes, such as Lycopods, Banana, Canna and Aroids are characterised by being provided with ample intercellular spaces. Large air-passages or *lacunæ* are found no where except in water-loving and aquatic plants. The air chambers of Equisetums, Grasses, Selaginellas and Marsilia have already been mentioned. Equally characteristics are a diminution of legnified elements, a degeneration of the stele, and a general predominance of soft walled parenchymatous cells. Thorns and spines are almost rare, and when hairs or wax-coatings occur their function is merely to render the plant surface unwettable. A still another characteristic is the presence of chlorophyll in the epidermal tissues. Hygrophytic vegetation corresponds to a plentiful supply of water and the main direction towards which it works is to maintain a vigorous transpiration not only through the stomata but some time also through the outer epidermal walls.

Hydrophytes:—In contrast to the hygrophytes or water loving plants, we have the *water-living* or aquatic plants. As has been said already, characters pecular to the former are shared also by the latter, though in a more pronounced degree. As examples of common aquatic plants we have Chara, Hydrilla, Vallisneria, Elodea, Jussieua repens, Potamogeton, Trapa natans, Nymphæas, Sagittarias, Nelumbiums, Lemna a few Ranunculus, and a few Pteridophytes and Mosses.

The almost invariable action of water upon plants is to bring about a '*degeneracy*' in the development of the mechanical tissues and a corresponding extention of the plant surface and intercellular spaces. The structures of all water plants correspond as regards the following points:—

1. The *roots* appear from every part of the submerged stem—from nodes as well as from internodes—as long, fibrous adventitious structures.

2. The *stem* is like that of hygrophytes sometimes very long, sometimes only a trailing rhizome or an elongated tuber.

3. The *petioles* are invariably enormously elongated, and leaves when they are submerged are finely dissected, and when floating are large, broad, rather roundish and thin.

4. The *epidermis* is not provided with stomata or cuticle the cells are regular and in close contact and contain chlorophyll grains with regard specially to the submerged parts. In arial parts or on the surface of floating leaves stomata and cuticle are developed as usual.

5. The *cortex* is not differentiated into layers such as collenchyma and sclerenchyma but consists simply of loose parenchymatous cells with abundant intercellular spaces. Large air passages arising schizogenously occupy the grater part of the cortex and a similar air passage, though larger and arising lysigenously, occurs in the medulla. In some marsh plants, as also in the common lily, the cortical cells are arranged in the form of a stellate tissue or the cells themselves may be stellate.

6. The *fibrovascular bundles* are reduced or at least are not centrifugaly developed in Dicots as is the rule. The bundles developed in a rudimentary state are disposed towards the axis; and neither is the lignification of a high order.

So great is the degeneracy of the lignified tissues that in many aquatic stems and roots bundles are not at all formed. Such is the case, for instance, with the roots of *Lemna* (Pana); in the centre there is the air-cavity surrounded by a zone of soft cells and further outwards by other cortical cavities. Similarly the submerged stem of water chestunt (*Trapa*) is very soft, and is kept afloat by the big air-chambers of the cortex and the bladdery petioles. Similar too is the case with the spongy roots of *Jussieua*. In some aquatic Commelynaceæ the whole plant structure is entirely devoid of lignified elements. As with lignification so with cutinisation, water appears to retard the latter process indefinitely. Hence there is no such thing as cork or periderm or cuticle in submerged plants. And the endodermis, far from being cutinised in the radial walls, simply fold up the latter in a peculiar way which gives the characteristic appearance of dark dots in transverse sections. Formation of vessels is as a rule greatly diminished ; indeed in most aquatic roots where the bundles are developed, punctated thick-walled woody cells are all that represent the complex xylem of the normal stem.

The leaves of aquatic plants are of two kinds : those that are submerged are universally thin and ribbon like, and those that are floating are round or orbicular and peltate. Chlorophyll grains are almost always found not only in the mesophyll cells but in those of the epidermis as well. Water plants which produce aerial leaves—neither submerged nor floating—have generally hastate or sagittate leaves ; they are typically hygrophylous. Moreover as in aquatic stem so in leaves intercellular spaces predominate, vessels degenerate, cutinisation and lignification are reduced, and turgidity of the abundant parenchymatous cells is the main mechanical cause by which the necessary rigidity is secured.

Climbing Plants.—In the interior of tropical forests, particularly in tropical America, the vegetation is almost exclusively composed of climbers. Forest climbing plants are distinguished by the collective term *Lianes*. They may be root-climbers, leaf-climbers, hook-climbers, tendil-climbers and twiners. The climbing or attaching organs of these plants, specially the stems of twiners, show some very peculiar structural characters. The internodes are generally very long, and in many cases the young axis does not unfold its leafy buds until the elongating cane-like stem passes through the intervals of branches of neighbouring trees. Later on the leaves expand and arch downwords, thus anchoring the parent on the supporting boughs. Other climbers, as the Bramble, are equipped with spines and bristles which point upwards and remain adpressed to the surface of the stem so long as it is young; when however a support has been gained the spinous structures recurve downwards and thus fasten the stem on to the support. On the other hand, twiners develop their stems in the most peculiar manner ; as a result of twining torsions inevitably follow, and many big lianes have their stems twisted like cables or furrowed into large canals and ridges. In the Pareshnath hills *Hiptage madhoblota* grows most luxuriantly with its twisted rope-like stems. In Chitagong several species of the climbing *Bauhinia* are found to form flat ribbon like arching stems. In the climbing Begonias the wood occurs in the form of four wedges arranged cross-wise, and similarly in many other woody Dicot climbers the wood and bast form alternating concentric zones.

The almost universal histological peculiarity of the more pronounced native *Lianes* lies in the xylem which is composed of numerous vessels of wide calibre and in the corresponding wide sieve tubes. Cortical processes projecting out in the form of wedges or ridges of cork and bark are also a special feature. Medullary rays are abundantly formed in the form of wide wedges driven between wedges of wood, as in the Menisperms. The pericycle is often develoved as a wide zone and mechanical tissues in the form of sclerenchyma pads are usually developed outside the bundles. (See Tinospora p. 343.)

APPENDIX I.

PRACTICAL MICROSCOPY.

The following notes are intended to help students in their practical histological works necessary for a thorough study of Part II of this book.

1. **List of apparatus** etc. (for each student) in common use in Botanical laboratories for histological work :—

1. A *Compound Microscope* provided with
   - (*a*) High and low power *Eye-pieces.*
   - (*b*) High and low power *Objectives.*
   - (*c*) *Draw tube* in the microscope-body.
   - (*d*) *Fine* and *rough-adjustment* Screws.
   - (*e*) *Nose-piece* to carry two or three objectives.

[For a description of the compound microscope, consult some standard work on Practical Botany, *e.g.* Strasburger and Hillhouse's Pr. Botany.]

2. A *Simple lens.*
3. A *Dissecting case* containing the following.—
   - (*a*) A *Razor*—Very slightly hollow ground, or better plane on one face and slightly hollow on the other.
   - (*b*) A *Scalpel* with a long and narrow blade.
   - (*c*) A pair of fine-pointed *Forceps.*
   - (*d*) A pair of fine-pointed *Scissors.*
   - (*e*) A pair of *camel-hair Brushes.*
   - (*f*) A pair of mounted *Needles.*
   - (*g*) Several (a dozen, say,) *Glass slides*—3 in. × 1 in.
   - (*h*) Several *Cover-glasses* (circular—⅜ in. diam.)
4. A few (flat-bottomed preferably) *Watch-glasses.*
5. A *Wash-Bottle* containing water.
6. A small *Spirit-Lamp.*
7. A few Procelain *Staining* and *Washing Dishes.*
8. A large Glass *Crystallising Dish* or *Basin* with cover.
9. *Blotting-papers*, cut into pieces 4in. × 1in. and packed in dozens.
10. *Velvet-Corks*, or, *Elder-pith* for section cutting.

2. **List of Reagents** and chemicals :—The following selected list answers nearly all practical purposes :—

1. Dilute Glycerine (equal parts glycerine and water)
2. Methylated Spirit.

3. 50 % alcohol and absolute alcohol.
4. Potash solution in water (5 %)
5. Iodine solution in water.
6. Chlor-zinc-iodine.
7. Aniline chloride solution (acidified slightly).
8. Eau de Javelle.
9. Sulphuric acid.
10. Watery or alcoholic solutions of the following stains :—
    - Safranin.
    - Eosin.
    - Aniline blue.

Microscopical study of plant structures involves the knowledge of :—

1. The microscope—its parts and use.
2. Hardening soft structures and softening hard structures.
3. Section-Cutting.
4. Clearing.
5. Staining.
6. Mounting,
7. Closing, and
8. Reagents—their use and reactions.

Fixation, Preservation and Hardening.—Many plant-structures are too soft for sectioning; they can be hardened by being left in absolute alcohol or methylated spirit for a couple of days. Left too long in alcohol specimens may become brittle, but this defect may be cured by leaving them in water for a day or half. Very soft cellular plants however become deformed in alcohol, or at least, the protoplasmic contents become coagulated in clots. In order to see their structures minutely in detail, the protoplasm and the cells must be *fixed*. The best fixing agent is a mixture of 5 % solution of chromic acid and a 1 % solution of acetic acid in equal parts. Both these reagents may be also used separately. They are invaluable in fixing the cells of Algæ, Fungi etc. Specimens of organs such as stems, leaves etc, collected at different times and from different parts of the country are usually preserved in methylated spirit.

Section Cutting.—Of cylindrical organs, such as stems and roots, sections may be cut in three directions.—

1. Transverse sections, passing at right angles to the organic axis.
2. Radial Longitudinal sections, passing longitudinally through the organic axis.

3. Tangential Longitudinal sections, passing longitudinally through the organ but not through the axis.

In cutting sections always avoid (a) to cut obliquely, (b) to force the razor through the tissues, and (c) to work on rough edges or surfaces. The surface of the material should be clean and moistened either with water or alcohol The razor should be allowed merely to slide on its sharp edge. No force or but little pressure should be applied ; and the razor should always be kept moist with water or alcohol.

Ordinarily all stems and roots may be held between the fingers of the left hand, and the razor worked with the right. To obtain a series of sections, specially from materials that are too small to be held by the hand, microtomes are used ; and small seeds, leaves etc. are imbedded in blocks of paraffin. (For embedding and use of microtome the student is referred to Strasburger and Hillhouse's Practical Botany).

Clearing—The cut sections are usually floated on water or alcohol in watch glasses. But before they can be mounted they often require 'clearing'. Clearing renders tissues more transparent, and by dissolving the cell contents makes the cell walls prominent. The common clearing agents are Potash (dilute watery solution), Chloral hydrate, and Eau de javelle. The clearing process is this : keep sections in the clearing agent in a watch glass for some 5-10 minutes, remove them next to water in another watch glass, stir well and then proceed with the next process.

Staining.—It is always an advantage to stain sections. Staining renders some of the tissues more apparent i.e. differentiates the tissues. It depends upon the property certain tissues and parts of cells have of taking or absorbing a relatively larger amount of the stain, and consequently of becoming more deeply coloured. Staining may be done in watch glasses in this way : After clearing the sections by the above process remove them to the staining fluid contained in a watch glass, keep in this liquid for a few minutes then remove sections to other watch glasses and wash in alcohol or water. Where the staining agent is an alcoholic solution, washing must be in alcohol ; where it is an aqueous solution, the washing should be in water The time required for the proper degree of staining varies in different cases. Thus Safranin requires some 15 to 20 minutes, Eosin some 5 minutes, Aniline blue requires but 1-2 minutes. "As a rule, the best staining is obtained by dilute solutions and long treatment" (Strasburger).

Mounting.—The mounting media are Glycerine, Glycerine jelly, or Canada balsam in xylol. The object of using these mounting agents is that the preparation can be kept under observation and control permanently, whereas if mounted in water or alcohol simply, the liquid will evaporate, and the observation would be defective. Preparations stained or washed in water may be mounted at once in glycerine ; they cannot be mounted in any other medium. Canada balsam or Glycerine jelly has the advantage over glycerine as it makes "permanent" preparations. To mount in the jelly, proceed as follows. Take a small slice of the jelly on the centre of the glass slide and warm gently. Soon the jelly melts to a clear liquid. The alcohol- or water-washed sections are then transferred to dilute glycerine, kept in it for a short time, and mounted in the liquid jelly on the slide. The cover glass, cleaned thoroughly with alcohol, is then carefully lowered, in such a way that no air bubbles are included. On coolling the jelly sets hard and the preparation is "permanent". More usually stained section are mounted in Canada balsam, but the process of mounting is more complicated than above. Here is the direction given by Strasburger. "Watery preparations must be first dedydrated in alcohol ; glycerine preparations first soaked for sometime in water, and then in alcohol ; and either of them afterwards cleared with oil of cloves," or xylol, and finally mounted in a drop of the Balsam solution in the centre of the slide and covered with cover-glass.

Closing.—Slides, specially those that are to be permanent, should be "sealed up" or "closed" by some reagents which set hard when exposed. Even preparations mounted in glycerine may be rendered permanent by properly sealing the cover glass. This is done by applying, by means of a fine brush, layers or coatings of *Gold size* over the junction of cover glass and slide. This substance dries up very rapidly. Closing may also be done by Canada balsam, but it takes time to set hard, specially when thin.

Use of Reagents.—

1. **Acetic acid.**—A dilute aqueous solution (1 % to 2 %) dissolves crystals of calcium carbonate (See Cystoliths). It is also used as a fixing agent.

2. **Alcohol.**—It (1) dehydrates preparation of specimens intended to be made permanent in Canada balsam ; (2) hardens plant-tissues, (3) dissolves chlorophyll and other pigments, wax, etheral oils etc.

3. **Aniline blue**—It is a good stain for cellulose walls which become bluish when the lignified walls are previously stained with

4. **Canada Balsam.**—It is used as a mounting medium or as a sealing agent. For these purposes it is dissolved in xylol to the consistency of thick syrup.

5. **Callus Reagent.**—It is used to bring out the callus of Sieve-plates; prepared by mixing equal parts of chlor-zinc-iodine and potassium iodide solution of iodine.

6. **Chloral Hydrate.**—It is used as a very good clearing agent. Leaves, sections of stems and roots become transparent with its use.

7. **Chlor-zinc-iodine.**—It may be used as a mounting medium for temporary preparations. It differentiates tissues very clearly; cellulose walls being stained violet or blue, lignified walls yellow or brown and the cuticle and corky cells deep yellow. It also turns starch grains deep blue and the protoplasm light yellow or brownish.

8. **Chromic acid.** It is a good fixing agent when used as 1 % to 2 % watery solution.

9. **Eau de Javelle.**—It causes swelling, disorganisation, and ultimate dissolution of proteid cell contents; hence it is used as a clearing agent, specially for growing points.

10. **Eosin.**—In dilute aqueous or alcoholic solutions it is a good protoplasmic stain (red). It affects lignified and cutinised cells but not permanently, though cellulose walls retain the stain.

11. **Iodine.**—It is one of the most important microchemical re-agents It stains starch grains blue, protoplasm deep yellow, cellulose walls light yellow, lignified or corky walls brownish yellow and resinous matters variously. With Sulphuric acid it turns cellulose deep blue.

12. **Potash.**—Dilute solution of caustic potash is used as a clearing agent. Its clearing action is due to the swelling of organised structures when treated with it. Hence it is also used to show the stratification of starch grains and cell-walls in conjunction with iodine. It can dissolve protoplasmic matters, and when concentrated is used as a test for suberin.

13. **Safranin.**—It is one of the good differentiating stains which bring out the different tissues in stems, roots etc. Thus strongly lignified walls become deep brownish-red, slightly lignified walls red, walls of sieve tubes rose red, and the other parts—the cellular parenchyma—are not much stained.

14. **Sulphuric Acid.**—It causes swelling in and finally dissolves starch and cellulose walls. It has no action on suberised or cutinised walls. It is used with iodine for the cellulose-blue reaction.

15. **Xylol.**—It is used as a clearing agent when stained and

dehydrated sections are mounted in canada balsam, immediately before the mounting. For permanent mounting in Canada balsam sections are passed successively through (*a*) alcohol dilute, (*b*) staining fluid, (*c*) water, (*d*) alcohol of gradually increasing strengths, (*e*) absolute alcohol, (*f*) xylol, (*g*) canada balsam.

APPENDIX II.

Common Indian plants illustrative of the important Natural orders or Families.

Acanthaceæ.—Thunbergia grandifloria (Nil-lota); Hygrophylla spinosa (Kulia-khara); Justicia paniculata (or *Andrographus paniculata* Kalmegh or Mahatita); Barleria ciliata (Jati); Justicia Adhatoda (or *Adhatoda vasica*—Bakas, Adhasa).

Amaryllidaceæ.—Crinum asiaticum (Sukh-darshan); Agave americana (the century plant).

Anonaceæ.—Anona squamosa (Ata); A.—reticulata (Nona); Uvaria longifolia (Polyalthia longifolia—Devdaroo); Artabotrys Odoratissimus (Kantali champa).

Apocynaceæ.—Carissa Carandas (Karamcha, Karanda); Plumeria acutifolia (Katchampa): Vinka rosea (Gool-firingi); Tabernæmontana coronaria (Tagur); Nerium Odorum (Karabi, Kaner); Echites frutescens (*Ichnocarpus frutescens*—Dudh-lola, Syam-lola, Doodhia).

Aroidæ.—Pistia stratiotes (Takapana, Jal khumbi); Arum campanulatum (Ol or Oal): A.—indicum or maculatum (*Alocosia indica*—Mankundu, Mankutchoo), Pothos (*Scindapsus*) officinalis (Gajpippul).

Asclepiadaceæ.—Hemidesmus indicus (Anant-mul); Calotropis gigantea Akanda, Madar); Sarcostemma brevistigma *Asclepias acida*—Som-lata); Pergularia odoratissima, or minor (Kunja-lata); Hoya carnosa.

Begoniaceæ.—Begonia lacinata (Hoirjoo).

Bignoniaceæ.—Bignonia suaveolens (*Stereospermum suaveolens*—Parul).

Boraginaceæ.—Heliotropium indicum (Hatisoor); Borago indica (chota kulpha)

Bromeliaceæ.—Ananassa sativa (Pine-apple).

Cactaceæ.—Cactus indicus (*Opuntia Dillenii*—Nagphani, Phani Mansa).

Capparidaceæ.—Gynandropsis pentaphyllya (Sada Hurhuria; Cleome viscosa (Hurhuria-yellow).

Caryophylaceæ.—Dianthus Chinesis (the Pink).

Chenopodiaceæ.—Chenopodium album (Bethu-shak); Beta vulgaris (or *Benghalensis*—Palam, Palung or Palak shak); Basella rubra (Poin-shak)

Combretaceæ.—Terminalia Catappa (Deshi Badam); T. belerica (Bahera); T. chebula (Haritaky, Harara);

Compositæ.—Vernonia cinerera (Kukshim *Serratula cinerera*); Tagetes patula (Genda); Zinnia elegans; Enhydra fluctuans (Hingcha); Helianthus annuus (Surajmukhi); Chrysenthemum; Carthamus tinctorius (Kushum,—the safflower).

Conifers.—Pinus Devdara (the common Pine).

Convolvulaceæ.—Cuscuta (Algosi-lata); Convolvulus (*Ipomæa*) paniculata—(Bhumikumra); C. (*or Ipomæa*) Batatas (Sakarkand alu); C. (or *I.*) repens (*reptans*) (Kalmi-shak).

Crassulaceæ.—Bryophyllum calycinum (Pathurkuchi); Cotyledon (*Kalanchœ*) lacinata (Himsagar)

Crucifereæ.—Raphanus sativus (Radish); Brassica oleracea (Cabbage); Sinapis dichotoma (*Brassica juncea*—Mustard).

Cucurbitaceæ.—Trichosanthes dioica (Patal or Palwal); T. palmata (Makal); Lagenaria vulgaria (Lau, Koddo); Luffa pentandra (Dhundul, Jhingley) Cucumis sativus (Sasa, Khira); C. Melo (Kharbuj); Citrullus vulgaris (Tarbuj); Cucurbita Pepo (Kumra, Kanhara.

Cyperaceæ.—Cyperus rotundus (Mootha); Scirpus Kysoor (Keysoor).

Dilleniaceæ.—Dillenia indica (*speciosa*,—Chalta).

Dioscoreaceæ.—Dioscorea alata (Kham-alu); D. fasciculata (Shushni-alu).

Dipterocarpeæ.—Dipterocarpus alatus (*incanus*—Garjan); Shorea robusta (Sal).

Euphorbiaceæ.—Euphorbia Antiquorum (Mansa-tekata, Trishirmansha); Manihot glaziovii (Rubber); Jatropha (Lal Bheranda); Croton Tiglium (Jaypal); Ricinus communis (Bheranda).

Gramineæ.—Oryza Sativa (Rice); Triticum Vulgare (Wheat); Zea mays (Maize); Avena sativa (Oats); Andropogon muricatus (Khus-

khus); Saccharum officinaram (Sugarcane); Bambusa (Bamboo); Calamus (Cane).

Labiateæ.—Ocymum sanctum (Tulsi). Mentha Sativa (Podina).

Lentibulariaceae—Utricularia stellaris (Jhanjhi)

Liliaceæ.—Asparagus racemosus (Satamuli); Smilax (Topchini); Dracæna (Khunkharapi Lidar); Gloriosa superba (Ulat-chandal); Allium cepa (Onion); A. sativum (Garlic).

Linaceae—Linum Usitatissimum (Tisi).

Loranthaceae.—Loranthus bicolor (Manda, Banda).

Lythraceae.—Lagerstrœmia regina (Jarool); Lawsonia inermis (*alba*—Mendi, Henna); Punica Granatum (Dalim);

Magnoliaceae.—Magnolia Pterocarpa (*Leriodendron grandiflorum*,—Duli-champa); Michelia Champaka (Swarna Champa).

Malpighiaceae.—Hiptage Madhoblota (Basanti, Mahadheolata Madhabilata).

Malvaceae.—Hibiscus Rosa—sinensis (Java); H. esculentus (Dhanros, Bhindi); H. mutabilis (Sthalpadma); Gossypium herbaceum (Kapas, the Cotton); Bombax heptaphyllum (or *malabaricum*,—Simul, the cotton tree).

Meliaceae—Melia Azederachta (Nim), Swietenia Mahogoni (Mahagny, mahogany tree); Cedrela Toona (Tun .

Menispermaceae.—Tinispora Cordifolia (Gulancha).

Moringaceae.—Moringa pterygosperma (Sajina).

Myrtaceae.—Melaleuca Leucadendron (Cajaputy); Psidium Guyava (Guava); Eugenia Jambos (Golab-jam); E. Jambolana (Kalajam, Jamun); E. alba (Jamrool); E. Caryophyllata (the clove tree, Lavanga)

Nyctaginaceae—Mirabilis Jalapa (Krishna-kali); Bœrhaavia procumbens (Punarnava, shotughnee),

Nymphæaceae.—Nelumbium speciosum (Padma); Nymphæa Lotus (Shalook, koee).

Oleaceae.—Jasminum pubescens (Kunda); J. zambac (Bel); Nyctanthes Arbor-tristis (Sephalika, Seoli, Singahar).

Onagraceae—Jussieua repens (Kasardam); Trapa bispinosa (Paniphal, Singhara).

Orchidaceae.—Vanda Roxburghii (Rasna).

Palmaceae.—Borassus flabelliformis (Tal): Caryota Urens (Sago palm); Cocos nucifera (cocoanut); Phœnix dactilyfera (*sylvestris*—Khajoor); Areca catechu (Supari); Calamus (Beth).

Pandanaceae.—Pandanus odoratissimus (*fascicularis*—Kea, Ketaky, Keora.)

Passifloraceae —Carica papaya (Papaw); Passiflora (Jhumkalata)

Piperaceae.—Piper Betle (Pan); P. nigrum (Gol-murich); P. longum (Pipul).

Plumbaginaceae.—Plumbago zeylanica (Chitra).

Polygonaceae.—Polygonum (Pani-murich).

Pontederaceae.—Pontederia vaginalis (Neelotpala).

Portulacaceae.—Portulaca meridiana (Looniya or Nooniya shak).

Ranunculaceae.—Nigella sativa (Kalajira); Naravelia zeylenica (chagulbaty).

Rhamnaceae.—Zizyphus Jujuba (Kool, Baer).

Rosaceae.—Rosa centifolia (Gulab): Eriobotrya Japonica (*Mespilus Japonica*, the Loquat).

Rubiaceae —Rubia manjistha (*Cordifolia*, Munjeet), Ixora Coccinea (Bandhuka, Rangan); Ixora Pavetta (*Pavetta indica* Kukurchura); Oldenlandia alata (*Pædearia fætida*, Gandha- bandhuli); O. biflora (*Corymbosa* Khet-papra); Gardenia florida (Gundharaj)

Santalaceae —Santalum Album (Chandan).

Sapindaceae.—Nephelium Litchi (Litchi, Litchu): N. Scytalia (*Longan* Ash-paul).

Scitamineae.—Globba bulbifera (Coonda pushpa); Kaempferia Galanga (chandramulika); K. rotunda (Bhoi champa); Hedychium coronarium (Dulal champa); Curcuma longa (Huldi); Zinziber officinalis (Zinger); Canna indica (Sarbajaya); Musa sapientum (Kola the Banana).

Scrophulariaceae.—Gratiola serrata (Bhumi-nim).

Sterculiaceae.—Pterospermum acerifolia (Kanakchampa); Abroma augusta (Ulatkamble)

Tiliaceae.—Grewia asiatica (Phalsa); Corchorus olitorius (Pat)

Umbellifereae.—Hydrocotyle asiatica (Thulkuri, Brahmamundaki): Ligusticum Ajoan (*carum cophicum*—Ajowan); Anethum Panmouri (*Foeniculum vulgare*—Panmouri); Daucus Carota (Gajur)

Urticaceae —Cannabis sativa (Ganja, Bhang); Urtica interrupta (*Fleurya interrupta*...Lal bichuti) Artocarpus integrifola (Kantal): Ficus religiosa (Piple, Aswatha); F. Indica (*bengalensis*, Banyan); F. glomerata (Gular, Dumur.)

Verbenaceae.—Tectona grandis (Teak, sagun); Clerodendron infortunata, (Volkamera infortunata...Bhant, Ghentu)

INDEX.

ERRATA.

FOR.	READ.
Chandramullika	Chandramulika (Sans.)
Rubiaceous	Rosaceous.
Michelia champaca	Artabotrys odoratissimus. [Michelia Champaka is *Swarna Champa* of Bengal]
results in	result of.
Phyllogeny	Phylogeny.
excellance	*excellence.*
compositaeæ	compositæ.
anthocianin	*anthocyanin*
pallisade	palissade