Bio Factsheet

Number 29

Plant Adaptations to Dry Environments

Xerophytes are plants which are adapted to live in dry conditions. Xeromorphic features are those which minimise water loss from the plant. The vast majority of the water which plants absorb via their roots is lost as water vapour from the aerial parts of the plant. This loss of water vapour is known as transpiration and is an inevitable consequence of the large moist surface area of cells which is exposed to air. The large surface area of cells is essential if carbon dioxide and oxygen are to be absorbed by leaves. However, excess water loss is the most common cause of plant death.

The most common features of xerophytes are summarised in the table below.

<table>
<tr><th>Adaptations</th><th>Explanation</th></tr>
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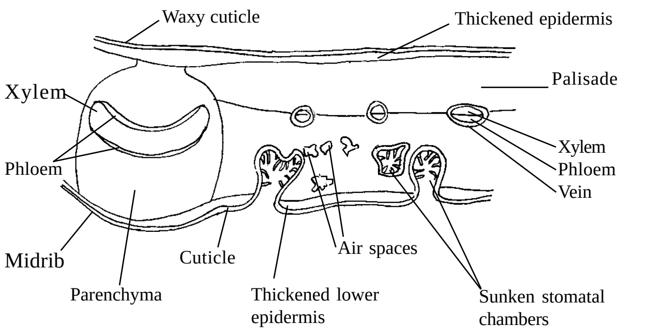
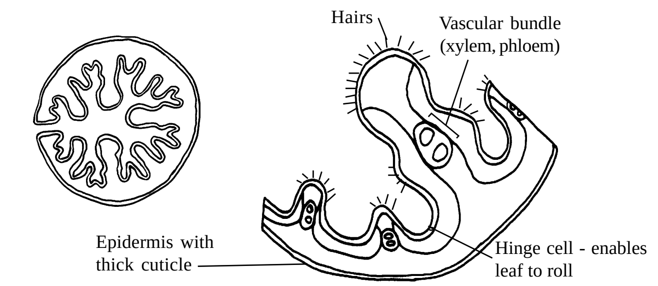
Leaves

T.S. of a xerophytic leaf - general features



T.S. of a Marram Grass leaf



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Usually small and thick and sometimes leathery with a low surface area to volume ratio. The thick epidermis and/or cuticle decreases loss of water and, along with well developed palisade mesophyll tissue, decreases the intensity of light which is reaching and therefore potentially drying photosynthetic tissues. The leaves of Mesquite *(Prosopis)* for example, which grows in very dry habitats, have cuticles ten times thicker than mesquite plants which are growing in damp areas.

Leaves may be reduced to spines (in cacti, for example) and photosynthesis is then restricted to the green stem. Succulents such as *Sedum* and *Mesembryanthemum* store water in their leaves.

Stomata are often only present on the bottom leaf surface (abaxial surface), often sunken or in grooves and surrounded by hairs (e.g. *Erica carnea*). This creates a chamber within which the relative humidity is high, reducing the diffusion gradient within the chamber and making evaporation of moisture less likely.

Many xerophytes have large numbers of stomata - this is thought to allow very rapid uptake of carbon dioxide during rare wet periods.

Well developed sclerenchyma provides mechanical strengthening to cell walls which prevents tissues collapsing even when they begin to dry out.

Marram Grass *(Ammophila arenaria)*, which commonly colonises sand dunes, has leaves which are entirely rolled up, which reduces the surface area of moist tissue which is exposed to air.

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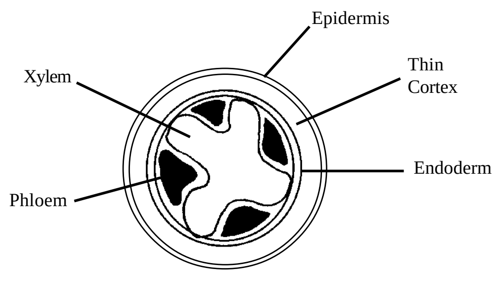
Roots



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Usually very well developed. Extensive or deep root systems to take advantage of superficial rainfall or to tap deep water reserves.

Thin cortex, therefore small distance between soilwater and xylem in the vascular tissue.

Vascular tissue often contains well developed xylem which allows rapid transport of water following absorption.

Water absorption in some species of giant cacti is accelerated by hydrophilic colloids which accumulate in their root cortex. These reduce the water potential of the root's tissue, accelerating water uptake by osmosis.

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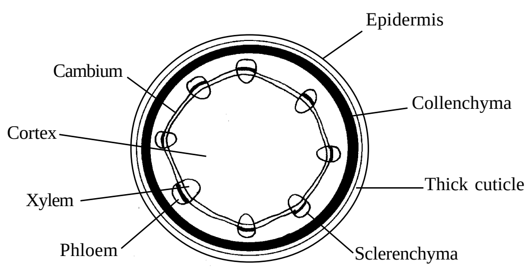
Stem



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Succulents have a thick waxy cuticle and epidermis to reduce water loss and hairs to trap a layer of still, moist air.

Succulents such as large desert cacti e.g. the saguaro cactus *(Carnegiea gigantia)* literally store tens of tonnes of water in their parenchymatous tissue.

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It is important to realise that many plants which show xerophytic features live in wet habitats and it is assumed that such features enable these plants to withstand droughts. However, some botanists believe that many xerophytic features are not actually concerned with water conservation at all. Features such as sunken stomata and numerous hairs in sub-stomatal chambers do not always reduce transpiration rates and an alternative suggestion is that these features are adaptations to reduce excess light intensities.

Crassulacean Acid Photosynthesis.

1. Carbon dioxide is fixed by phosphoenol pyruvate carboxylase (PEPC) into malic acid (MA).

2. MA is stored overnight in vacuoles of large succulent photosynthetic cells.

3. In the morning when temperature increases and relative humidity decreases, the stomata close to reduce transpiration losses.

4. MA is decarboxylated i.e. CO_2 is removed.

5. CO_2 is then fixed by ribulose bisphosphate carboxylase (RuBC) in the conventional Calvin cycle.

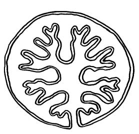
Crassulacean Acid Metabolism (CAM)

CAM plants use water more efficiently than either C_3 or C_4 plants. CAM differs from C_4 plant photosynthesis because all of the above reactions occur in the same cell whereas in C_4 plants, the reactions of PEPC and RuBC occur in different cells. CAM is much more widespread than C_4 photosynthesis but most CAM plants are succulents.

Practice Questions

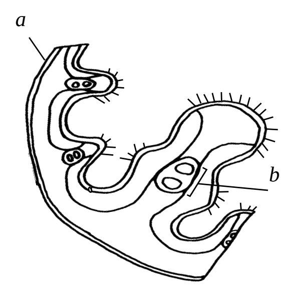
1. Fig 1 shows a transverse section of a marram grass leaf *Ammophila arenaria*, marram grass is a xerophyte. Fig 2 shows a section of this leaf in more detail.

Fig 1.



Section of a leaf of marram grass.

Fig 2.

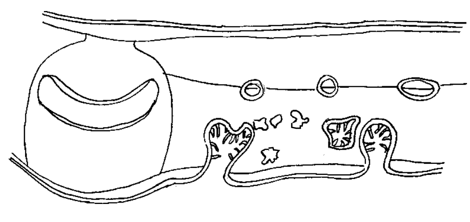


(a) Name the structures labelled *a* and *b*. (2 marks)

(b) Describe two xeromorphic features shown in the leaf above and in each case, explain how the feature helps to reduce water loss. (4 marks)

2. Describe **two** features of a xerophytic leaf seen in Fig 3 and explain how each helps to reduce the rate of water loss. (4 marks)

Fig 3.



Answers

Semicolons indicate marking points.

1. (a) *a*-epidermis;
   b-vascular bundle/xylem and phloem/vascular tissue/vein;

   (b) Presence of hairs;
   reduces air movement/traps water vapour/traps air/increases relative humidity;
   thick cuticle;
   reduces evaporation/diffusion of water/water loss;
   leaf rolled;
   reduces external (exposed) surface area/air movement/increases relative humidity;

2. Presence of hairs in stomata;
   reduces air movement/traps water vapour/traps air/increases relative humidity;
   thick cuticle/epidermis;
   reduces evaporation/diffusion of water/water loss;
   sunken stomata;
   humid air accumulates in the pits/reduces the diffusion gradient within the chamber, making evaporation of moisture less likely;

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