XEROPHYTES

- "Plants that are adapted to survive in dry environments having extreme shortage of water by reducing transpiration are called xerophytes".
- In most respects, xerophytes are reverse of hydrophytes in structural organization.
- Where water is relatively scarce or the amount of water that can be absorbed is limited or where evaporation is excessive, the plants display respective characteristic structural features.

General adaptive features of xerophytes: -

1. **Roots** are frequently strongly developed, except in cacti. Plants like *Calotropis* have roots of considerable length and size. Such roots accumulate larger amounts of water and food. In some extreme xerophytes like *Opuntia*, root hair extends to the root tip. In plants like *Pinus edulis*, roots possess rigid thickened walls. In some cases, like *Asparagus*, roots become fleshy and store water, such roots contain mucilage also.
2. **Leaves** show far greater variation. In *Agave americana*, leaf tissues are closely packed and thick layers of cuticle produced. In *Salix glaucophylla*, thick layer of wax grains are present outside the cuticle. In *Ficus elastica* and *Nerium*, there are three layers of epidermal cells. Stomata are in pits in *Nerium*. In *Sphaeralcea incana*, epidermis is thickly covered with trichomes. Such leaves are called trichophyllous. In plants like *Pinus*, sclerenchymatous hypodermis is present. It is thought to reduce the injurious effects of wilting. Such leaves are called sclerophyllous leaves. Many xerophytes have foliage leaves are thick and fleshy composed of water storage tissue. In *Peperomia*, tissue may consist of an epidermis, several cells in thickness. Such leaves are called malacophyllous. In *Mesembryanthum crystallinum*, few of the epidermal cells are much distended and project considerably beyond the epidermal level, causing the leaves to glisten in sunlight. In some cases, as in *Casuarina*, the leaves are reduced and scale-like. Such leaves are called microphyllous.
3. Protective features are remarkably developed both in amount and in kind, and their advantages are enormous owing to the exposure of xerophytes to transpiration. Many species are leafless, the cylindrical stems exposing relatively small surface to transpiration. In many cases, there is temporary reduction in surface, as in those legumes whose leaves close in dry weather; such plants are called resurrection plants.
4. In woody xerophytes, there is prominent bark development, the cork in particular being of high significance in checking transpiration. The surfaces of both leaves and stems are covered with spines in *Solanum xanthocarpum*, *Argemone mexicana*, etc.

5. Oils and resins are often abundantly developed as in *Pinus*.
6. Presence of sap and latex is a common occurrence in many *Euphorbias* and cacti.
7. Osmotic pressure of the cell sap is often very high.
8. Conductive tracts are prominent, vessels being larger and longer and the walls thicker. Lignification is prominent and annual rings are well-developed.
9. Bast fibres and other mechanical elements reach their highest development in the xerophytes.
10. Cells are smaller in size and thick-walled, especially in leaves.
11. Xylem cells are smaller in size.
12. Epidermal cells possess more liquids on the transpiring surface.

Physiological Adaptations of Xerophytes: -

- Rate of transpiration per unit area is greater in spite of the reduced net rate of transpiration.
- Rate of photosynthesis per unit area is rapid.
- Levitt (1956) and Iljin (1957) have shown that the ratio between sugar and starch is also lower in these plants.
- Osmotic pressure is higher.
- According to Iljin (1957), protoplasm is less viscous and more permeable in the xerophytic plants.
- They are resistant to wilting.
- They bear flower and fruit earlier.

I. SUCCULENT XEROPHYTES: -

There are two types of succulent xerophytes – those with fleshy stems and those with thick and succulent leaves.

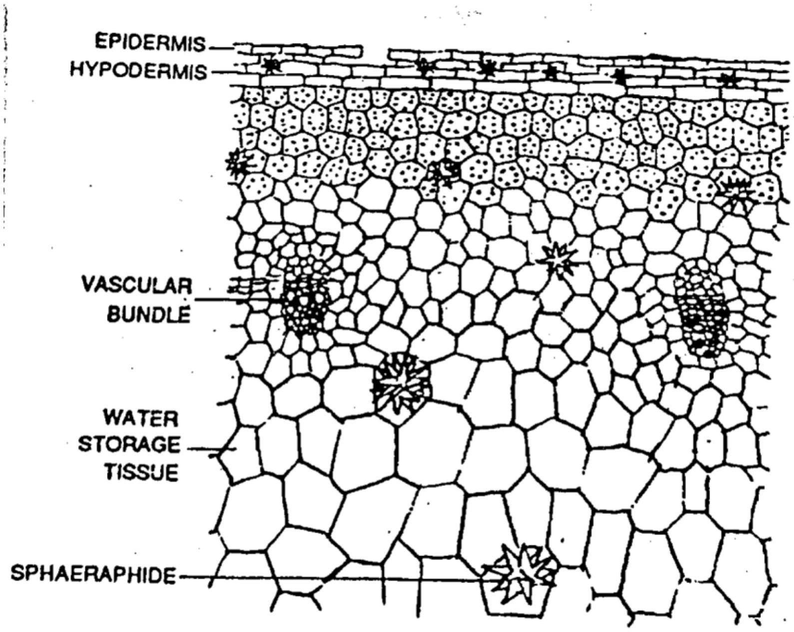
Succulence in both the cases is due to:

- Proliferation of cells in parenchymatous regions
- Reduction in size of intercellular spaces
- Enlargement of the vacuoles.

I.1. Succulent Xerophytes with Fleshy Stem: -

Examples of such plants are *Opuntia*, *Echinocactus*, *Euphorbia*, etc.

Ecological Adaptations in the Anatomy of *Opuntia* stem (phylloclade):



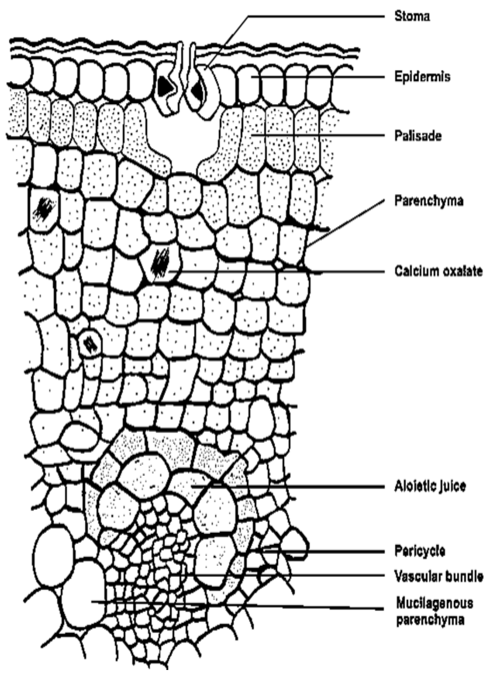
- Phylloclade is made up of epidermal layer having thick-walled cells.
- Cuticle is also well-developed and forms a thick layer.
- Below epidermis is the two to three-layered hypodermis.
- Next to this is the chlorenchymatous cortex. This region is made up of three to four layers of palisade-like cells which contain abundant chloroplasts and serve as photosynthetic region.
- Next to this region is the water-storage tissue, which consists of large thin-walled cells with few intercellular spaces.
- The cells are highly vacuolate and contain mucilage that can hold water.

Some of the cacti eg., the giant cacti (*Cereus giganteus*) are known for their water storage capacity. In *Cavanillesia*, the trunk assumes the shape of a barrel. During rainy seasons, the stems accumulate large quantities of water, which becomes depleted during subsequent drought. The fluted stems of *Cereus giganteus* undergo alternate expansions and contractions during wet and dry periods respectively, with maximum circumferential difference being considerable. These plants have leaves and stipules reduced to spines.

I.2. Succulent Xerophytes with Fleshy leaves (Malacophyllous Xerophytes): -

- These kinds of plants possess a water tissue which consist of turgescent parenchyma cells with delicate cellulose walls, thin peripheral layers of cytoplasm, and few or no chloroplasts.
- In many succulents, the water tissue is not sharply delimited from ordinary chlorenchyma, and may be made up of entirely of turgescent green cells, or the leaf may be thick with chlorophyll decreasing towards the centre as in *Senecio*. In *Agave americana*, the outermost chlorenchyma cells are elongated, representing true parenchyma cells, while the cells in the centre become more and more isodiametric and also poorer in chlorophyll.
- In *Aloe* also, the water storage tissue is centrally located and sharply delimited. It has a comparatively thick cuticle.
- The epidermis is thick-walled in *Yucca, Sansievera* and *Agave*.

Ecological Adaptations in the Anatomy of *Aloe* leaf:



- A third kind of water tissue differs from the rest in its peripheral position. In such cases, the epidermal cells store water.
- In *Aloe*, epidermis is single layered with sunken stomata and thick cuticle.
- The central tissue of the leaf is composed of large parenchyma cells with delicate wall, large vacuoles, peripheral cytoplasm and very few or no chloroplasts. The tissue is highly mucilaginous. It is known as water storage tissue.

- On the either side of water storage tissue there are smaller parenchyma cells with more chloroplasts. This is mesophyll which forms main photosynthetic storage tissue.
- At the junction of mesophyll and water storage tissue there are vascular bundles which are well developed.

II. Non-succulent or Woody Xerophytes: -

This class of xerophytes includes all such non-succulent plants that can endure wilting. This endurance is limited to a short period in woody plants. Examples include *Nerium, Pinus, Casuarina, Equisetum, Calotropis,* etc.

- Root system is profusely developed and there is rapid elongation of the tap roots. The roots of *Calotropis* grow very deep in the soil and make a permanent contact with the subsoil.
- Plants possess high osmotic pressure which is a physiological development necessitated by high solute content of the unleached soils.
- They can minimize the rate of transpiration during extreme conditions of dessication that bring about wilting. This is accomplished in several ways as follows:
  - Rolling of leaves, as in *Ammophila*
  - By producing special set of leaves in dry periods
  - By bearing delicate leaves during rainy season and shedding them immediately when ground water is exhausted, e.g., *Euphorbia splendens*.

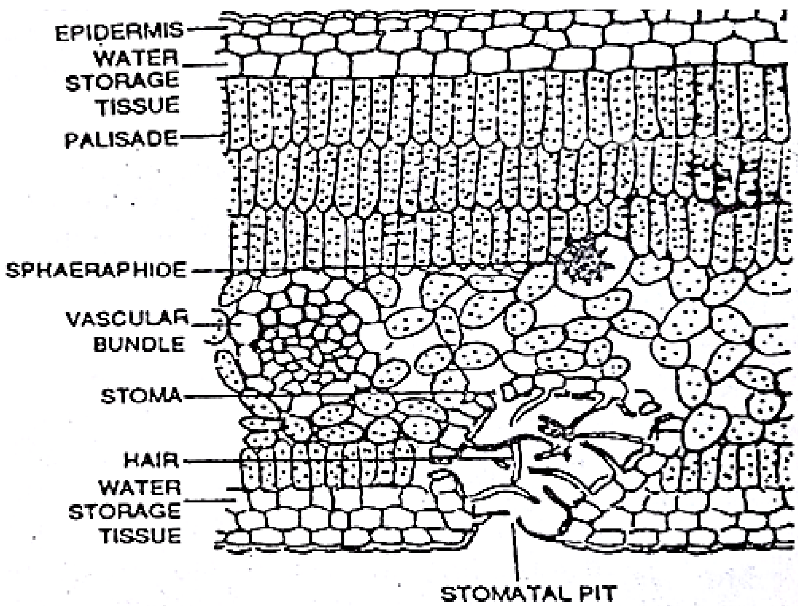
Xerophytes which retain their leaves during dry periods show following characteristics:

- Leaves are cutinized, e.g., *Pinus*
- They possess waxy coating. E.g., *Salix*.
- Stomata are smaller in size and remain closed.
- Sunken stomata as in *Nerium*.
- Densely pubescent surfaces also minimize the rate of transpiration because they keep the air currents well above the stomata, e.g. In *Calotropis*.
- Folding of leaf surfaces, e.g., *Ammophila*. Epidermis in such leaves contain water and the amount of water content in them regulates the leaf-closing and leaf-opening in them.
- Presence of many layered epidermis as in *Nerium* gives rigidity to the leaf and prevents shrinking.

- In sclerophyllous xerophytes as in *Banksia*, leaves possess epidermal sclerenchymatous layer.

In some woody xerophytes like *Casuarina*, the leaves are reduced in size and are scaly. It reduces the likelihood of necrosis and the small size of leaves also prevents the leaf surface from over-heating when exposed to strong solar radiation. Cell size and size of the vacuoles is reduced in woody xerophytes. The reduced cell size in plant organs prevents the pulling away of the protoplasm from the cell walls and rupture of plasmodesmata under conditions of drought and dessication.

Ecological Anatomy of *Nerium* leaf:



- Both upper and lower epidermal layers are multiseriate. They are composed of a few layers of compactly arranged isodiametric colourless cells. Both the epidermal layers are very strongly cuticularized. There are distinct sunken stomata on the lower epidermis. A good number of trichomes develops from the bordering cells and remain projected within the stomatal pit.

- Mesophyll consists of palisade and spongy cells. But unlike other dorsiventral leaves, palisade cells occur here both towards upper and lower epidermis and spongy cells are located in between them. Calcium oxalate crystals are scattered within the mesophyll cells.

- The vascular bundles are collateral and closed ones with xylem on the upper and phloem on the lower sides. They remain surrounded by parenchymatous bundle sheaths.

COMPARISON OF MORPHOLOGICAL / EXTERNAL FEATURES OF HYDROPHYTES, MESOPHYTES AND XEROPHYTES

No.	Hydrophytes	Mesophytes	Xerophytes
1.	Roots generally greatly reduced, even absent; if present, unbranched without root hairs.	Root system well-developed, tap or fibrous roots with root hairs.	Root system generally very deep, extensive, reaching deeper layers of soil; several times larger than shoot, hard and woody.
2.	Most rooted and immersed hydrophytes have well developed, extensive, creeping underground stems with profuse adventitious roots embedded in mud.	Stem is aerial, mostly erect but of limited growth; sometimes stem is metamorphosed into leaf-like cladode.	Aerial stem of plants is well developed and much branched. In case of herbaceous plants, they are often prostrate.
3.	Stem is soft and tender. In most cases shoots have short condensed internodes.	Stem is rigid and stout.	Texture of stem ranges from soft to hard-woody type.
4.	Leaves thin, narrow, linear, some with long petioles and large lamina, covered with wax or hairs, dissected into segments in some plants.	Leaves large, thin, generally without waxy surfaces.	Leaves small, sometimes much reduced to scales or modified into spines, in some leathery and thick with shining surface and waxy coating, covered with hairs.

COMPARISON OF ANATOMICAL / INTERNAL FEATURES OF HYDROPHYTES, MESOPHYTES AND XEROPHYTES

No.	Hydrophytes	Mesophytes	Xerophytes
1.	Aerenchyma extensive almost in all vegetative organs.	Aerenchyma lacking.	Aerenchyma lacking.
2.	Cuticle generally absent.	Cuticle developed.	Cuticle thick, well developed.
3.	Stomata either absent, or if present, only at upper surface or even non-functional.	Stomata on one or both the surfaces.	Stomata less in number, generally confined to lower surfaces of leaves, sunken.
4.	Mesophyll undifferentiated into palisade and spongy parenchyma.	Palisade well developed and differentiated.	Palisade generally on both sides of leaves, cells and vacuoles small.
5.	Chlorophyll in addition to leaves also in other parts of plant.	Chlorophyll mostly in leaves.	Chlorophyll mostly in stems and leaves.
6.	Epidermal cells thin-walled.	Epidermal cells thick.	Epidermal cells conspicuously thick-walled.
7.	Lignified mechanical tissues lacking, conducting elements very few, non-lignified.	Mechanical and vascular tissues well developed.	Mechanical and vascular tissues very well developed.
8.	Glandular hairs and various types of secreting organs do not occur.	Various types of glandular hairs and secretory organs present.	Hydathode-like secretory organs are found to be present in many plants.

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