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Stress Physiology

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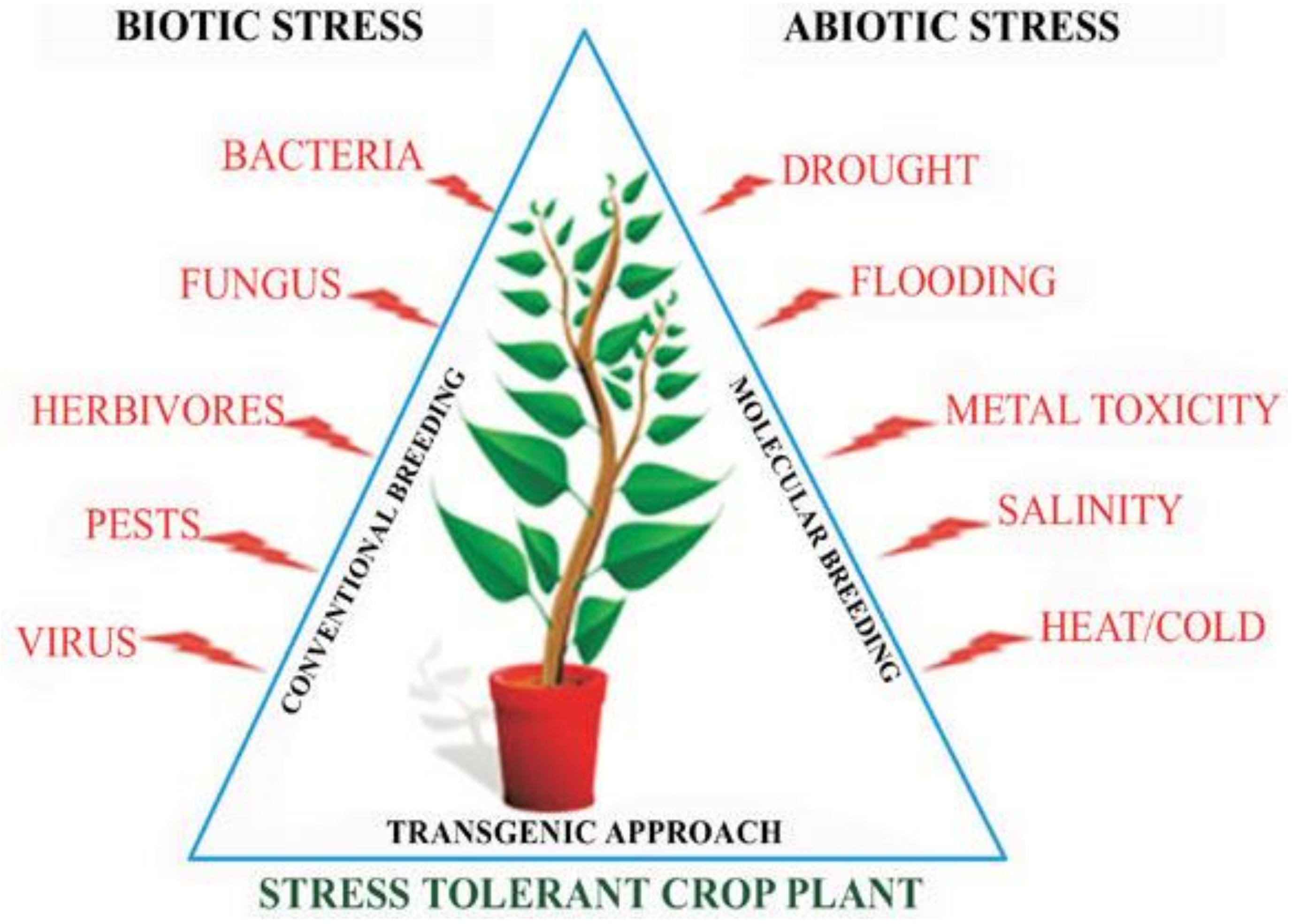
Introduction

- Stress
- Stress tolerance / Stress resistance
- **Acclimated**



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Water Stress

- Water Deficient → Water stress → Minimize transpiration → Leaf abscission (Ethylene) → Roots grow into deeper soil → Stomatal Closure (ABA) → Hydropassive Closure
- Hydropassive Closure – This closing mechanism is likely to operate in air of low humidity, when direct water loss from the guard cells is too rapid.
- Hydroactive closure, closes the stomata when the whole leaf or the roots are dehydrated and it depends on metabolic processes in the guard cell.
- A reduction in the solute content of the guard cells results in water loss and decreased turgor, causing the stomata to close.

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Effects of Water Stress

- Water Deficit Limits Photosynthesis within the Chloroplast.
- Water Deficit Increases Wax Deposition on the Leaf Surface
- Osmotic stress induces crassulacean acid metabolism in some plants.
- **Osmotic Stress Changes Gene Expression**
- A large group of genes that are regulated by osmotic stress was discovered by examination of naturally desiccating embryos during seed maturation. These genes code for so-called LEA proteins.
- Osmotic stress typically leads to the accumulation of ABA.
- Stress-Responsive Genes Are Regulated by ABA-Dependent and ABA-Independent Processes.

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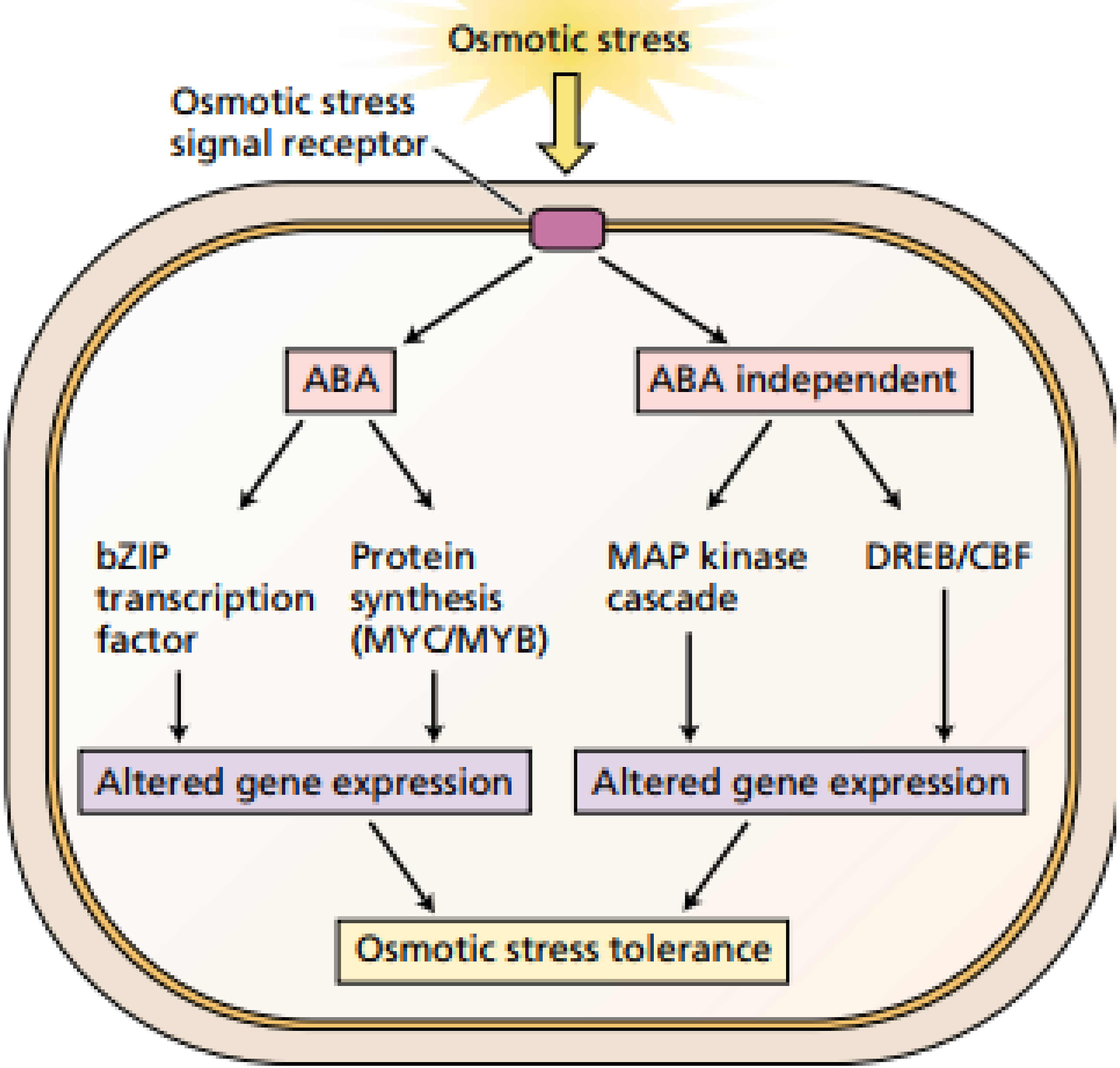

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Heat Stress

- Most tissues of higher plants are unable to survive extended exposure to temperatures above 45°C.
- Nongrowing cells or dehydrated tissues (e.g., seeds and pollen) can survive much higher temperatures.
- Periodic brief exposure to sub lethal heat stresses often induces tolerance to otherwise lethal temperatures, a phenomenon referred to as **induced thermotolerance**.
- Water and temperature stress are interrelated.
- Shoots of most C3 and C4 plants with access to abundant water supply are maintained below 45°C by evaporative cooling; if water becomes limiting, evaporative cooling decreases and tissue temperatures increase.
- High leaf temperature and water deficit lead to heat stress

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- At High Temperatures, Photosynthesis Is Inhibited before Respiration.
- The temperature at which the amount of CO_2 fixed by photosynthesis, equals the amount of CO_2 released by respiration, in a given time interval is called the temperature **compensation point**.
- At temperatures above the temperature compensation point, photosynthesis cannot replace the carbon used as a substrate for respiration. As a result, carbohydrate reserves decline, and fruits and vegetables lose sweetness.
- Adaptations include: reflective leaf hairs and leaf waxes; leaf rolling and vertical leaf orientation; and growth of small, highly dissected leaves.

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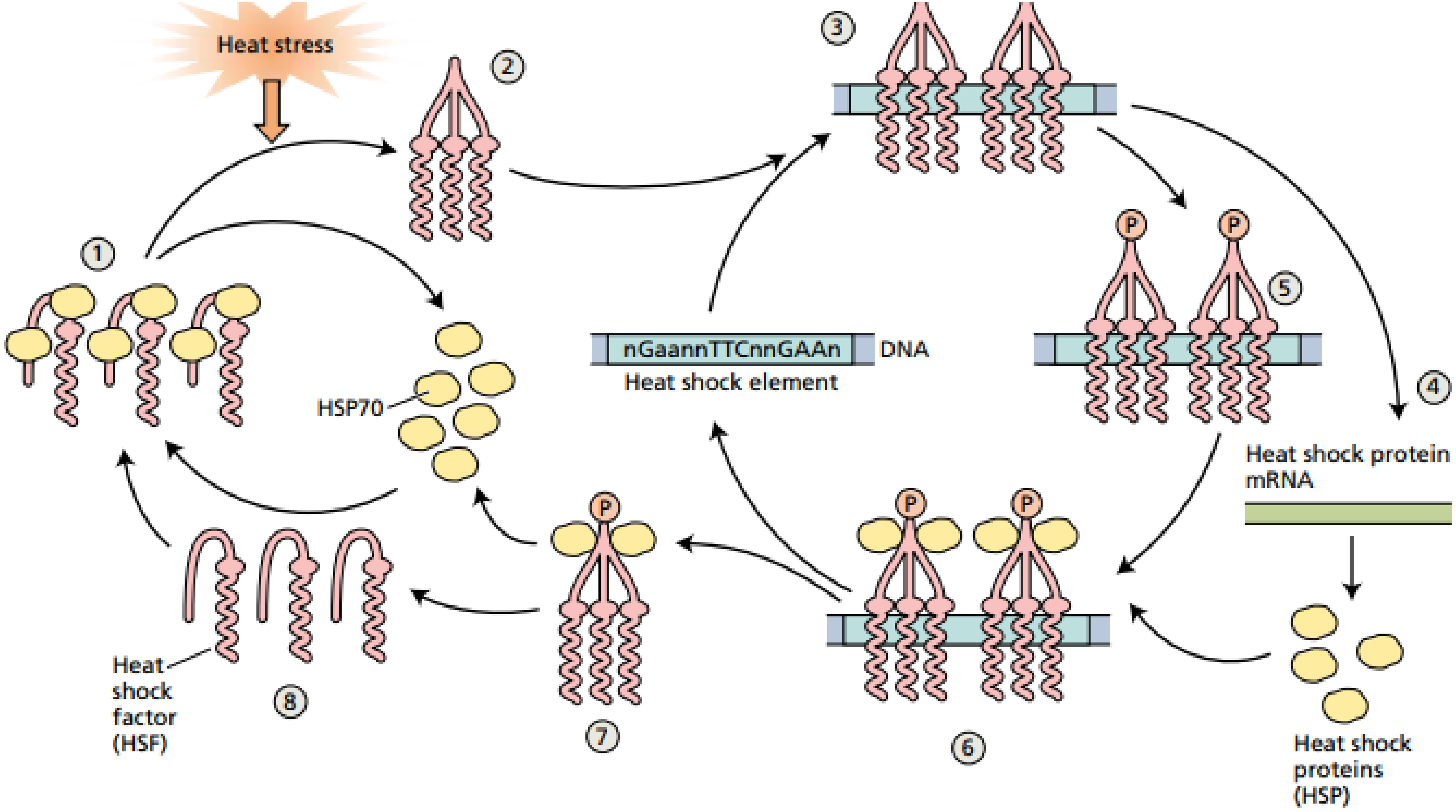
Adaptation to Heat Stress



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Chilling and Freezing

- When plants growing at relatively warm temperatures (25 to 35°C) are cooled to 10 to 15°C, chilling injury occurs.
- Growth is slowed, discoloration or lesions appear on leaves, and the foliage looks soggy, as if soaked in water for a long time.
- If roots are chilled, the plants may wilt.
- Freezing injury, on the other hand, occurs at temperatures below the freezing point of water.

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Membrane Response

- In chilling-sensitive plants, the lipids in the bilayer have a high percentage of saturated fatty acid chains, and membranes with this composition tend to solidify into a semi crystalline state at a temperature well above 0°C.
- Membrane lipids from chilling-resistant plants often have a greater proportion of unsaturated fatty acids than those from chilling-sensitive plants and during acclimation to cool temperatures the activity of desaturase enzymes increases and the proportion of unsaturated lipids rises.
- Thus, desaturation of fatty acids provides some protection against damage from chilling.

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Ice Crystal Formation

- Fully hydrated, vegetative cells can retain viability if they are cooled very quickly to avoid the formation of large, slow-growing ice crystals that would puncture and destroy subcellular structures.
- During rapid freezing, the protoplast, including the vacuole, supercools; that is, the cellular water remains liquid even at temperatures several degrees below its freezing point.
- Several hundred molecules are needed for an ice crystal to begin forming.
- The process whereby these hundreds of water molecules start to form a stable ice crystal is called ice nucleation.
- Some large polysaccharides and proteins facilitate ice crystal formation and are called ice nucleators.

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Gene Involvement in Cold Acclimation

- During cold episodes the synthesis of "housekeeping" proteins (proteins made in the absence of stress) is not substantially down-regulated, during heat stress housekeeping-protein synthesis is essentially shut down.
- The synthesis of several heat shock proteins that can act as molecular chaperones is up-regulated under cold stress in the same way that it is during heat stress.
- Some of the HSPs are not unique to high-temperature stress. They are also induced by widely different environmental stresses or conditions, including water deficit, ABA treatment, wounding, low temperature, and salinity. Thus, cells previously exposed to one stress may gain cross protection against another stress.
- Important class of proteins whose expression is up-regulated by cold stress is the antifreeze proteins. These proteins have the ability to inhibit ice crystal growth.

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Cold Stress Genes

- Many cold stress–induced genes are activated by transcriptional activators called C-repeat binding factors (CBF1, CBF2, CBF3; also called DREB1b,DREB1c, and DREB1a, respectively).
- CBF/DREB1-type transcription factors bind to CRT/DRE elements (C-repeat/dehydration-responsive, ABA-independent sequence elements) in gene promoter sequences. CBF/DREB1 is involved in the coordinate transcriptional response of numerous cold and osmotic stress–regulated genes, all of which contain the CRT/DRE elements in their promoters.
- **CBF1/DREB1b is unique in that it is specifically induced by cold stress and not by osmotic or salinity stress, whereas DREB2 type are induced only by osmotic and salinity stresses and not by cold.**
- The expression of CBF1/DREB1b is controlled by a separate transcription factor, called ICE (Inducer of CBF expression).

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Salinity Stress

- Salinity Depresses Growth and Photosynthesis in Sensitive Species.
- Plants minimize salt injury by excluding salt from meristems, particularly in the shoot, and from leaves that are actively expanding and photosynthesizing.
- Resistance to moderate levels of salinity in the soil depends in part on the ability of the roots to prevent potentially harmful ions from reaching the shoots.
- Casparian strip imposes a restriction to the movements of ions into the xylem.
- To bypass the Casparian strips, ions need to move from the apoplast to the symplastic pathway across cell membranes.
- This transition offers salt-resistant plants a mechanism to partially exclude harmful ions

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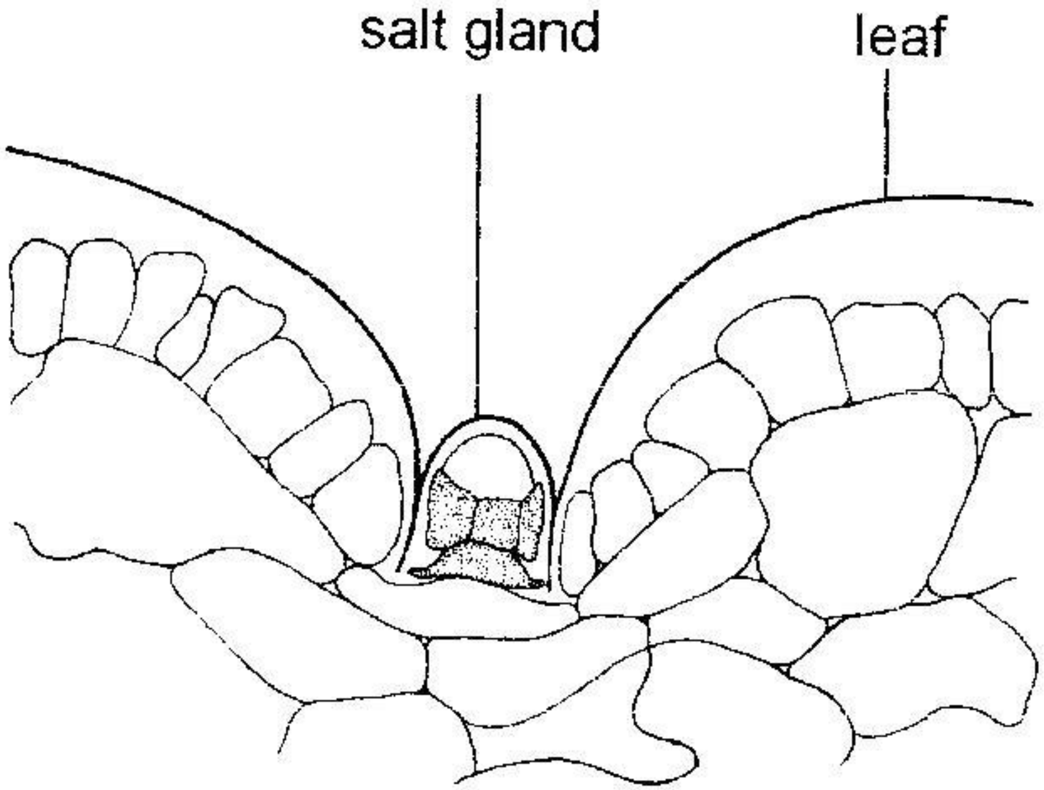

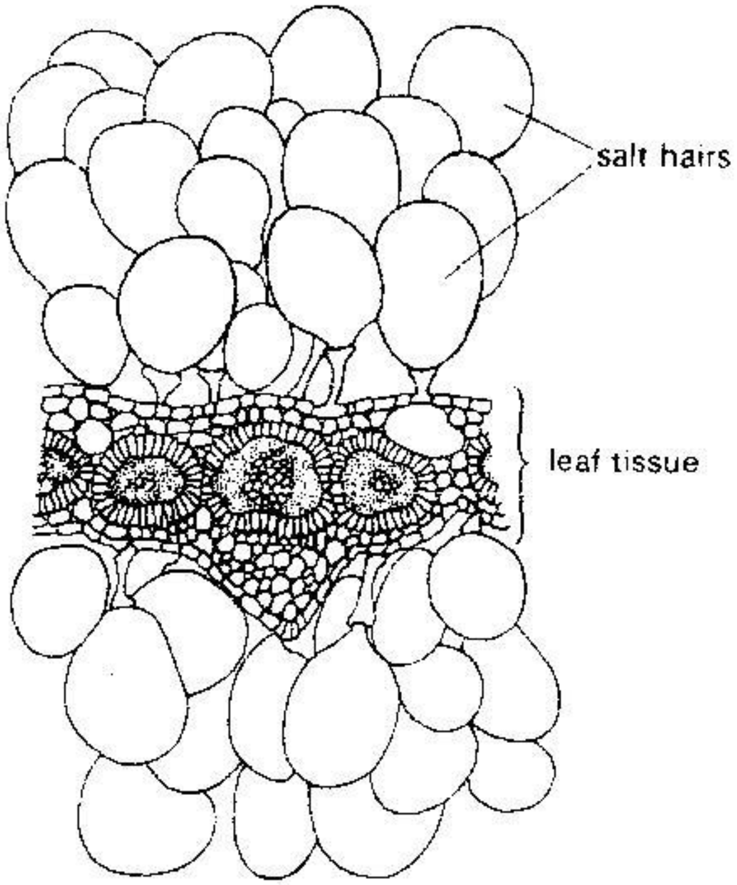

Figure 10.11 a salt gland of *Avicennia*

Figure 10.11 b. Salt glands of *Atriplex mollis*

In both cases, salt is washed off from the surface of the leaves by rain.

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Educating to Guide the Dreamer!

Thank You!

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