



STOMATAL CONTROL COUPLES LEAF TRANSPIRATION TO LEAF PHOTOSYNTHESIS

Most leaf transpiration results from the diffusion of water vapor through the stomatal pore.

The microscopic stomatal pores provide a low-resistance pathway for diffusional movement of gases across the epidermis and cuticle.

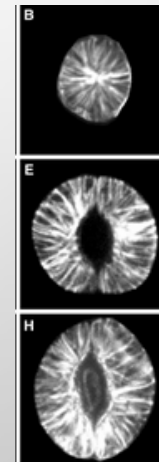
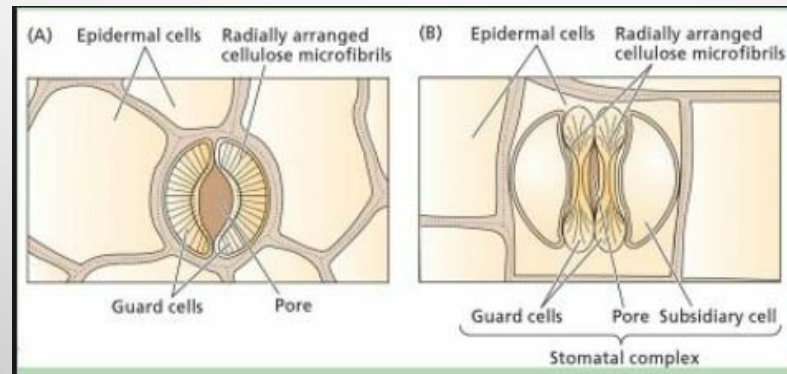
Changes in stomatal resistance are important for the regulation of water loss by the plant and for controlling the rate of carbon dioxide uptake necessary for sustained CO_2 fixation during photosynthesis.

Leaf can regulate its stomatal resistance by opening and closing of the stomatal pore. this biological control is exerted by a pair of specialized epidermal cells, the **guard cells**, which surround the stomatal pore.

At night, when there is no photosynthesis and thus no demand for CO_2 inside the leaf, stomatal apertures are kept small or closed, preventing unnecessary loss of water.

The cell walls of guard cells have specialized features

In dicots and nongrass monocots, guard cells have an elliptical contour (often called “kidney-shaped”) with the pore at their center. Subsidiary cells are often absent, the guard cells are surrounded by ordinary epidermal cells. A distinctive feature of guard cells is the specialized structure of their walls. The alignment of cellulose microfibrils, which reinforce all plant cell walls and are an important determinant of cell shape, play an essential role in the opening and closing of the stomatal pore.

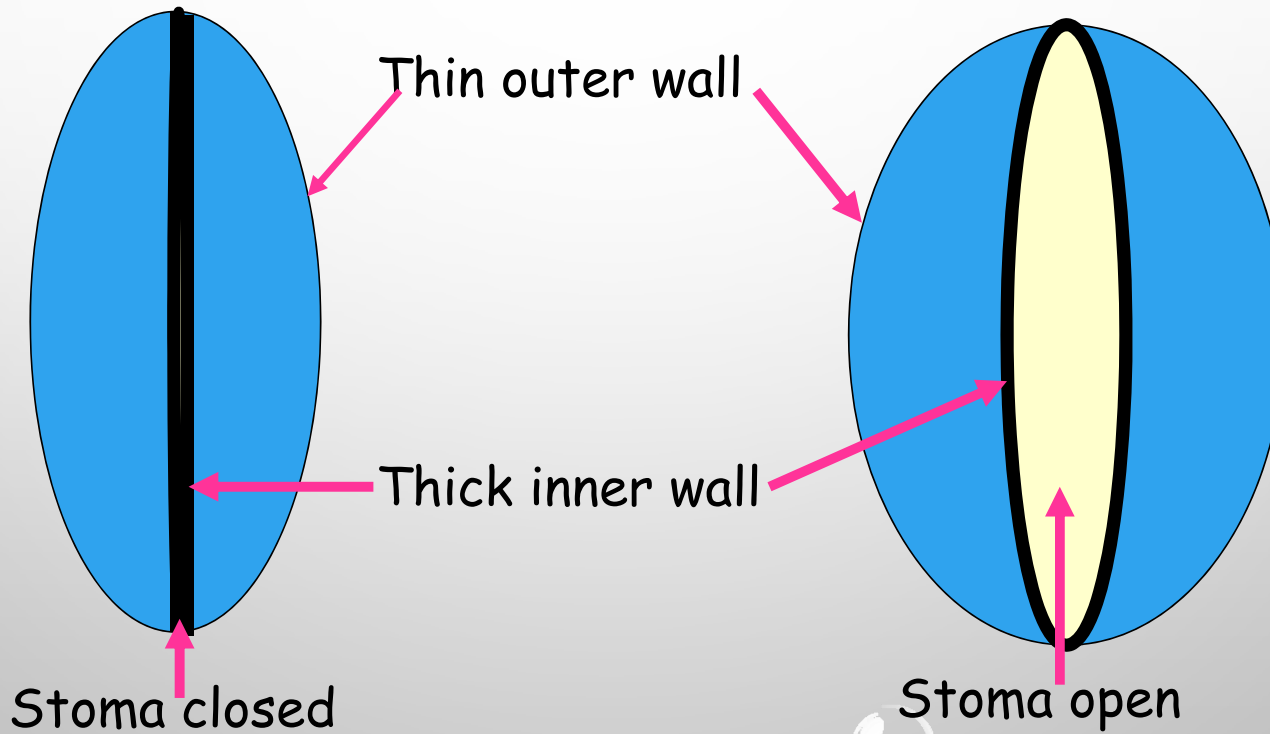


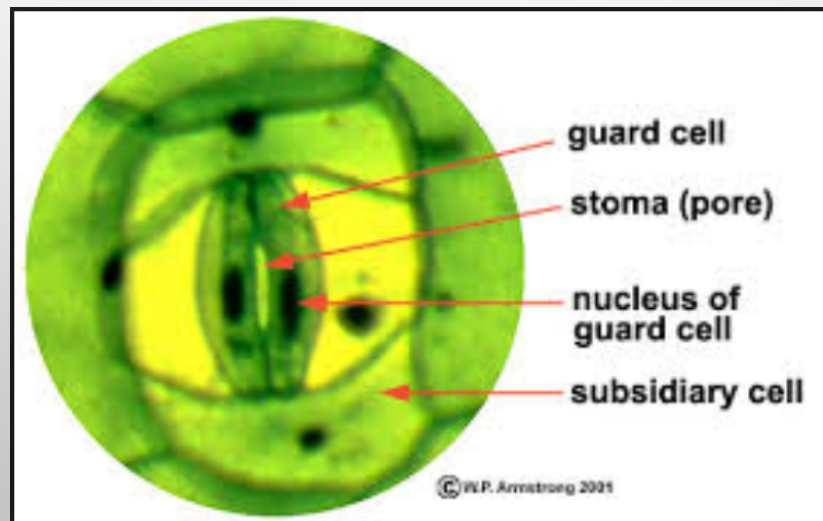
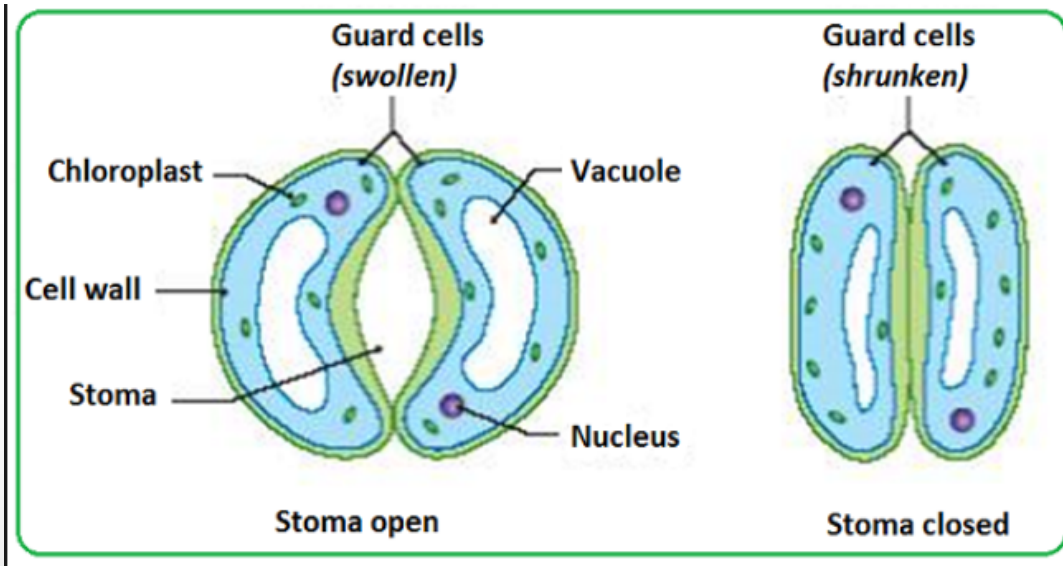
The radial alignment of the cellulose microfibrils in guard cells and epidermal cells of (A) a kidney-shaped stoma and (B) a grasslike stoma (source: Taiz L., Zeiger E., 2010)

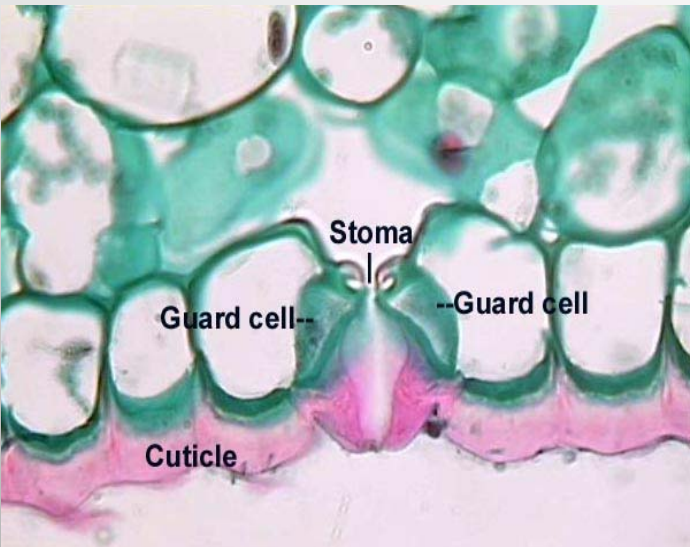
The guard cells control the opening and closing of the stomata

Guard cells flaccid

Guard cells turgid





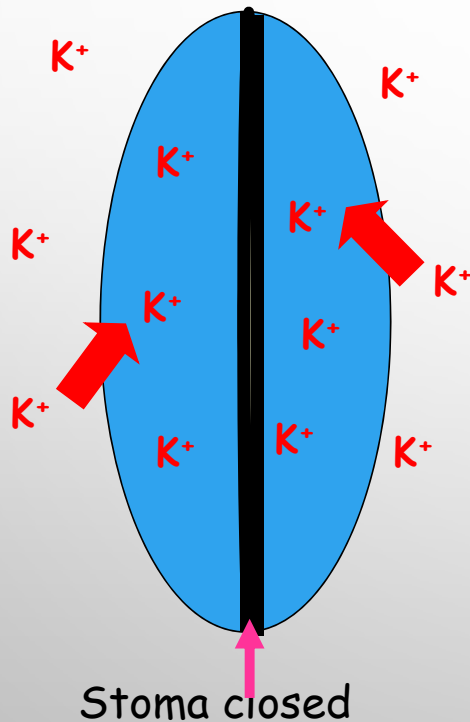


AN INCREASE IN GUARD CELL TURGOR PRESSURE OPENS THE STOMATA

When environmental factors such as light, temperature, leaf water status, and intracellular CO₂ concentrations are sensed by guard cells, The early aspects of this process are ion uptake and other metabolic changes in the guard cells. The decrease of osmotic potential (Ψ_s) resulting from ion uptake and from biosynthesis of organic molecules in the guard cells. Water relations in guard cells follow the same rules as in other cells. As Ψ_s decreases, the water potential decreases, and water consequently moves into the guard cells. As water enters the cell, turgor pressure increases. Because of the elastic properties of their walls, guard cells can reversible increase their volume by 40 to 100%, depending on the species. Such changes in cell volume lead to opening or closing of the stomatal pore. Subsidiary cells appear to play an important role in allowing stomata to open quickly and to achieve large apertures.

REGULATING STOMATAL OPENING:—THE POTASSIUM ION PUMP HYPOTHESIS

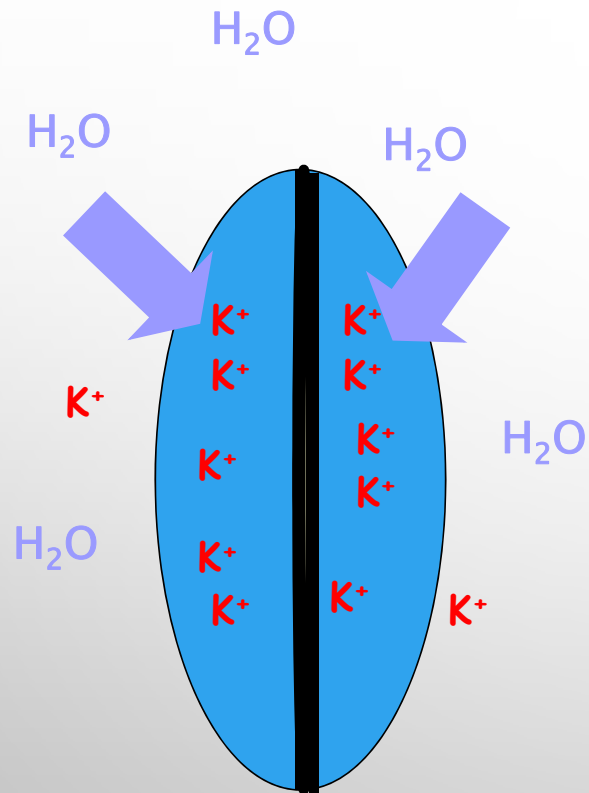
Guard cells flaccid



K^+ ions have the same concentration in guard cells and epidermal cells

Light activates K^+ pumps which actively transport K^+ from the epidermal cells into the guard cells

REGULATING STOMATAL OPENING:—THE POTASSIUM ION PUMP HYPOTHESIS

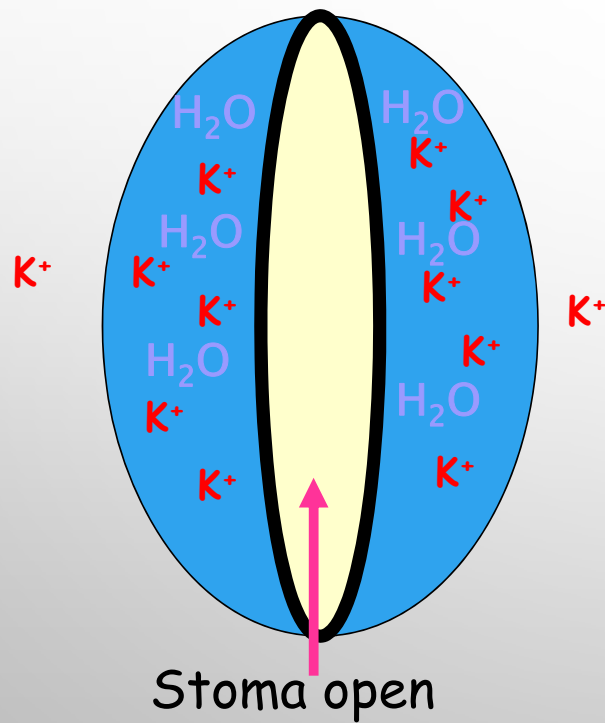


Increased concentration of K^+ in guard cells

Lowers the Ψ in the guard cells

Water moves in by osmosis, down Ψ gradient

Guard cells turgid



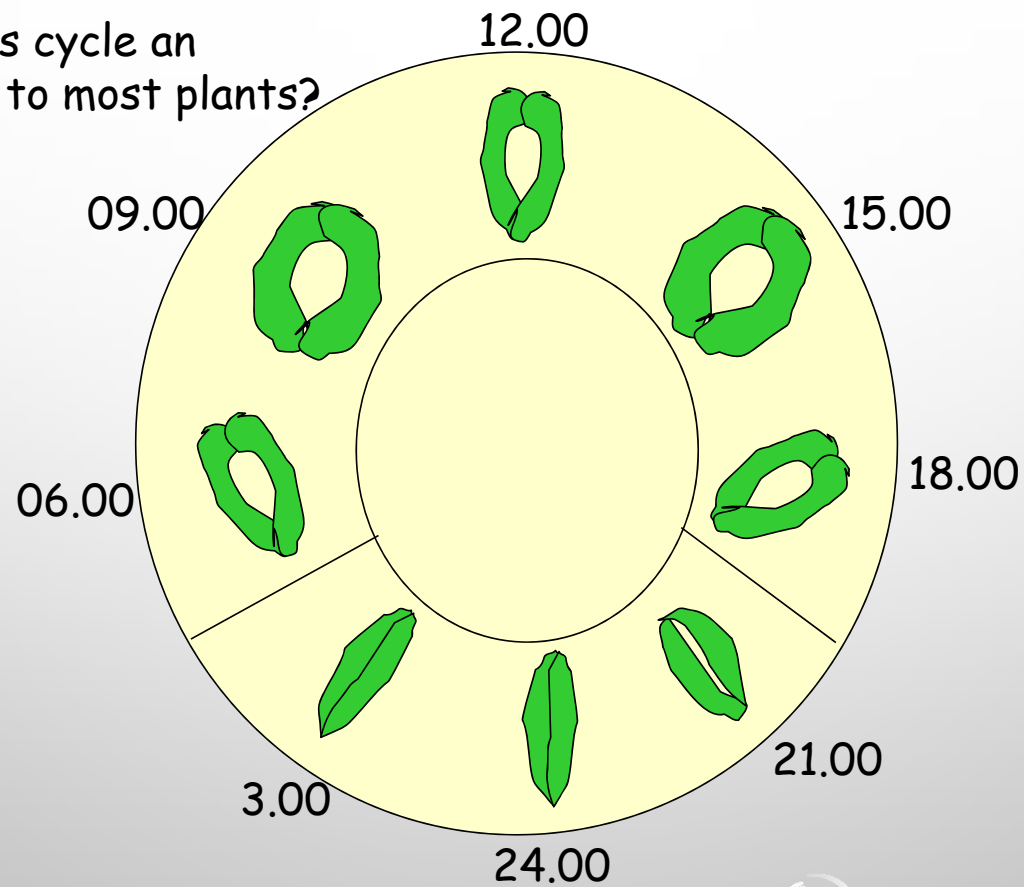
Increased concentration of K⁺
in guard cells

Lowers the Ψ in the guard cells

Water moves in by osmosis,
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24H CYCLE OF STOMATAL OPENING AND CLOSING

Why is this cycle an advantage to most plants?



PLANT WATER STATUS

The water status of plant cells is constantly changing as the cells adjust to fluctuations in the water content of the **environment** or to changes in **metabolic state**.

The plant water status is dependent on: the **soil moisture content**, the **capacity for water absorption by roots**, and the **hydraulic conductivity** of root and shoot tissues.

Water potential is often used as a measure of the water status of a plant.



Plants are seldom fully hydrated.

During periods of **drought**, they suffer from water deficits that lead to **inhibition of plant growth and photosynthesis**.

Several physiological changes occur as plants experience increasingly drier conditions (**Figure**).

Cell expansion is most affected by water deficit.

In many plants reductions in water supply **inhibit shoot growth and leaf expansion** but **stimulate root elongation**.

Drought does impose some absolute limitations on physiological processes, although the **actual water potentials** at which such limitations occur **vary with species**.

Physiological changes due to dehydration:

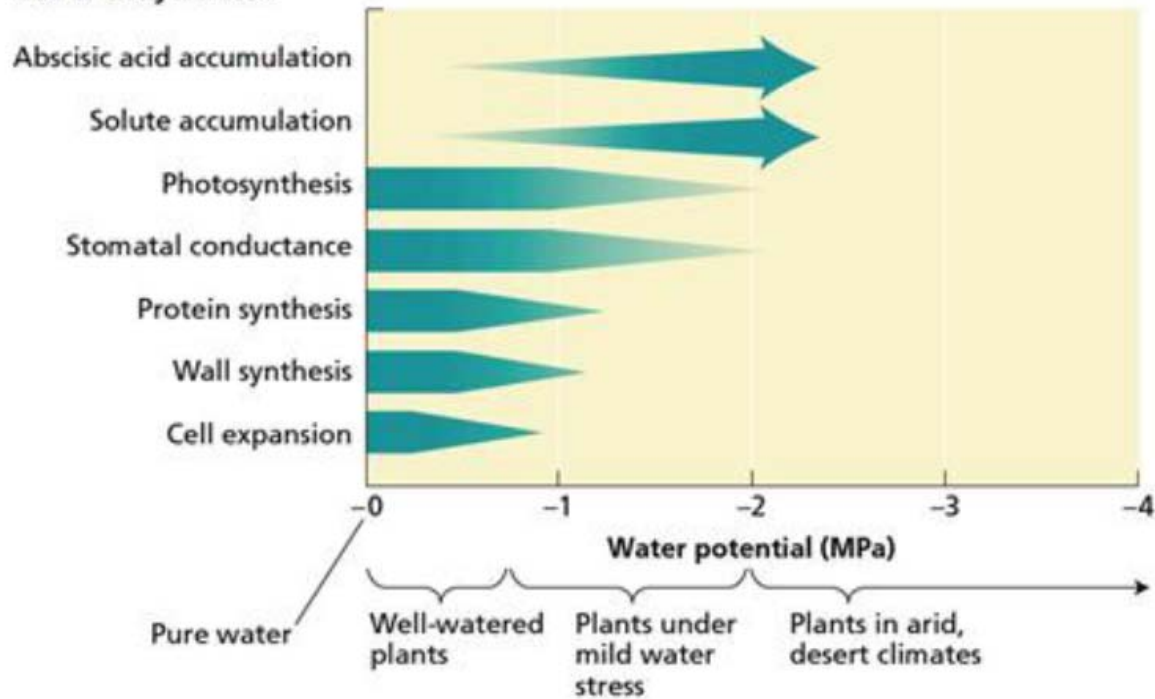


Figure 1.10 Sensitivity of various physiological processes to changes in water potential under various growing conditions (source: Taiz L., Zeiger E., 2010)

The plant may *spend energy* to accumulate solutes to maintain turgor pressure, invest in the growth of non-photosynthetic organs such as roots to increase water uptake capacity, or build xylem conduits capable of withstanding large negative pressures. Thus, physiological responses to water availability reflect a trade-off between the benefits accrued by being able to carry out physiological processes (e.g., growth) over a wider range of environmental conditions and the costs associated with such capability.

Adaptations to Reduce Water Loss in Xerophytes

- **THICK WAXY CUTICLE** to reduce evaporation
- **REDUCED LEAF AREA** e.g. needles
- **HAIRY LEAVES**:– the hairs trap a layer of saturated air
- **SUNKEN STOMATA**:– the pits above the stomata become saturated
- **ROLLED LEAVES**:– this reduces the area exposed to the air and keeps the stomata on the inside so increasing the water vapour inside the roll
- **SILVER SURFACE**: to reflect sun
- **FLESHY LEAVES**: to hold water

Adaptation to Increase Water Uptake in Xerophytes

- **DEEP EXTENSIVE ROOT** SYSTEM TO MAXIMISE WATER UPTAKE
- **ACCUMULATION OF SOLUTES IN THE ROOT** SYSTEM TO REDUCE THE Ψ , SO MAKING THE Ψ GRADIENT FROM THE SOIL TO THE ROOT CELLS STEEPER
- **SOME VERY SHALLOW ROOTS** TO **ABSORB DEW** WHICH CONDENSES ON THE SOIL AT NIGHT

INFLUENCE OF EXTREME WATER SUPPLY

- plant growth can be limited both by water deficit and by excess water.
- *drought* is the meteorological term for a period of insufficient precipitation that results in plant water deficit.
- *excess water* occurs as the result of flooding or soil compaction. the deleterious effects of excess water are a consequence of the displacement of oxygen from the soil.
- when soil is water-saturated, the water potential (ψ_w) of the soil solution may approach zero, but drying can reduce the soil ψ_w to below -1.5 mpa, the point at which *permanent wilting* can occur.

water deficit is stressful, but too much water can also have several potentially negative consequences for a plant.

flooding and soil compaction result in poor drainage, leading to reduced O_2 availability to cells.

flooding fills soil pores with water, reducing O_2 availability. dissolved oxygen diffuses so slowly in stagnant water that only a few cm of soil near the surface remain oxygenated.

at low temperatures the consequences are relatively harmless. however, when temperatures are higher (greater than $20^\circ C$), O_2 consumption by plant roots, soil fauna, and microorganisms can totally deplete O_2 from the soil in as little as 24 hours.

flooding sensitive plants are severely damaged by 24 hours of anoxia (lack of oxygen).

soil anoxia damage plant roots directly by inhibiting cellular respiration.

the critical oxygen pressure (cop) is the oxygen pressure below which respiration rates decrease

Symptoms of Overwatering

Organs swell, crack open

Fungi thrive (Damp-off)

Yellowing of leaves

Root Death by Asphyxiation

Wilting

Symptoms of Underwatering

Growth Inhibition (Dwarfing)

Leaves with brown tips and edges

Blueing of leaves

Abscission of leaves

Wilting

Notice that the shared symptom is WILTING!

This leads to much overwatering!

These symptoms are easily explained by understanding OSMOSIS!

Guttation

- **Guttation** is the appearance of drops of xylem sap on the tips or edges of leaves of some vascular plants, such as grasses. Guttation is not to be confused with dew, which condenses from the atmosphere onto the plant surface. Secretion of water on to the surface of leaves through specialized pores, or hydathodes.

Showing guttation fluid in leaves



What is the main cause of guttation in plants?

- The main cause of guttation in plants is root pressure, during night when root pressure is high sometimes due to this pressure watery drops ooze out with the assistance of special structures which help in guttation called the hydathodes.

MECHANISM OF GUTTATION

- Under certain conditions like **soil flooded** with overnight rain water and with high **relative humidity** of the day atmosphere, the root system of some plants like **tomato**, **potato**, etc., absorb excess of water by active uptake. As a result, **hydrostatic pressure** develops in the root system which actually pushes water upwards. So the water along with other soluble components of the cells is forced out of the **xylem elements** located into Epithem tissue.

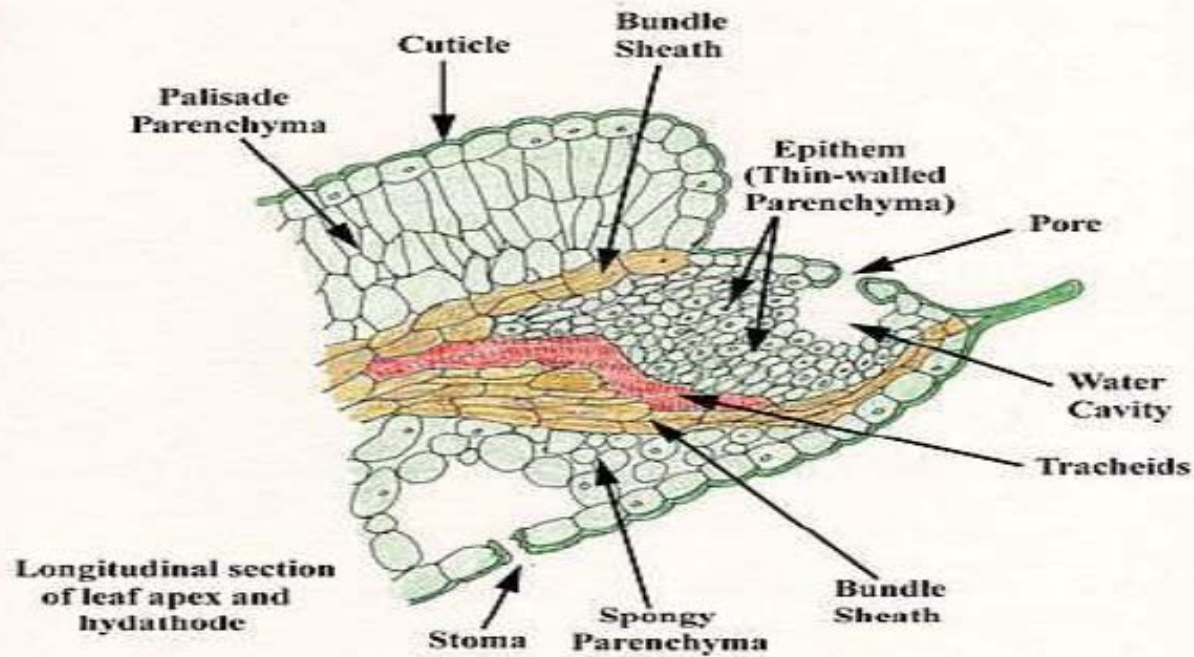
As result, the space behind the water stomata gets filled with the **water** and with more **root pressure** operating; the liquid is virtually pushed out of the **pore**, where the stomata do not offer any resistance. Probably transfer cells may also help in the retrieval of **minerals** and other components from the **xylem elements** and secreting out along with water.

Hydathode

Guttation-exudation of water from hydathodes of leaf margins is caused by root pressure. It is often mistaken for dew in the morning because it occurs at night when water is not processed as quickly within the plant.



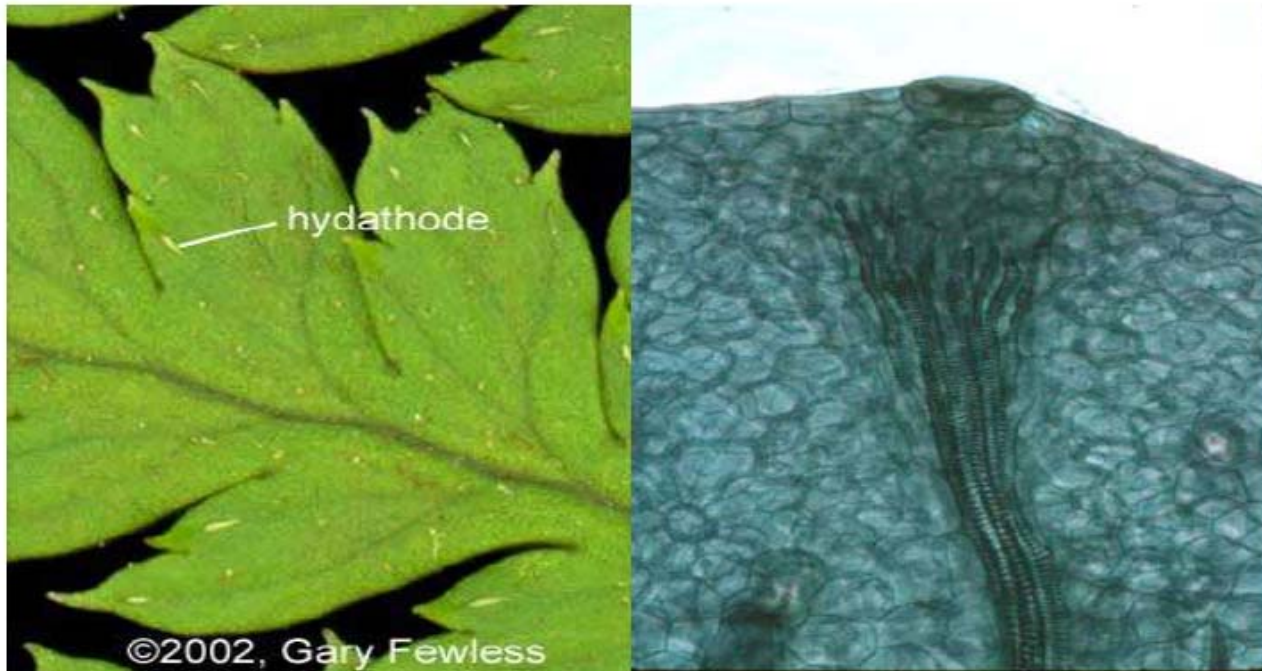
Leaf with guttation droplet from hydathode



HYDATHODES

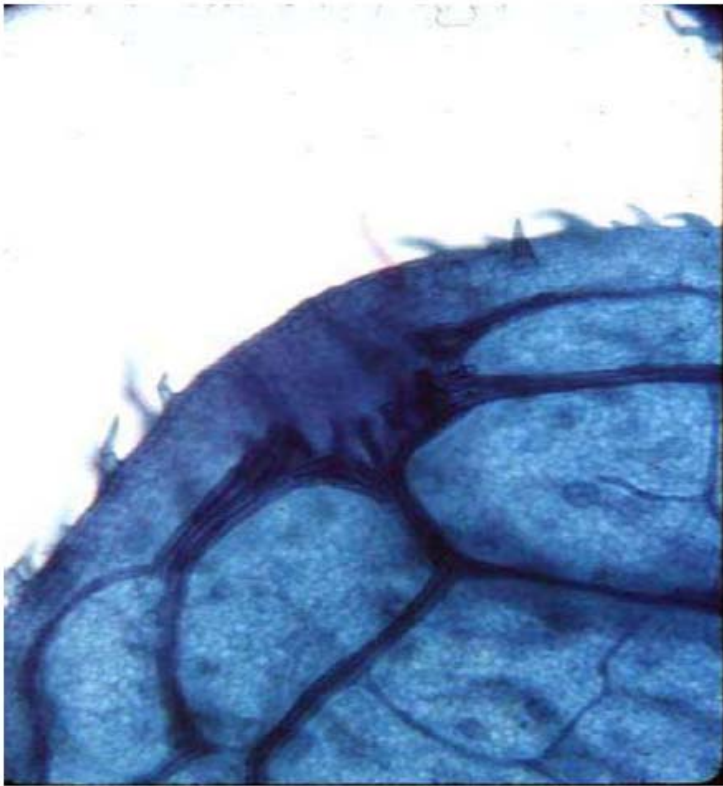
- ✦ A **hydathode** is a type of secretory tissue in leaves, usually of Angiosperms, that secretes water through pores in the epidermis or margin of leaves, typically at the tip of a marginal tooth or serration.
- ✦ They probably evolved from modified stomata. It is involved in guttation, where water is released from the top in order to transport the nutrients in the water from the roots to the leaves. Hydathodes are connected to the plant vascular system by a vascular bundle.

Hydathodes

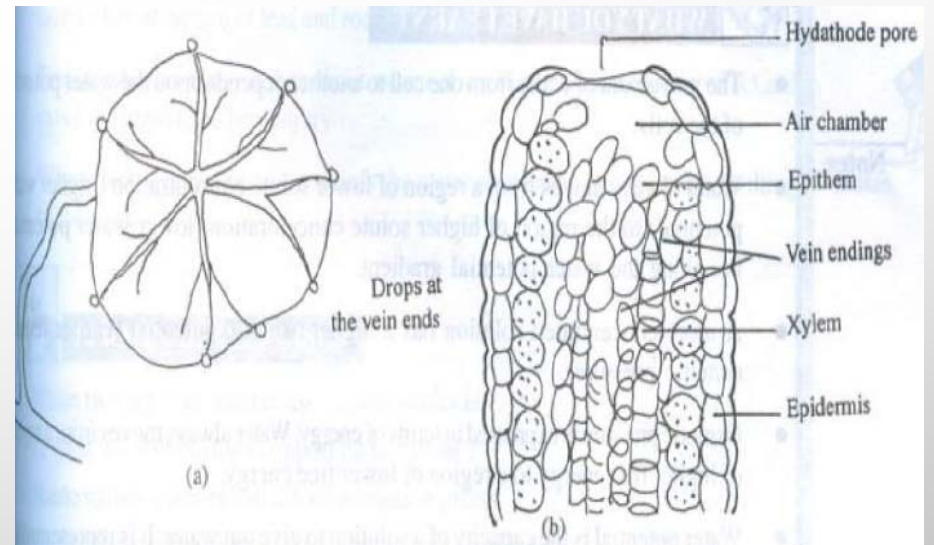


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Sinningia (Gesneriaceae) leaf clearing
focused on single water pore and vascular
bundle end in hydathode.



Coleus leaf tooth clearing showing vascular bundle ends in hydathode.



The differences between guttation and transpiration

Trans piration	Guttation
1.Takes place through cuticle, lenticel and stomata.	1.Takes place through hydathodes
2.It usually occurs in the day	2. It usually occurs in the night
3. Water lost in the form of water vapour	3. Water lost in the form of droplets
4. The water lost is pure	4.Guttation droplets contain organic and inorganic solvent.
5. It gives a cooling effect	5. It does not give a cooling effect.
6. Its beneficial to plants as its maintains body temperture by cooling effects.	6. Its less significant to ;plant and some time causes injury to plant by deposition to of salts on the leaf tips after evaporation.
7.Occure during dry day	7.ocuure during humid periods .

**Guttation Shown is a compound leaf of strawberry
(*Fragaria*).**




Differences between stomata & Hydathodes

Stomata	Hydathodes
1. Occure in epiderm of leaves ,young stems .	1. Occure at the tip or margin of leves that grown in moist shady place .
2. Stomatal aperture is guarded by two kidney shaped guard cells.	2. Aperture of hydathodes is surround by a ring of cuticularized cells
3. The two guard cells are generally surrounded by subsidiary cell.	3. Subsidiary cells are absent
4. Opening and closing of the stomatal aperture is regulated by guard cells .	4. Hydathode pores remain always open .
5. These are involved in transpiration and exchange of gases .	5. These are involved guttation .

When should I irrigate?

~~Mid-day?~~ Remember the water spots, magnifying lenses?

~~Evening?~~ Soil warm from afternoon, add water = fungi

Morning?  Soil cool for less evaporation waste
Spots evaporate from leaves before sun gets high

Other Pointers:

Preserve water in soil with mulch

Proper spacing of plants avoids soil heating and evaporation

Water less often but more deeply to encourage deeper rooting

Lighten waterlogging clay soils with sand or perlite!

Plant Factors Affecting Water Needs

	More	Less
It is a seedling		✓
It is growing rapidly	✓	
It is reproducing (flowers and fruits)	✓	
It is dormant		✓
It has succulent leaves		✓
It has waxy leaves		✓
It has hairy leaves		✓
It has thin, fine, dissected leaves	✓	
It has deep roots		✓

Environmental Factors Affecting Water Needs

	More	Less
It is in a clay soil		✓
It is in a sandy soil	✓	
The temperature is hot	✓	
The wind is blowing	✓	
The humidity is high		✓
The sun is bright (no clouds)	✓	

QUESTION

S

1. WHAT IS TRANSPIRATION? GIVE THREE ENVIRONMENTAL FACTORS WHICH WILL INCREASE TRANSPIRATION RATE.
(2MARKS)
2. EXPLAIN HOW POTASSIUM IONS ARE MOVED INTO THE GUARD CELLS IN LIGHT, AND HOW THIS AFFECTS THE GUARD CELLS AND STOMATA. (6MARKS)
3. GIVE THREE ADAPTATIONS A XEROPHYTE MAY HAVE TO REDUCE TRANSPIRATION AND EXPLAIN HOW THEY DO THIS.
(4MARKS)
4. PLANTS CLOSE THEIR STOMATA AT NIGHT AND SOME ALSO CLOSE THEIR STOMATA AROUND MID DAY. EXPLAIN WHY THIS IS ADVANTAGEOUS TO THE PLANT
(2MARKS)



Click on the marks above
to check your answer

ANSWER Q 1

- TRANSPIRATION IS THE LOSS OF WATER FROM A PLANT BY EVAPORATION
- HIGHER TEMPERATURE, INCREASED AIR MOVEMENT, LOWER HUMIDITY

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ANSWER Q 2

- **POTASSIUM IONS ARE PUMPED INTO THE GUARD CELLS BY ACTIVE TRANSPORT**
- **AGAINST THE CONCENTRATION GRADIENT**
- **THIS LOWERS THE WATER POTENTIAL INSIDE THE GUARD CELLS**
- **WATER IS DRAWN IN BY OSMOSIS**
- **FROM THE SURROUNDING CELLS WHICH HAVE A HIGHER WATER POTENTIAL/DOWN THE WATER POTENTIAL GRADIENT**
- **GUARD CELLS SWELL AND BECOME TURGID**
- **GUARD CELLS BEND**
- **CAUSING THE STOMATA TO OPEN**

ANY 6 FROM THE ABOVE

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ANSWER Q3

ANY THREE FROM:-

- THICK WAXY CUTICLE ON LEAVES REDUCES EVAPORATION
- CURLED LEAVES REDUCE EVAPORATION BY TRAPPING HUMID AIR INSIDE THE CURL SO REDUCING THE WATER POTENTIAL GRADIENT
- REDUCED LEAF AREA, E.G. SPINES, REDUCES THE AREA FROM WHICH EVAPORATION CAN OCCUR
- HAIRY LEAVES –TRAP A LAYER OF HUMID AIR AROUND THE LEAF,SO REDUCING THE WATER POTENTIAL GRADIENT
- SUNKEN STOMATA – MOIST AIR TRAPPED ABOVE STOMATA, SO REDUCING THE WATER POTENTIAL GRADIENT

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ANSWER Q4

- STOMATA CLOSED AT NIGHT WHEN THERE IS NO LIGHT FOR PHOTOSYNTHESIS, SO REDUCING WATER LOSS BY EVAPORATION/TRANSPIRATION VIA THE STOMATA
- CLOSING STOMATA AT MID DAY, WHICH IS THE HOTTEST PART OF THE DAY, IS AN ADVANTAGE IN HOT DRY ENVIRONMENTS, AS TRANSPIRATION IS REDUCED.

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CAN YOU THINK OF ANY SYNOPTIC LINKS?

- WATER POTENTIAL
- OSMOSIS
- ACTIVE TRANSPORT
- RESPIRATION (ENERGY REQUIRED FOR ACTIVE TRANSPORT)
- PHOTOSYNTHESIS (LIGHT AND CO₂ REQUIRED FOR PHOTOSYNTHESIS, CO₂ ENTERS VIA STOMATA, WATER USED IN PHOTOSYNTHESIS)