SARDAR PATEL UNIVERSITY
B.Sc. (BOTANY) Sem. : VI Code: US06CBOT22 (T)
ANATOMY OF ANGIOSPERMS
Total Credit: 4 (Four Lectures per week)
(Total Marks 100, Internal-30 marks, External 70-marks)
Syllabus with effect from: June 2020

UNIT CONTENT : 4. Adaptive and Protective Systems:
Epidermal tissue system, cuticle, epicuticular waxes, trichomes(uni-and multicellular, glandular and nonglandular, two examples of each), stomata (classification); Adcrustation and incrustation;
Anatomical adaptations of xerophytes and hydrophytes.

Epidermal tissue system,

Epidermis: This system solely consists of the outermost skin or epidermis of all the plant organs beginning from the underground roots to the fruits and seeds. This layer represents the point of contact between the plants and the outer environment and, as such exhibits diversities in structure.

It is primarily a protective tissue, which protects the internal tissues against excessive loss of water by transpiration and mechanical injury. Subsidiary functions like storage of water, mucilage, secretion and, though rarely, even photosynthesis, may also be carried on.

But for stomatal and lenticular openings the epidermis is a continuous layer. Normally it is uniseriate - typically consisting of one layer of cells.It derives its origin from the protoderm of the meristematic region.

Normally it may be assumed that these layers have originated from the protoderm by periclinai divisions. The outermost layer of multiple epidermis is similar to ordinary uniseriate one. The inner layers are different from other tissues in absence of chlorophyll.

They may be outer layers of cortex originating from the ground meristem, but resemble the epidermis both in structure and function.
The epidermal cells are living with lining layer of protoplast around large central vacuole. The plastids are normally small and colourless. Chloroplasts are present only in the guard cells of the stomata in case of organs exposed to sunshine, but they occur in the epidermal cells of aquatic plants and plants growing in moist and shady situations.Mucilage, tannins and crystals may occasionally be present.

Epidermal cells exhibit wide diversities as regards their size, shape and arrangement. But they may be said to be essentially tabular in shape (Fig. 555 A & B) compactly set, so that a continuous layer without intercellular spaces is formed. Only in the petals of some flowers intercellular spaces are found, but they remain covered by outer cuticle. In surface view they are more or less isodiametric in shape.

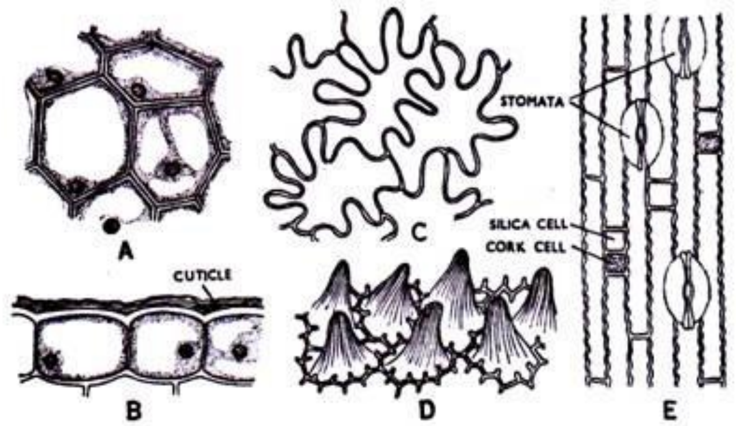


FIG. 555. Epidermal cells. A. Ordinary epidermal cells from a leaf in surface view. B. Same in sectional view. C. From leaf of *Solanum* (potato) in surface view. D. From the petal of *Viola* showing ridge-like infoldings of lateral walls and protruding papillae. (*After Strasburger*). E. Of *Saccharum* (sugar-cane) with silica cells and cork cells.

Epidermal cells have unevenly thickened walls, the outer and radial walls being much more thick than the inner walls. In some cases they may be so massive that the central lumen is almost obliterated. The walls are strongly cutinised, what is very important for protection against mechanical injuries and prevention of loss of water.

The fatty substance cutin is found in the wall - in interfibriller and intermicellar spaces of the cellulose and forms the cuticle occurring all over the outer wall of the epidermal cells (Fig. 556 A&B).

It remains as a separate layer and in some cases it may be removed as a whole. The cuticle is often found to project into the radial walls as peg-like bodies (Fig. 556C). Cuticle is absent only in the epidermis of roots and some submerged aquatic plants.

The thickness of the outer walls of the epidermal cells depends on the environmental conditions of the plants. It is quite thin in plants with adequate water supply, and it is unusually thick in plants growing in dry situations.

The surface of the cuticle may be smooth or may possess ridges and cracks. The cutinised portion of the walls, the portion lying beneath the cuticle, has been found to consist of alternating layers of cutin and pectic materials.

Formatted: Font: (Default) Arial, 14 pt, Bold, Font color: Custom Color(RGB(136,136,136)), Complex Script Font: Arial, 14 pt, Bold, Border: : (No border)

Waxy matters are often deposited on the cuticle in form of rods and grarules (Fig. 556E).The so-called ‘bloom’ of many fruits and glaucous characters of many stems and leaves are due to these deposits. Lignification is rather rare in epidermal cells.

In some dicotyledonous families like Malvaceae,Rutaceae, etc.,the epidermal cells individually or in groups undergo mucilaginous changes, particularly in the seeds. Special sac-like cells remain scattered in the epidermis of some members of family Cruciferae.

These are idioblastic cells resembling the laticiffers, but they contain an enzyme, myrosin, and so they are called myrosin cells. It has been stated in a preceding chapter that many dicotyledonous families like Urticaceae, Moraceae, possess cystoliths.

The cystolith-containing cells of epidermis are referred to a lithocysts. The epidermis is often made up of a layer of sclereids, as found in the seed-coats of Pisum and Phaseolus of family Leguminosae (Fig. 537D) and in the scales of garlic-Allium sativum of family Liliaceae (Fig. 537E).

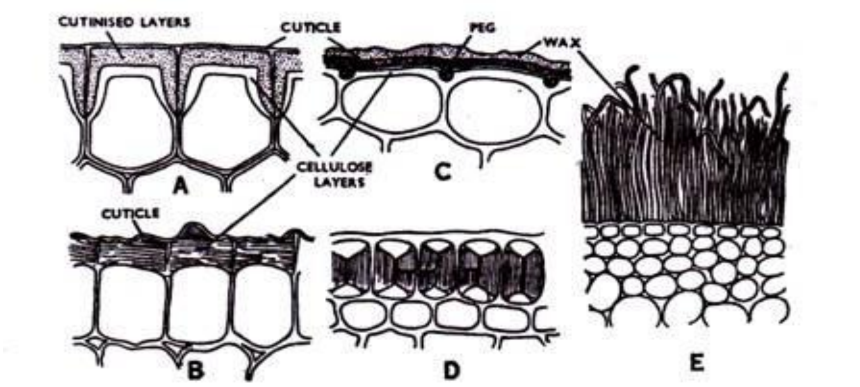


Fig. 556. Epidermal cells. A. From *Aloe*. B. From *Allium* (onion). C. From *Musa* (banana). D. Lignified cells in *Pinus* (Pine). E. Coating of waxy rods in *Saccharum* (sugarcane).

Formatted: Font: (Default) Arial, 14 pt, Bold, Font color: Custom Color(RGB(136,136,136)), Complex Script Font: Arial, 14 pt, Bold, Border: (No border)

The origin of the shoot epidermis may be traced from the apical meristem. It arises from the outer layers-of tunica, according to tunica-corpus theory, or from the dermatogen of Haustein or protoderm, as suggested by Haberlandt, which may be called primordial epidermis.

The cells are tabular, lack in cutinisation of wall and their function is mainly absorption of water and solutes.So the terms epiblema,piliferous layer or rhizodermis have been applied to it.

Epidermis, as a rule, persists as uniseriate layer throughout its life in the organs where distinct secondary growth does not take place. In some monocotyledons, though secondary increase is absent, a kind of periderm is formed, and thus the epidermis is destroyed.

Bulliform Cells : In the leaves of monocotyledons, excepting a few families, a peculiar type of comparatively larger, highly vacuolate and thin-walled cells occur in the epidermis. These are called bulliform (meaning, bubble-like) cells.
In transverse section they appear as a fan-like band because the median cell is usually the largest in size (Figs. 557 & 557A). They may be present on both sides of a leaf, but are more common on the upper side running parallel to the veins.

They either cover large areas or remain restricted to the grooves. These are mainly water-containing cells with no chlorophyll. The walls are usually thin, but the outer walls may be thick and cutinised like other epidermal cells, often filled with silica.

There are three views as regards the functions of bulliform cells. According to the **first view** they are concerned with the unrolling of the developing leaves. It is suggested that these cells undergo sudden and rapid expansion at a certain stage of leaf development and consequently bring about unfolding of the leaves.

The **second view** is that they have a role to play in the hygroscopic opening and closing movements of mature leaves, due to changes in turgor. They have also been called motor cells by workers holding the above view.

The **third view** is that they are simply concerned with water-storage and have no other function.

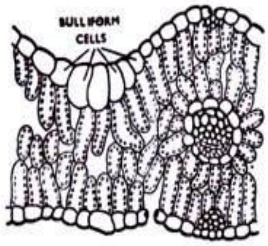


FIG. 557. Bulliform cells in a section of a leaf of *Triticum* (wheat).

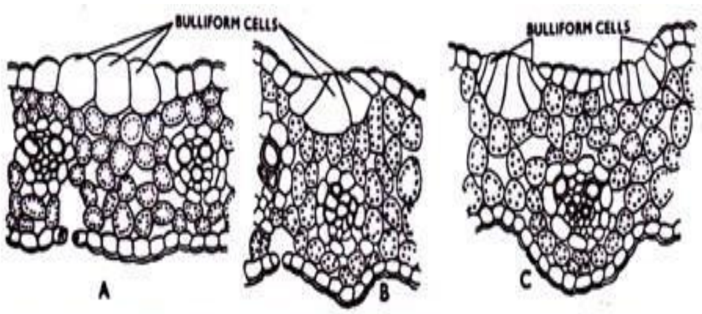


FIG. 557A. Bulliform cells in grass leaves (cross-sections). A. In *Zea* (Maize); B. In *Saccharum* (sugarcane); C. In *Poa*.

Formatted: Font: (Default) Arial, 14 pt, Bold, Font color: Custom Color(RGB(136,136,136)), Complex Script Font: Arial, 14 pt, Bold, Border: : (No border)

Formatted: Font: (Default) Arial, 14 pt, Font color: Custom Color(RGB(66,65,66)), Complex Script Font: Arial, 14 pt

Epidermal Outgrowths : Outgrowths of diverse forms, structures and functions develop from the epidermis. All these appendages which are epidermal in origin, are referred to as trichomes.
Thus they are different from the emergences like the prickles of roses, as the latter are formed by epidermis and a part of cortex. Trichomes may occur on all parts of the plant body.

Some of them persist throughout the life of the organs, whereas many of them are ephemeral bodies. They may remain alive or become dead and continue as such. Trichomes have been put into a number of groups on the basis of their morphological characters.

(a) Hairs : Hairs constitute a very common type of trichome. They may be unicellular or multicellular. Unicellular hairs are often simple unbranched elongated bodies or they may be branched.
Some of them are very much elongated and twisted, so that they have woolly appearance (Fig. 564-C). Multicellular hairs may be formed of one row of cells (Fig. 564 A, D, E & F) or of many layers as found in the base of petiole of Portulaca.

Often these hairs branch in very peculiar fashions; some of them assume dendroid or tree-like appearance (Fig. 564 G & H), or the branches come out in one plane giving it stellate or star-like shape.

They are also called stellate hairs (Fig. 564 I), A multicellular hair has usually two parts, the basal part which remains embedded in the epidermis is the foot and the other which projects out is the body. An initial cell divides periclinally into two parts, of which the outer one forms the body and the inner one, the foot.

(b) Scales or Peltate hairs:
These hairs consist of disc-like plate of cell (Fig. 564 J) put on a short stalk or directly attached to the foot.

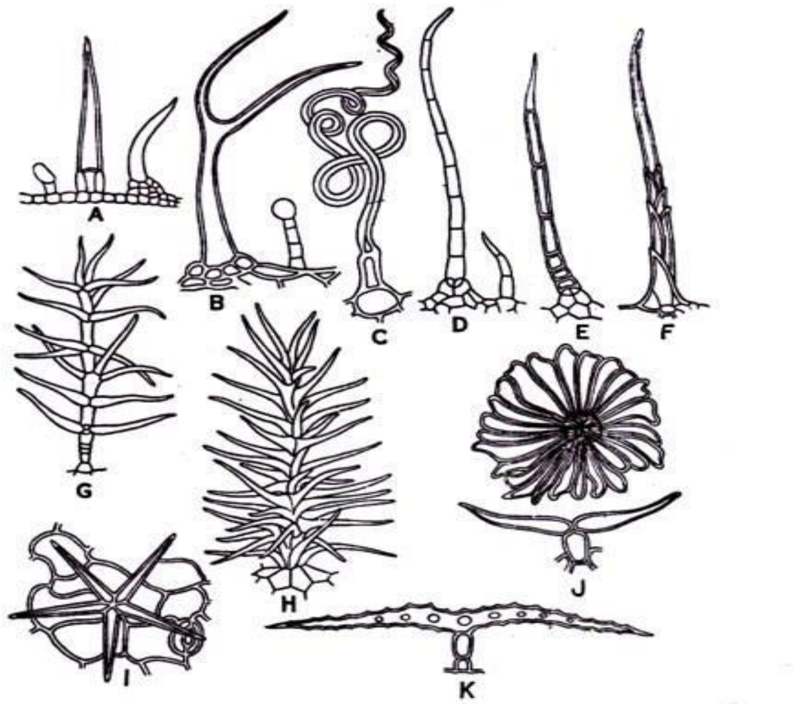


FIG. 564. Epidermal hairs—different types. A. Sharp hairs of *Lantana*. B. Lobed hair of *Amarantus*. C. Wooly hair of *Banksia*. D. Of *Lycopersicum* (tomato). E. Of *Helianthus* (sunflower). F. Of *Mimosa*. G. Dendroid hair of *Platanus*. H. Same of *Mimosa* spp. I. Stellate hair of *Althaea* (Malvaceae). J. Peltate hair in surface and side view of *Olea*. K. T-shaped hair of *Dicrasus* (Amarantaceae).

(c) Colleters: These are glandular trichomes. Some hairs have multicellular stalk and head, the latter is composed of glandular cells (Fig. 565). Sticky exudations present on the surface of certain leaves and buds are secreted by colleters. Salt-secreting glands as found in Tamaricaceae and calcium- secreting glands of Plumbaginaceae are really interesting (Fig. 565A).

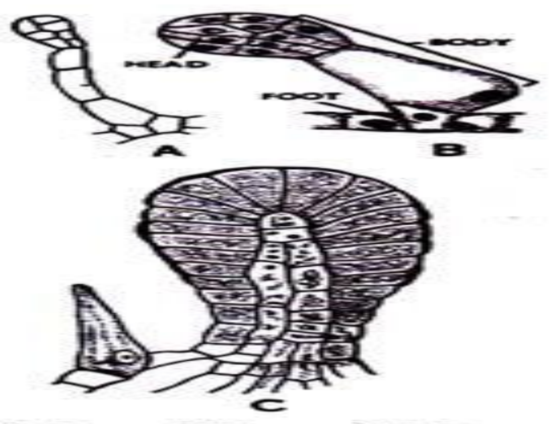


FIG. 565. Colleters (glandular trichomes). A. Of *Nicotiana* (tobacco). B. Same enlarged C. From stipule of *Viola*.

Formatted: Font: (Default) Arial, 14 pt, Bold, Font color: Custom Color(RGB(136,136,136)), Complex Script Font: Arial, 14 pt, Bold, Border: : (No border)

Formatted: Font: (Default) Arial, 14 pt, Bold, Font color: Custom Color(RGB(136,136,136)), Complex Script Font: Arial, 14 pt, Bold, Border: : (No border)

(d) Water vesicles or bladders:

They form a very interesting type of trichome where some epidermal cells become greatly distended and serve as water reservoir.

They occur in one of the most commonly grown species and is named for the transparent glistening swellings on its edible leaves.

The so-called 'ice-plant' (Mesembryanthemum crystallinum of family Aizoaceae) where the surface of the leaves and young stems appear to be covered by ice-beads (Fig. 566).

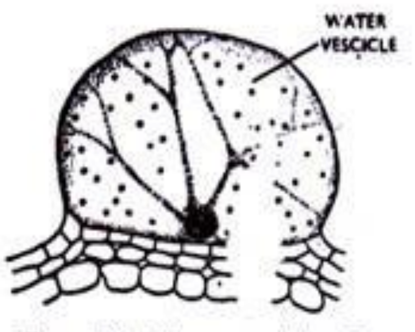


Fig. 566. Water icle of *Mesembryanthemum cr, tallinum.* (*After Haberlandt.*)

Those occurring in Artiplex, also called vesiculate hairs, dry up with maturity and persist as a white layer on the leaf surface (Fig. 565A).

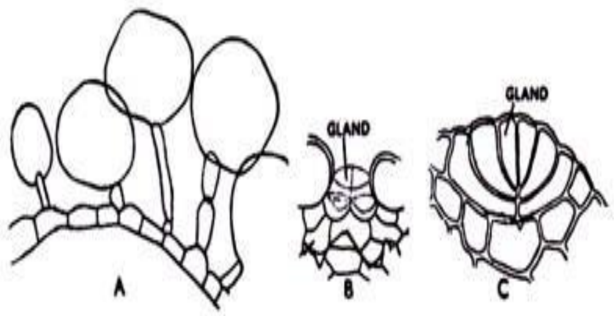


Fig. 565A. Trichomes. A. Vesiculate hairs of *Atriplex*. B. Salt gland of *Tamarix*, C. Calcium-secreting gland of *Plumbago*.

The walls of trichomes are commonly of cellulose covered by cuticle. They sometimes remain impregnated with silica and calcium carbonate. Trichomes other than glandular ones have highly vacuolated protoplast. The cotton fibres, which are really hairy outgrowths from the seeds, have secondary walls of almost

Formatted: Font: (Default) Arial, 14 pt, Bold, Font color: Custom Color(RGB(136,136,136)), Complex Script Font: Arial, 14 pt, Bold, Border: : (No border)

Formatted: Font: (Default) Arial, 14 pt, Bold, Font color: Custom Color(RGB(136,136,136)), Complex Script Font: Arial, 14 pt, Bold, Border: : (No border)

pure cellulose. The stinging hairs of nettle (Urtica dioica) possess a peculiar type of wall structure for releasing the contents of the gland.

The hair (Fig. 244) resembles of fine capillary tube with silicified upper end and calcified lower end. The base remains embedded in the epidermal cells. Coming in contact with the skin the tip breaks at a predetermined point and the sharp edge penetrates into the skin when the contents (histamine and acetycholine) are injected, so to say, to the wound.

Trichomes : Trichomes are the term used to refer to tiny outgrowths from the plant epidermis. Although the term ''Trichomes'' generally refers to outgrowth ranging from small hairs to larger outgrowths like thorns, it is typically used to refer to the tiny hairs that can be seen emerging from the surface of leaves and other epidermal surfaces of plant.

Characteristics of Trichomes

- These are the elongations or the extensions of epidermal cells.
- They are found singly or in groups.
- Trichomes may be unicellular or multicellular.
- They are highly variable in shape varying from small protuberances of epidermal cells to very complex, multicellular, branched or stellate structures.
- They are cutinized.
- They may consist of either living or dead cells.
- They persist throughout the life of a plant or may fall very soon.

Functions of the trichomes include

- Control of the transpiration rate
- Reduction of heating effect of sunlight
- General protection of plant body from harmful insects and other agencies

Root Hairs : Root hairs are hair-like outgrowth of a plant root that absorbs water and minerals from the soil. Root hairs are tubular extensions of the epidermis that greatly increase the surface area of the root. They constantly die off and being replaced by new ones as the root grows and extends itself into the soil.

Characteristics of Root Hairs

- Root hairs are tubular outgrowths of epiblema cells.
- Root hairs are unicellular.
- Root hairs are always un-branched.

- They are found in clusters in young roots near their tips. It is known as root hair zone.
- Root hairs are not cutinized
- Root hairs are short lived.
- Root hairs take part in absorption of water from the soil.
- Hairs with living cells contain very little cytoplasm in their cells

Root-hairs : **R**oot epidermis fundamentally differs from shoot epidermis in origin and in absence of cuticle and stomata.
But it bears hairs at a particular zone. Unlike the hairs and trichomes discussed above, the root-hairs are not outgrowths or appendages,but they are prolongations of the epidermal cells. During the formation of root-hairs, growth in length of the epidermal cells is checked.

It has been found in some plants that root epidermis possesses two types of cells, short cells and long cells due to unequal division, and the hairs are formed from the short ones (Fig. 567) which are called trichoblasts.

Root-hairs are short-lived bodies.

During the growth of the root, old hairs are destroyed and replaced by new ones. They are responsible for the absorption of water and mineral solutes from the soil.

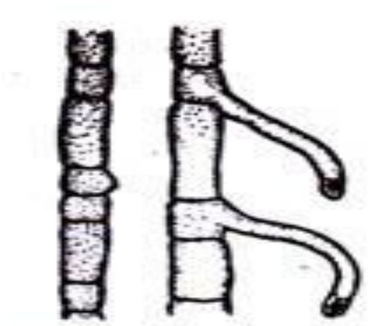


FIG. 567. Root-hairs from short cells in *Cyperus*.

Formatted: Font: (Default) Arial, 14 pt, Bold, Font color: Custom Color(RGB(136,136,136)), Complex Script Font: Arial, 14 pt, Bold, Border: : (No border)

cuticle, A **plant cuticle** is a protecting film covering the epidermis of leaves, young shoots and other aerial plant organs without periderm. It consists of lipid and hydrocarbon polymers impregnated with wax, and is synthesized exclusively by the epidermal cells.

Description : The plant cuticle is a layer of lipid polymers impregnated with waxes that is present on the outer surfaces of the primary organs of all vascular land plants. It is also present in the sporophyte

generation of hornworts, and in both sporophyte and
gametophyte generations of mosses The plant cuticle forms a coherent outer covering of the plant that can be isolated intact by treating plant tissue with enzymes such as pectinase and cellulase.

Composition : The cuticle is composed of an insoluble cuticular membrane impregnated by and covered with soluble waxes. Cutin, a polyester polymer composed of inter-esterified omega hydroxy acids which are cross-linked by ester and epoxide bonds, is the best-known structural component of the cuticular membrane. The cuticle can also contain a non-saponifiable hydrocarbon polymer known as Cutan. The cuticular membrane is impregnated with cuticular waxes and covered with epicuticular waxes, which are mixtures of hydrophobic aliphatic compounds, hydrocarbons with chain lengths typically in the range 16^c to 36^c.

Functions : The primary function of the plant cuticle is as a water permeability barrier that prevents evaporation of water from the epidermal surface, and also prevents external water and solutes from entering the tissues. In addition to its function as a permeability barrier for water and other molecules (prevent water loss), the micro and nano-structure of the cuticle have specialised surface properties that prevent contamination of plant tissues with external water, dirt and microorganisms. Aerial organs of many plants, such as the leaves of the sacred lotus (*Nelumbo nucifera*) have ultra-hydrophobic and self-cleaning properties that have been described by Barthlott and Neinhuis (1997). The lotus effect has applications in biomimetic technical materials.
Dehydration protection provided by a maternal cuticle improves offspring fitness in the moss *Funaria hygrometrica* and in the sporophytes of all vascular plants. In angiosperms the cuticle tends to be thicker on the top of the leaf (adaxial surface), but is not always thicker. The leaves of xerophytic plants adapted to drier climates have more equal cuticle thicknesses compared to those of mesophytic plants from wetter climates that do not have a high risk of dehydration from the under sides of their leaves.

epicuticular waxes, : **Epicuticular** wax is a coating of wax covering the outer surface of the **plant** cuticle in land **plants**. It may form a whitish film or bloom on leaves, fruits and other **plant** organs. ... The main functions of the **epicuticular** wax are to decrease surface wetting and moisture loss.
Chemically, it consists of hydrophobic organic compounds, mainly straight-chain aliphatic hydrocarbons with a variety of substituted functional groups.
The main functions of the epicuticular wax are to decrease surface wetting and moisture loss. Other functions include reflection of ultraviolet light, assisting in the formation of an ultrahydrophobic and self-cleaning surface and acting as an anti-climb surface.

trichomes(uni-and multicellular, glandular and nonglandular,two examples of each),

Trichomes : Types and Functions

Introduction : Trichomes is the term used to refer to tiny outgrowths from the plant epidermis. Although the term "trichomes" generally refers to outgrowths ranging from small hairs to larger outgrowths like thorns, it is typically used to refer to the tiny hairs that can be seen emerging from the surfaces of leaves and other epidermal surfaces of plants.

They are either unicellular or multicellular (epidermal cells), which means that some require a microscope to take a closer look.

****** The word trichome originated from the Greek word "Trichoma" that refers to hair growth.

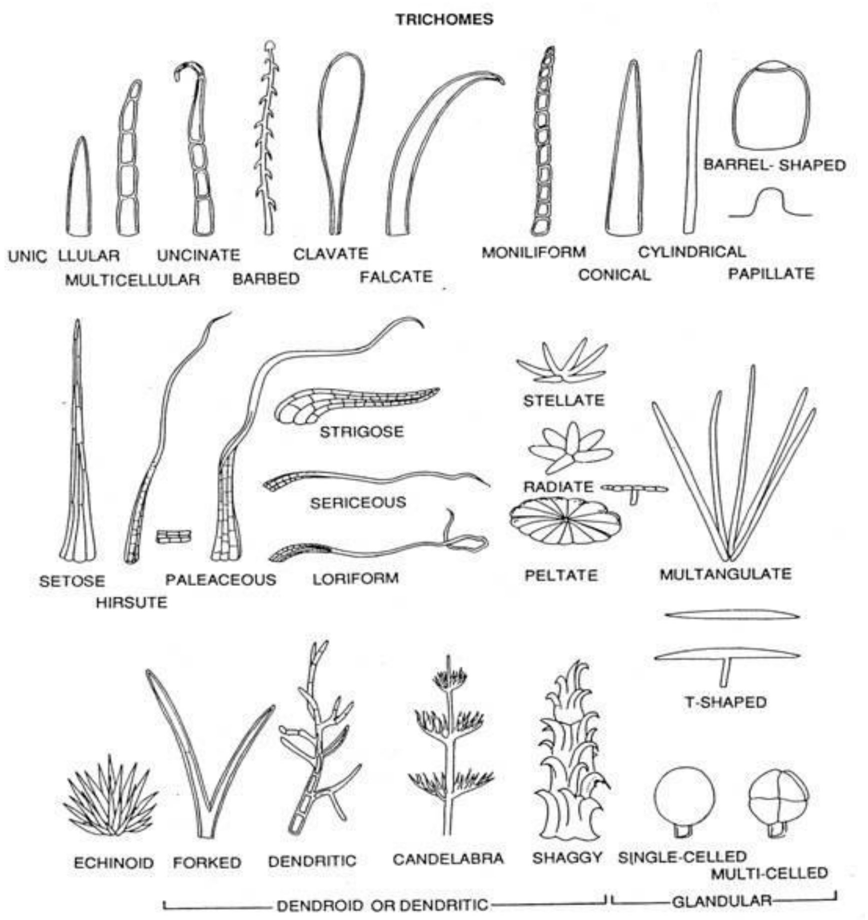
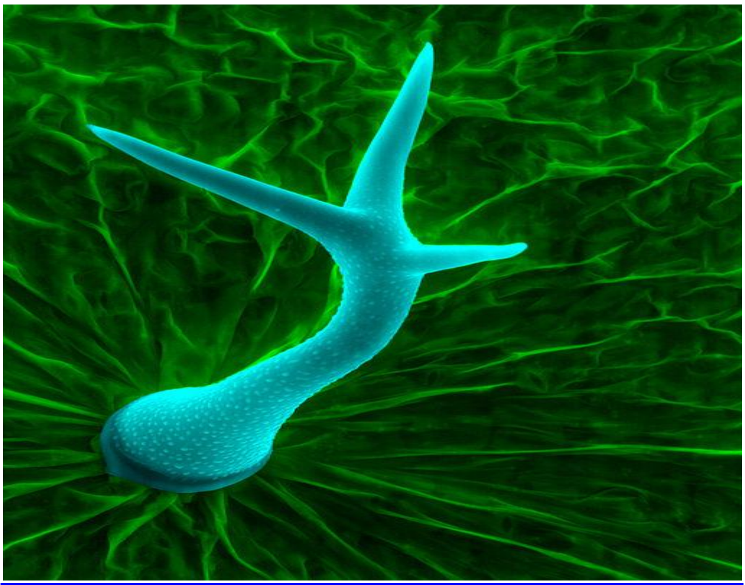


Fig. 37.22. Trichomes of different types.



Scanning electron micrograph of trichome:a leaf hair of thale cress ,

Types of Trichomes : As unicellular and multicellular epidermal appendages, there are a variety of trichomes that exist. These vary in size, morphology, origin as well as where they are located and the ability to secrete.

Glandular and Non-Glandular Trichomes

Glandular Trichomes : These types of trichomes are known to secrete various substances including water, nectar, resins, mucilage and terpens among others. Apart from their capacity to secrete, glandular trichomes can also be grouped in accordance to the number of cells.

***** Glandular trichomes is the term used to refer to an array of glands.

Glandular trichomes not only vary in the type of substances they secrete and their location, but also with regards to the mode through which they produce these secretions.

There are both unicellular and multicellular glandular trichomes. Moreover, they can also be uniseriate (they are arranged in single series or layer) or multiseriate (arranged in several series).

Unicellular glandular - For these types of hairs, it's possible to see morphological differences between apical and basal part of the cells. They may also occur branched or un-branched.

Multicellular glandular trichomes - these types of trichomes appear as outgrowths of the epidermis with a head consisting of cells that secrete and store great amounts of specialized metabolites.

The glandular trichomes include the stinging hairs and glandular hairs. The Urtica dioica is a good example of plants that have stinging hairs. The hairs of these plants have in place a basal bulb that gives rise to a protruding stiff and slender structure. The hairs are capable of secreting a poisonous substance that can irritate the skin when people come in contact with the plant and the sharp hair part penetrates the skin.

As for the glandular hairs (unicellular and multicellular) they can produce a variety of substances including oils and resins which makes them important in various industries including pharmaceuticals.

Examples of glandular trichomes :

- Saltbush (Atriplex) (secretes water)
- Docks and Sorrels (secretes water)
- Basil plants (secretes lipids)

Secretions

For the glandular trichomes, there are a wide variety of secretions that are produced by various plants. For this reason, glandular trichomes can be classified on the basis of the type of substances that they secrete. The following is one of the classifications that have been suggested with regards to secretions:

Unmodified or slightly modified substances - This includes such substances as salts and nectar

Substances that are synthesized by constituent cells :

- Hydrophilic substances
- Stinging hairs
- Lipophilic substances

***** One of the main weaknesses of this method of classification is that there are glandular hairs that are capable of secreting a variety of substances.

Non-Glandular Trichomes

The non-glandular trichomes vary in anatomy, morphology and microstructure. Despite this diversity, they are mostly grouped on the basis of their morphology.

Like the glandular trichomes, non-glandular trichomes also exist as either unicellular or multicellular. However, they can also exist as either branched or un-branched. A majority of these have been shown to be branched, simple and shaped like a star. As for the un-branched non-glandular trichomes, they can exist as uniseriate, biseriate or multiseriate. They also vary in shape, size and length and can be found in a variety of plants.

Different types of non-glandular trichomes can be found in different locations of a single plant. For instance, whole some of these can be found on the leaf of the plant (unicellular non-glandular trichomes on Coridothymus capitatus) two-celled trichomes can be located at the base of abaxial side of the leaf.

The following are examples of non-glandular trichomes:

- Gossypium with vesicular hair (non-flattened)
- Styrax
- T- shaped Corokia

Trichomes Functions :

There different types of trichomes that serve different functions for plants. There functions are largely dependent on the type of trichome as well as their location on the plant. While the function of some trichomes remains unknown, we will look at some of the known functions of trichomes.

Protection : Like animals, plants have also evolved over time. This has seen plants developing a range of mechanism for protection. This enhances the life span of the plant and ensures their survival.

Trichomes are some of the means through which some plants protect themselves from animals, extreme environmental conditions and thus enhancing their chances of survival. For instance, the trichomes (glandular) that develop in cannabis plants secrete a bitter substance and a strong aroma that prevents some animals from eating it. In particular, some glandular hairs tend to secrete lipophilic substances that prevent animals from consuming the leaves of the plant.

Apart from chemicals that wade off animals and pathogens, some trichomes secrete a type of mucilage that serves to trap insects when they come in contact with the plant leaves. This substance also helps prevent excessive water loss from the leaves as well as protecting the plant from excessive moisture.The non-glandular trichomes develop to form a thick and dense surface around the leaves which serves to protect leaves and the plant in general from harsh environmental conditions as well as protection from pathogens.

With some plants such as Tragia cannabina stinging hairs develop to protect the plant from herbivores. When an animal comes in contact with the hair, they break off and penetrate the body of the animal causing irritations.

Absorption of Water and Moisture

Non-glandular trichomes can also be found in the roots of the plant as hair-like structures where they support the absorption of water and other minerals required by the plant. These trichomes are more likely to exist as tubular structures that grow outwards to absorb water and minerals from the soil. However, they are very small with a thin cell wall, and thus can not last long. Once they die, they become lignified and are unable to absorb water and minerals any longer. However, new ones continue to form.

In some of the plants (such as apples and sorghum) the unicellular hairs can secrete mucilaginous droplets, which ensures that the plant does not dry out. Therefore, ensuring that the plant can survive for longer.

Some of the other functions of trichomes include:

- Elimination of excess toxic substances and salts from such plants as the Atriplex
- Waxes protect plants from extreme heat and sunlight
- Oils from such plants as Cymbopogon act as insect repellent,
- Protection of developing buds by such trichomes as the Ephemeral trichomes

Marijuana Trichomes : Also referred to as cannabis, marijuana is a plant that contains a mind altering substance. Recent studies have shown that certain chemicals from the plant have medicinal benefits for various patients.

Like a number of other plants, trichomes develop on the plant when it starts growing and develop fully when the plant starts flowering.

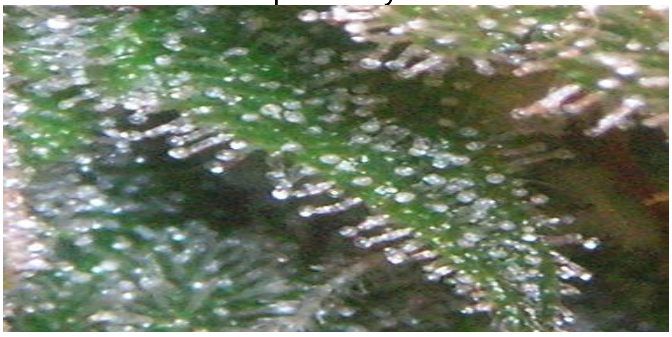
For marijuana, the trichomes exist as resin glands that produce various oils that protect the plant by acting as deterrents. At the same time, these substances protect the plant from extreme conditions and fungal growth.

There are three types of trichomes that develop in the cannabis plant. These include:

- Bulbous trichomes - These trichomes appear as small pointed structures on the surface of the plant. They are the smallest trichomes and are responsible for secreting resins.

- Capitate-sessile - This type of trichomes is bigger compared to bulbous trichomes and tend to develop before the plant starts flowering. They are flattened and contain cannabinoids.

- Capitate stalked trichomes - These are the largest of the three types of trichomes and form during flowering. They are largely involved in the synthesis of cannabinoids and terpenoid synthesis.



Cannabis Trichomes ,

Harvesting : Given that some of the trichomes (capitate-stalked trichomes) in marijuana contain the substance that produces the psychoactive effect, they influence the time of harvesting.

Here, the coloration of the glandular heads of the trichomes rather than the amount of trichomes is the determining factor for harvesting.

Using a microscope, it's possible to view the head of the capitate-stalked glandular trichomes. This coloration varies between different marijuana strains as well as depending on the maturity stage of the plant.

As the concentration peak of THC (Tetrahydrocannabinol) nears, trichomes have a translucent coloration. This color is the result of trichome glands producing the resin. However, the levels of CBD (Cannabidiol) is still low at this point. At the same time, the aromatic molecules are also at their peak.

In most cases, the plant leaves are harvested when the head of the glandular trichome starts turning opaque. And so there is a higher level of THC that can produce the best effects.

stomata (classification); **Stomata :** The continuity of the epidermis of aerial organs is interrupted by the presence of some minute pores or openings on it. These pores are called the stomata, through which exchange of gases takes place between the internal tissues and the outer atmosphere. A stoma has a small slit or pore and two specialised epidermal cells, called guard cells, on the two sides. Often other epidermal cells adjacent to the stoma undergo modifications.
They differ from other epidermal cells and become associated with the stoma functionally. These are referred to as subsidiary or accessory cells (Figs 559 & 561). Though gaseous interchange actually occurs through the pore, called stomatal aperture or opening, the term stoma includes the whole thing, the pore, guard cells and subsidiary cells, when present.

In surface view the guard cells look cresent or kidney-shaped in appearance, being attached to each other at the margin of the concave side with the aperture lying in between them (Fig. 558A). They may be easily distinguished from ordinary epidermal cells, because they possess dense cytoplasm, prominent nuclei, chloroplasts, and even starch grains.

A cavity is present just beneath the stoma, what is called sub-stomatal chamber or cavity (Fig. 558B). It is in communication with the intercellular space system of the internal tissues.

The walls of the guard cells are unevenly thickened, the wall along the aperture being strongly built and that away from the aperture being thin and extensible.

The guard cells have cutinised outer walls with a layer of cuticle which extends through the aperture and joins the inner wall.

Due to strong cutinisation often ledges of wall materials are noticed on the upper and lower sides of the ventral wall, so that in sectional view they appear like horns or beaks. The ledges project above and below and overarch the two chambers, referred to as the front cavity and back cavity, which communicate with each other through the pore (Figs. 58B & 560A).

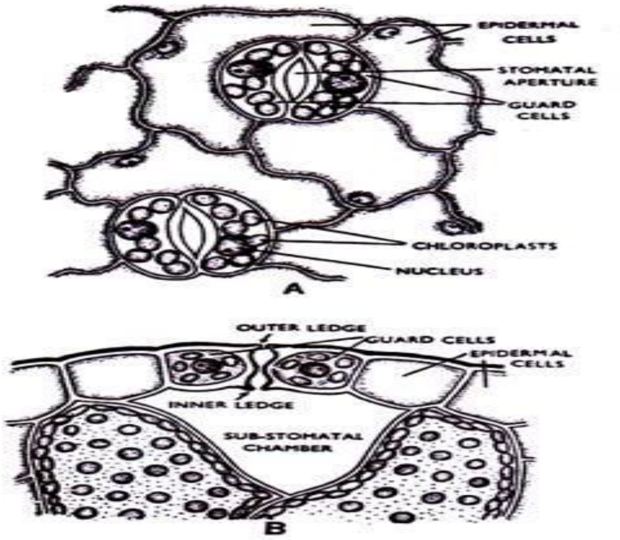


FIG. 558. Stomata. A. In surface view. B. In sectional view.

The guard cells, due to uneven thickening of the wall, what is really an outstanding character, can regulate the opening and closing of the stomatal aperture. Normally stomata remain open in daytime and close up with nightfall.

In the grass and sedge families the guard cells of the stomata are peculiarly dumb-bell- shaped where the middle portion is straight and strongly thickened and the two ends are swollen or bulbuous (Fig. 559) and thin-walled.

Stomata occur in all aerial parts of the plants, most abundantly in the foliage leaves. Those present on the floral parts and in the aquatic plants are normally functionless. In leaves they may occur on both upper and lower surfaces. In woody plants with dorsiventral leaves they are located on the lower epidermis. In herbaceous plants with isobilateral or centric leaves they occur on both the surfaces. Even in that case stomata are more abundant on the lower side than on the upper.

In floating leaves they occur only on the upper epidermis. In an individual leaf stomata are more numerous near the apex and minimum near the base, the

Formatted: Font: (Default) Arial, 14 pt, Bold, Font color: Custom Color(RGB(136,136,136)), Complex Script Font: Arial, 14 pt, Bold, Border: : (No border)

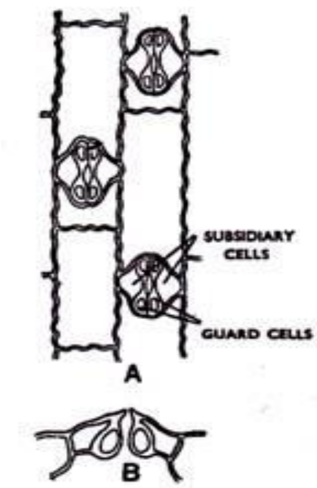


Fig. 559. Stomata from leaf of *Zea* (maize). A. Surface view. B. Sectional view.

middle portion having a distribution, which is an average of the apex and base. In leaves with parallel venation, as in the monocotyledons, and the needles of conifers stomata remain arranged in parallel rows (Figs. 555E & 559), whereas in reticulately-veined leaves they lie scattered (Fig. 563).

The number of stomata occurring on the epidermis of leaves is fairly large, which may range between a few thousand to over a hundred thousand per square cm. It has been estimated that a maize plant may have more than two hundred million stomata. So one can hardly estimate the number in a large tree.The guard cells may be at the same level with adjacent epidermal cells or they may be placed above or lie sunken below the surface of the epidermis. Sunken stomata (Fig. 560) are characteristic of the plants of dry situations, where they often appear to be located at the bottom of a cup-shaped depression, which is called the external cavity or outer chamber.This is an effective mechanism for reducing transpiration.

The subsidiary cells are highly thickened here. In the leaves of Nerium a groove or depression is formed, what is called stomatal pit (Fig. 560B) and stomata remain very much sunken.

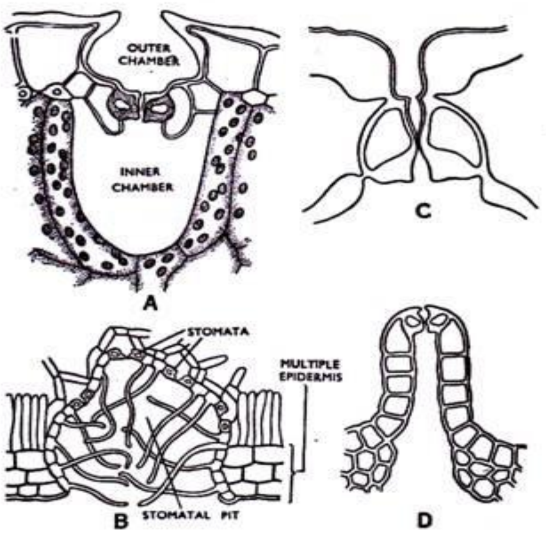


Fig. 560. Stomata in sectional view. A. Sunken stomata in *Hakea*. B. In *Nerium*. C. In *Allium* (onion). D. Raised stoma in peduncle of *Cucurbita*.

Formatted: Font: (Default) Arial, 14 pt, Bold, Font color: Red, Complex Script Font: Arial, 14 pt

Modern workers (Cf. Metcalfe and Chalk) have suggested the following types of stomata in the dicotyledons on the basis of the characters stated above.

A. Anomocytic or irregular-celled type (Fig. 563A):
Stoma remains surrounded by a limited number of cells which cannot be distinguished from other epidermal cells. Thus the subsidiary cells are absent. This is also called ranunculous type, common in the families Ranunculaceae, Capparidaceae and others.

B. Anisocytic or unequal-celled type (Fig. 563B):
Here the stoma remains surrounded by three subsidiary cells of which one is distinctly smaller than the other two. It is otherwise known as cruciferous type common in Cruciferae.

C. Diacytic or cross-celled type (Fig. 563C):
Here the stoma remain enclosed by a pair of subsidiary cells whose common wall is at right angles to the guard cells. This is also called caryophyllaceous type, common in Caryophyllaceae, Acanthaceae and others.

D. Paracytic or parallel- celled type (Fig. 563D):
The stoma is accompanied on either side by one or more subsidiary cells which lie parallel to the long axis of the pore of guard cells. This is also referred to as rubiaceous type common in Rubiaceae, Magnoliaceae and others.

In view of the fact that diversities occur as regards the nature of the stomata the terms ranunculous, etc., are rather confusing, and anomocytic, etc., suggested by Metcalffe and Chalk appear to be more appropriate.

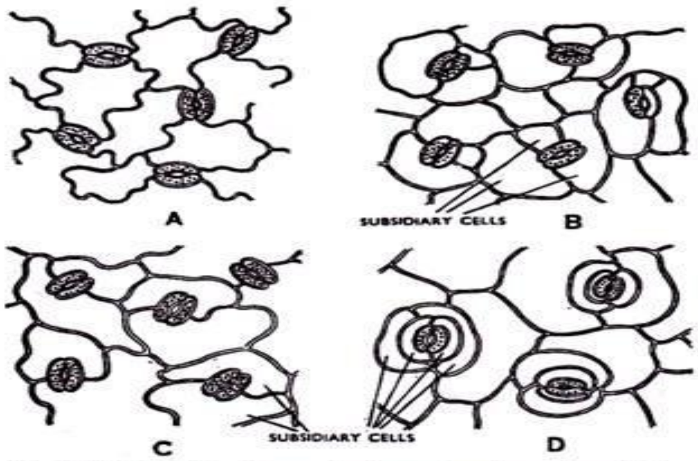


FIG. 563. Stomata—types. A. *Anomocytic* or irregular-celled type in *Clematis*. B. *Anisocytic* or unequal-celled type in *Iberis*. C. *Diacytic* or cross-celled type in *Dianthus*. D. *Paracytic* or parallel-celled type in *Gardenia*.

Formatted: Font: (Default) Arial, 14 pt, Bold, Font color: Custom Color(RGB(136,136,136)), Complex Script Font: Arial, 14 pt, Bold, Border: : (No border)

In the monocotyledons the most common one is the graminaceous or grass type (Fig. 559). Here the two guard cells are dumb-ball-shaped having a narrow middle portion and bulbuous ends. Two distinct subsidiary cells lie parallel to the long axis of the pore.

In recent years intensive investigations have revealed a few other types as well (Fig. 563A). In Orchidaceae, Amaryllidaceae and others the guard cells are not associated with any subsidiary cells.

Guard cells surrounded by four to six subsidiary cells have been noticed in many species of Araceae, Commelinaceae, Musaceae and others. In Palmae, Pandaceae guard cells have four subsidiary cells—two of them are lateral and two polar ones.

The latter ones are smaller in size and round in shape. The term tetracytic has been used for this type.

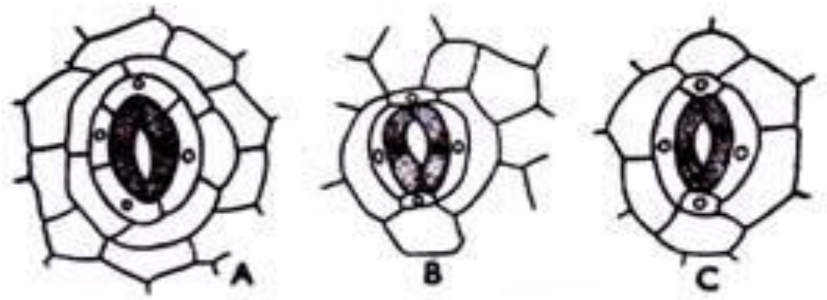


FIG. 563A. Stomata types in monocotyledons. A. In *Stretlitzia*; B. In *Commelina*; C. In *Pandanus*.

It has been suggested that stomata with many subsidiary cells are primitive, and those with few or no subsidiary cells have been derived by reduction.

The stomata are very important from physiological point of view. It is through them that interchange of gases takes place between the intercellular space system of the internal tissues and the outer atmosphere and thus important physiological functions like photosynthesis, respiration and transpiration become possible.

Water-stomata or hydathodes are also epidermal openings through which liquids often with dissolved salts, are exuded from the plants. They have been discussed in the preceding chapter.

Adcrustation and incrustation ; **Adcrustation** is the process of the addition of any substance on a surface or substance from inside the whole substance. It means that nothing is added on the surface to make the substances thick or big, rather the growth comes from the whole body. The growth of fruits and subsequent parts is an example of **adcrustation**.

The **incrustation**, on the other hand, is the process by which the substances grow with the addition of new layers on the surface of the body. The cell walls of the **plants** grow by the process of **incrustation**.

Anatomical adaptations of xerophytes and

Ecological Adaptations in Xerophytes

Xerophytes are group of plants that survive in dry regions. They grow in deserts, dry hilly regions. They adapt themselves to dry and sandy or rocky soils having poor water content and extreme atmospheric conditions. Xerophytes can withstand drought, intense light, extreme temperature and strong wind. Such a habitat is termed as xeric.

Xerophytes are able to live in these environments because they contain special features that help them prevent water loss. Certain xerophytes have waxy covering over their stomata, thus preventing water loss. Some of them have very few stomata, or stomata that open at night. These adaptations limit the loss of water and allow the plant to survive in dry environments.

Some of the xerophytes have the ability to store water. These plants are termed as succulents. This is another adaptation to xeric conditions.

Types of xerophytes

Depending on their ability to withstand drought condition of the soil, following are the different classes of xerophytes:

1. **Ephemeral annuals (drought escaping):** Such xerophytes complete their life cycle before the arrival of dry condition;
   e.g., *Argemone mexicana*, *Cassia*, *Solanum xanthocarpum* etc.
2. **Succulents:** These are drought resisting xerophytes. Succulents grow in habitats with less or no water but store water whenever available. They are perennial in habit and resist drought by accumulating water in leaves, stems and roots; e.g., *Opuntia*, *Aloe*, *Cactus* etc.
3. **Perennial non-succulents (drought-resistant):** These are drought enduring xerophytes. They grow in habitat with almost no water, they also cannot store water. During drought growth of the plant stops and it takes place only during the brief period of plenty of water supply during rainfall;
   e.g., *Nerium*, *Calotropis procera, Acacia arabica,* etc.

Adaptive features of xerophytes :

Morphological adaptations.

Root :

1. The root system is well developed.
2. The plants usually have a long and stout tap root which branches profusely.

3. Presence of root hairs.
4. The roots go deep into the soil in search of water.

Shoot:

1. The shoot is generally hard and woody.
2. It is mostly covered with hairs, wax, and silica etc.
3. Stem may also be fleshy and growth remains stunted.
4. Some of the plants show modified stems; e.g., in *Opuntia*, the stem forms leaf-like structure termed as **phylloclade**. In *Asparagus* and *Ruscus*, the leaf-like structure formed by the leaf is termed as **cladode**.

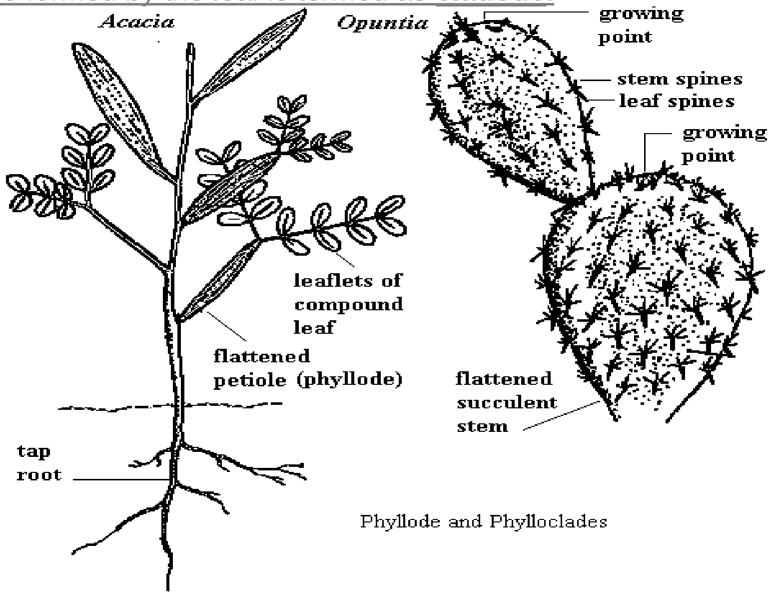


Fig: Phylloclade in *Opuntia*

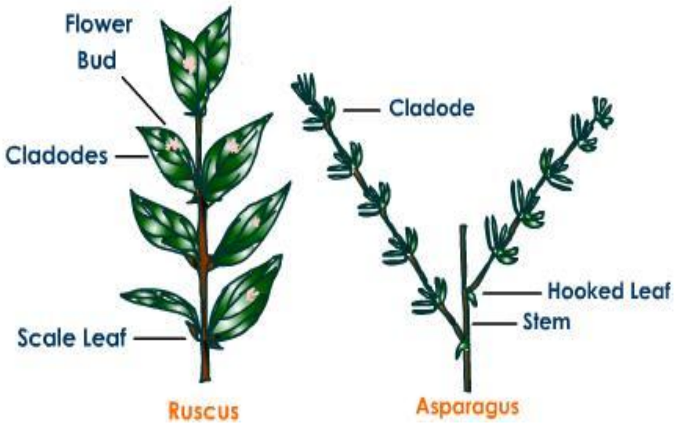


Fig: Cladode in *Ruscus* and *Asparagus*

Leaves: The leaves are modified in such a way that water loss due to transpiration reduces to minimum. Depending on the shape of the leaves and their structure, xerophytes are classified into following four classes:

1. **Sclerophyllous:** Leaves are stiff and hard; e.g., *Banksia* etc.
2. **Trichophyllous:** Leaves are covered with hairs; e.g., *Nerium, Calotropis.*

3. **Microphyllous:** Leaves are smaller in size and reduced; e.g. *Asparagus, Casuarina, Pinus* etc.
4. **Malacophyllous:** Leaves are soft and fleshy; e.g., *Begonia, Salicornia* etc.

The leaves of xerophytes are generally caducous; e.g., *Euphorbia.* In some cases, these may even be absent; e.g., *Capparis aphylla*. In grasses, the leaves roll when the condition becomes dry and hot.

Reproduction: Most of the xerophytes multiply by their perennial organs such as stem. They also reproduce sexually when water becomes available for their growth.

Anatomical Adaptations

General anatomical characters of xerophytes.

1. Presence of thick cutical on leaf and stem epidermis.
2. Presence of waxy layer on the epidermis for reflection of light.
3. Sunken stomata is present. A thick envelop of hair on epidermis and around sunken stomata. This layer forms an insulating envelope and checks increasing temperature.
4. Epidermal cells are radially elongated to absorb necessary amount of light.
5. Leaves are small, reduced and may even be absent. If so, palisade and chlorenchyma is present in the cortex of the stem.
6. Intercelluar spaces are only a few and also very small.
7. Mechanical tissues like collenchyma and sclerenchyma are well developed.
8. Presence of water storage tissue.
9. Dead tracheids, parenchyma, intercellular spaces, mucilaginous substances are generally present for absorption and retention of sufficient amount of water.
10. Vascular tissues are present in large amount.
11. In some desert grasses, the leaves roll due to the presence of motor or bulliform cells in the epidermis. These cells are sensitive to changes in turgor and thus, contract when conditions are dry. This results in upward rolling of leaves and cutting of the stomatal contact with external atmosphere. This reduces the rate of transpiration. This feature is termed as **hydrochasy**.

Anatomy of *Casuarina* stem:

1. **Epidermis:** This outer most single layer of cells shows ridges and grooves. A thick cuticle is present in the outer surface of the epidermal cells. Sunken stomata are present in the grooves. These are covered with hairs.
2. **Cortex:** It is divisible into three parts; hypodermis, palisade and parenchyma. Hypodermis is made of a T-shaped group of sclerenchyma in the ridges. A few layers of palisade are present below the sclerenchymatous hypodermis. The remaining part of the cortex consists of parenchyma. A single cortical vascular bundle is present below each of the ridges. This is conjoint, collateral, endarch and open.
3. **Endodermis:** This layer possesses numerous starch grains.

4. **Pericycle:** A sclerenchymatous patch above each vascular bundle represents pericycle.

5. Vascular tissues: The vascular bundles are arranged in a ring. The vascular bundles of the inner rings are present below the grooves and they alternate with cortical vascular bundles. These vascular bundles are also conjoint, collateral, endarch and open.

6. The vascular bundles show a small amount of secondary growth.

Xerophytic characters:

1. Presence of thick cuticle.
2. Sclerenchymatous hypodermis.
3. Presence of palisade in the cortex.
4. Sclerenchymatous cap over the vascular bundles.
5. Presence of parenchymatous pith with numerous intercellular spaces.

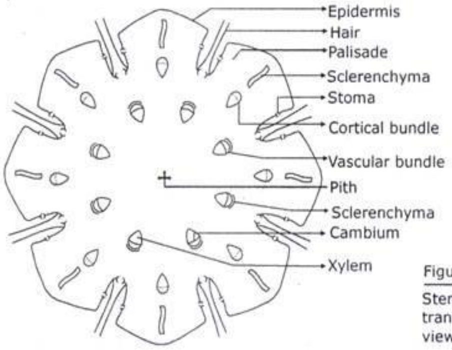


Figure 31.28
Stem of *Casuarina* in transverse sectional view (diagrammatic).

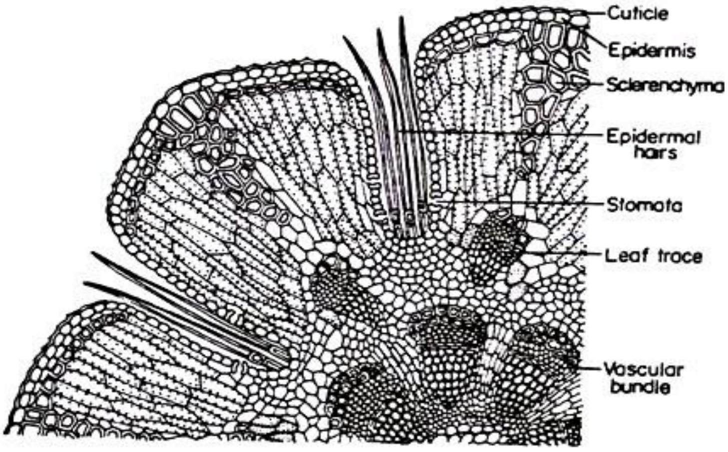


Fig. 8.7 : T.S. of *Casuarina* stem

Fig: T.S of *Casuarina* stem

Anatomy of *Nerium* leaf:

1. **Epidermis:** Upper as well as lower epidermis are multiseriate. These layers possess thick cuticle. Sunken stomata occur in the lower epidermis with dense cluster of hairs.
2. **Mesophyll:** It is differentiated into palisade and spongy parenchyma. Palisade tissues occur near both the epidermis while spongy parenchyma is present in between. Numerous crystals of calcium oxalate are present in the palisade cells. In the midrib, only parenchyma is present instead of palisade and spongy parenchyma.
3. **Vascular tissues:** Vascular bundle present in the midrib is larger than those present in the wings. A parenchymatous bundle sheath surrounds each vascular bundle. Xylem in the vascular bundle directs toward upper epidermis and the phloem towards the lower epidermis.

Xerophytic characters:

1. Presence of thick cuticle.
2. Both upper as well as lower epidermis are multiseriate or multiple.
3. Presence of sunken stomata.
4. Dense cluster of hairs cover the sunken stomata.
5. Numerous crystals of calcium oxalate are present in the palisade cells.
6. Well developed vascular tissues.

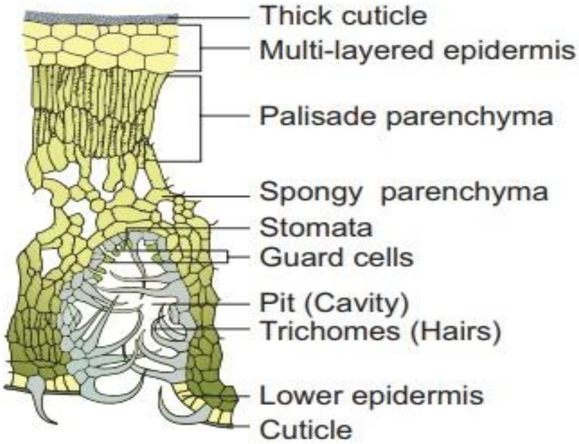


Figure 3: T.S. of Nerium leaf

Hydrophytes. Ecological Adaptations in Hydrophytes

Plants grow in different environments. They develop various useful morphological and anatomical characters to adapt themselves according to their environment. Depending upon these morphological and anatomical characters and the nature of their habitat, plants are classified into three groups-hydrophytes, xerophytes and mesophytes.

Hydrophytes : Hydrophytes are the plants which grow in habitats where water is abundant. They are further divided into the following six groups.

1. **Free floating:** These plants float freely and independently on water surface; e.g., *Eichhornia, Lemna, Pistia* etc.
2. **Floating and possessing roots:** These plants float on the surface of water. These plants attach themselves to the bottom with the help of their roots; e.g., *Nymphaea, Trapa* etc.
3. **Submerged:** These plants occur below the water surface, but they do not attach themselves to the bottom; e.g., *Ceratophyllum, Najas* etc.
4. **Submerged and possessing roots :** These plants occur below the water surface and also remain attached to the bottom of water reservoir; e.g., *Hydrilla, Vallisneria* etc.
5. **Ambhibious and possessing roots:** These plants grow in waterlogged soils. Examples are, *Polygonum*, *Marsilea* etc.
6. **Emergent and possessing roots:** These plants grow in shallow waters and remain attached to the bottom. A part of the plant is below the water surface and a part above it. Examples are, *Cyperus*, *Typha* etc.

Fig: Hydrophytes

Morphology of Hydrophytes

Roots:

1. Roots are either completely absent (e.g., *Ceratophyllum)* or poorly developed (e.g., *Hydrilla*).
2. Root pockets are present instead of root caps (e.g., *Eichhornia, Lemna, Pistia* etc.).
3. Some plants develop floating roots in addition to normal adventitious roots (e.g., *Jussiaea repens*)

Stems:The stem of hydrophytes shows the following adaptations.

1. In most of the hydrophytes the stem is long, slender, spongy and flexible; e.g., *Hydrilla*, *Potamogeton* etc.
2. The stem may float horizontally on water surface (e.g., *Azolla)* or may be thick, short and stoloniferous; e.g., *Eichhornia.* It may be attached to the bottom of the pond by a rhizome (e.g., *Nymphaea*).

Petiole ; The petioles have special modifications to suit the aquatic environment. Following are some of the modifications.

1. Long, slender and delicate petioles are present in hydrophytes with their leaves floating on water surface (e.g., *Nymphaea*).
2. In some plants petiole is swollen to form a bulb like structure to help the plants to float on water (e.g., *Eichhornia).*

Leaves : The leaves of hydrophytes show the following characteristics:

1. In submerged hydrophytes the leaves are thin, long and in the shape of a ribbon, (e.g., *Vallisneria*) or finely dissected (e.g., *Ceratophyllum).*
2. Floating leaves are large, entire and flat (e.g., *Nymphaea).* These leaves have a coat of wax. The leaves may also have hairs (e.g., Salvinia).

3. The leaves of emergent and amphibious hydrophytes are heterophyllous, i.e., the leaves below the water are long, narrow and dissected while those outside the water are entire and broad. This is also termed as dimorphism of leaves. Heterophylly is shown in plants such as *Ranunculus, Limnophila heterophylla, Sagittaria, Sagitifolia* etc.

Reproduction : Hydrophytes are mostly perennial. They generally reproduce by vegetative methods. Hydrophytes form new colonies through stolons and offsets.

Anatomy of hydrophytes :

1. All hydrophytes show presence of large air chambers. The tissue that forms air chambers is termed as **aerenchyma**.
2. Mechanical tissue, i.e., sclerenchyma is either poorly developed or absent.
3. Vascular tissue, particularly xylem is poorly developed.
4. Cuticle is absent.
5. Stomata are absent in submerged hydrophytes.

Roots

Epiblema is not cuticularised.

Cortex is mostly parenchymatous.

Aerenchyma may also be present.

Xylem is poorly developed in comparison to phloem.

Amphibious hydrophytes show xerophytic characters in addition to hydrophytic characters.

The roots of these plants have well developed mechanical and vascular tissues, besides aerenchyma.

Stem :

1. Cuticle is absent in epidermis.
2. Cortex is large and parenchymatous.
3. It is largely made of aerenchyma.
4. Xylem is poorly developed in comparison to phloem.
5. The vascular tissues are so reduced that these form a single vascular bundle.

Leaves :

1. The leaf epidermis does not have cuticle.
2. However, in floating leaves wax or hairs cover the upper epidermis. Stomata are present only in the upper epidermis.
3. Stomata are absent in the in the submerged leaves.
4. Large air chambers and spongy parenchyma are present in the leaves.
5. Palisade parenchyma is generally absent.

6. In amphibious hydrophytes cuticle, stomata, palisade tissue and well developed tissue are present.

Anatomy of *Eichhornia* Root

1. **Epiblema:** It is the outermost single layer of cells. Cuticle is absent.
2. **Cortex:** It is divisible into three parts. The outer cortex consists of compactly arranged parenchyma. Middle cortex shows aerenchyma consisting of many air chambers. The inner cortex consists of compactly arranged isodiametric parenchyma.
3. **Endodermis and pericycle:** Both these layers are very distinct.
4. **Vascular tissue:** Vascular bundles are radial and exarch. The xylem elements are only a few.
5. **Hydrophytic characters:**

a). Undifferentiated parenchymatous cortex.
b). Presence of aerenchyma.
c). Absence of mechanical tissue.
d). Poorly developed vascular tissue.
e). Parenchymatous pith.

Anatomy of *Hydrilla* Stem

1. **Epidermis:** This is the outermost single layer of cells. The cuticle is absent.
2. **Cortex:** It is mainly aerenchymatous and shows large number of air chambers. The air chambers towards the periphery are larger than those present in the middle of the cortex.
3. **Endodermis and pericycle:** The layers are not distinct.
4. **Vascular tissue:** The amount of phloem more. A large central cavity represents xylem.

Hydrophytic characters:

a). Thin walled epidermis.
b). Absence of cuticle.
c). Presence of air chambers in the cortex.
d). Vascular tissue poorly developed.
e). The amount of phloem is more than that of xylem.

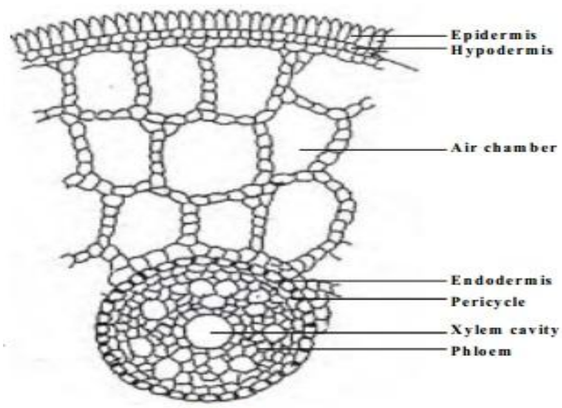


Fig : T.S. Hydrilla Stem

Fig: T.S through *Hydrilla* stem

Anatomy of *Eichhornia* Petiole:

1. **Epidermis:** This is a single layer of cells where the cuticle is absent.
2. **Hypodermis:** Parenchymatous tissue that is present below the epidermis forms the hypodermis.
3. **Aerenchyma:** The remaining part of the petiole is termed as ground tissue. It has many air chambers or lacunae. The size of the air chambers gradually increases towards the centre.
4. **Vascular tissues:** Numerous vascular bundles are present here and there between the air chambers. A distinct parenchymatous envelope surrounds each vascular bundle. Phloem occurs in the peripheral part of the bundle and a single element of xylem is present in the centre.
5. **Hydrophytic characters:**

a). Thin walled epidermis.
b). Absence of cuticle.
c). Absence of mechanical tissue.
d). Presence of aerenchyma and air chambers.
e). The phloem is distinct in comparision to xylem.

Fig: T.S. of petiole of *Eichhornia*