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.

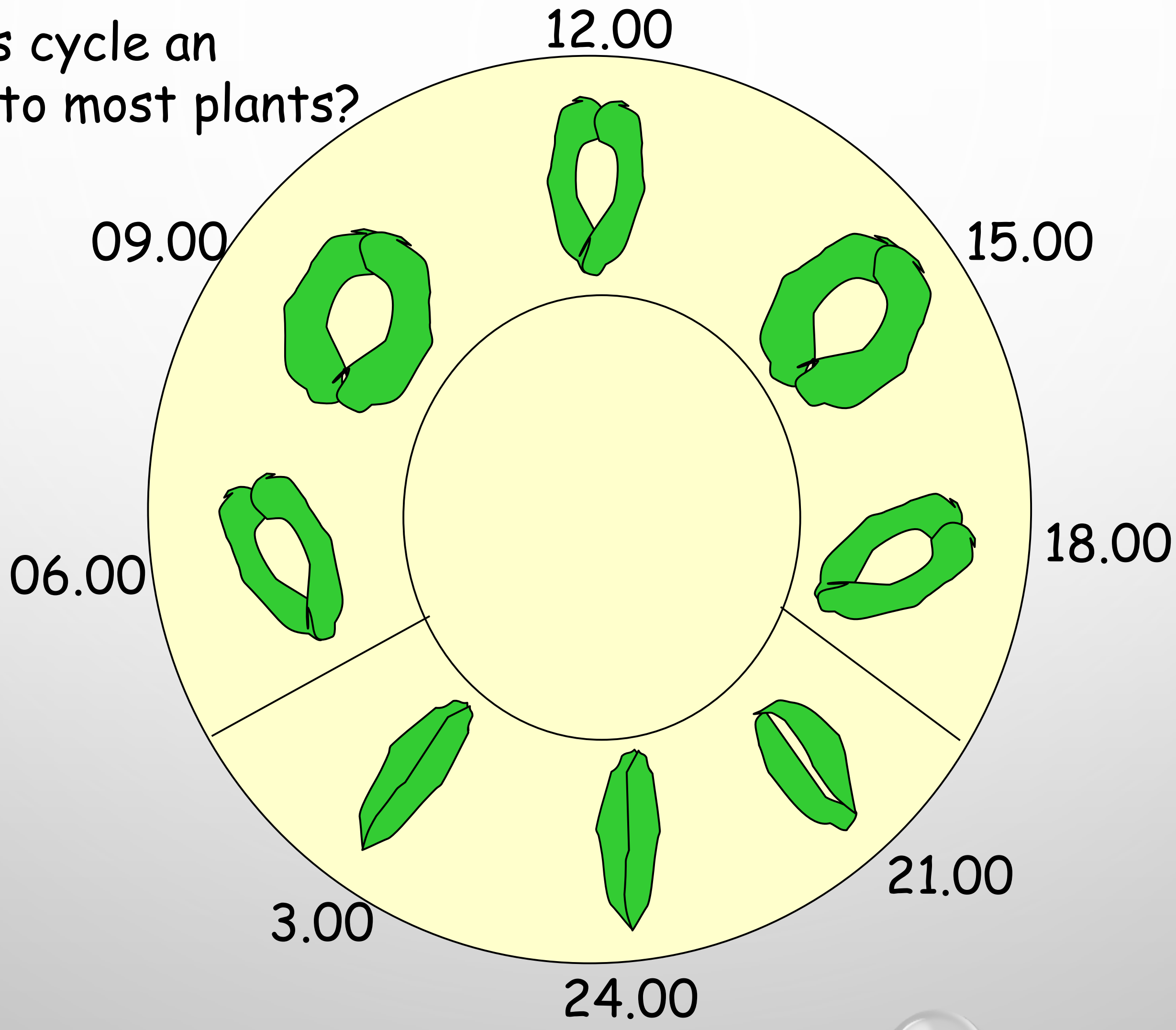
Changes in stomatal resistance are important for the regulation of water loss by the plant and for controlling the rate of carbon dioxide uptake necessary for sustained co2 fixation during photosynthesis.

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 co2 inside the leaf, stomatal apertures are kept small or closed, preventing unnecessary loss of water.

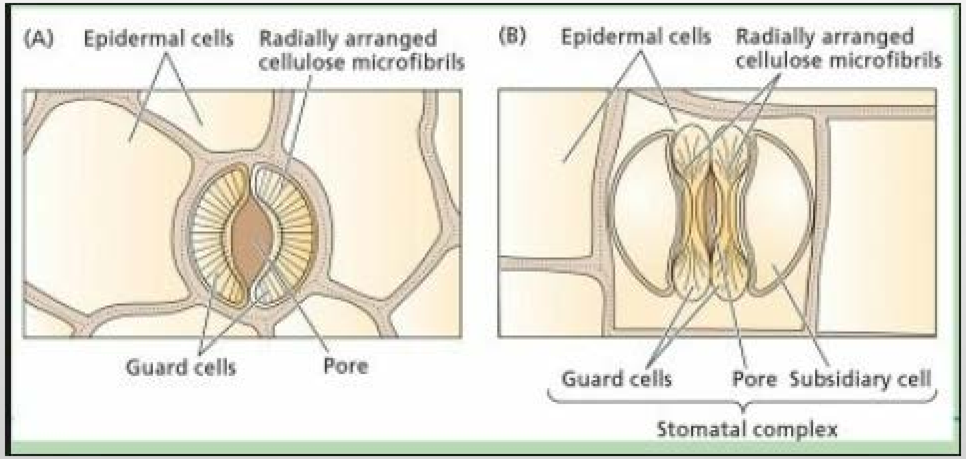
24H CYCLE OF STOMATAL OPENING AND CLOSING

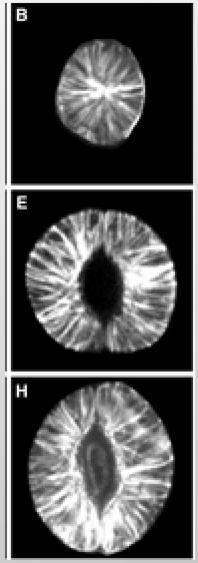
Why is this cycle an advantage to most plants?



The cell walls of guard cells have specialized features

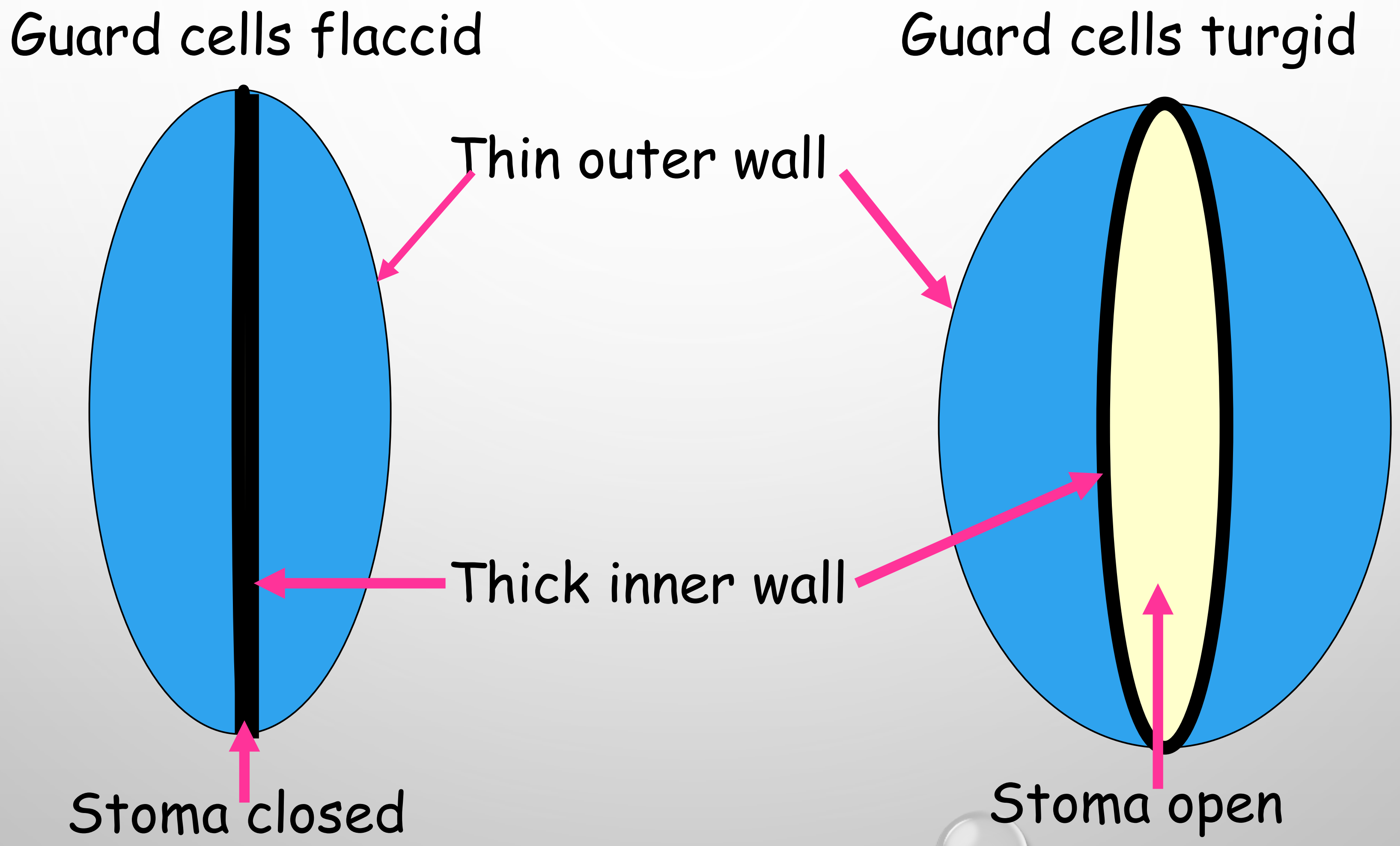
In dicots and nongrass monocots, guard cells have an elliptical contour (often called "kidney-shaped") with the pore at their center. Subsidiary cells are often absent, the guard cells are surrounded by ordinary epidermal cells. A distinctive feature of guard cells is the specialized structure of their 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.

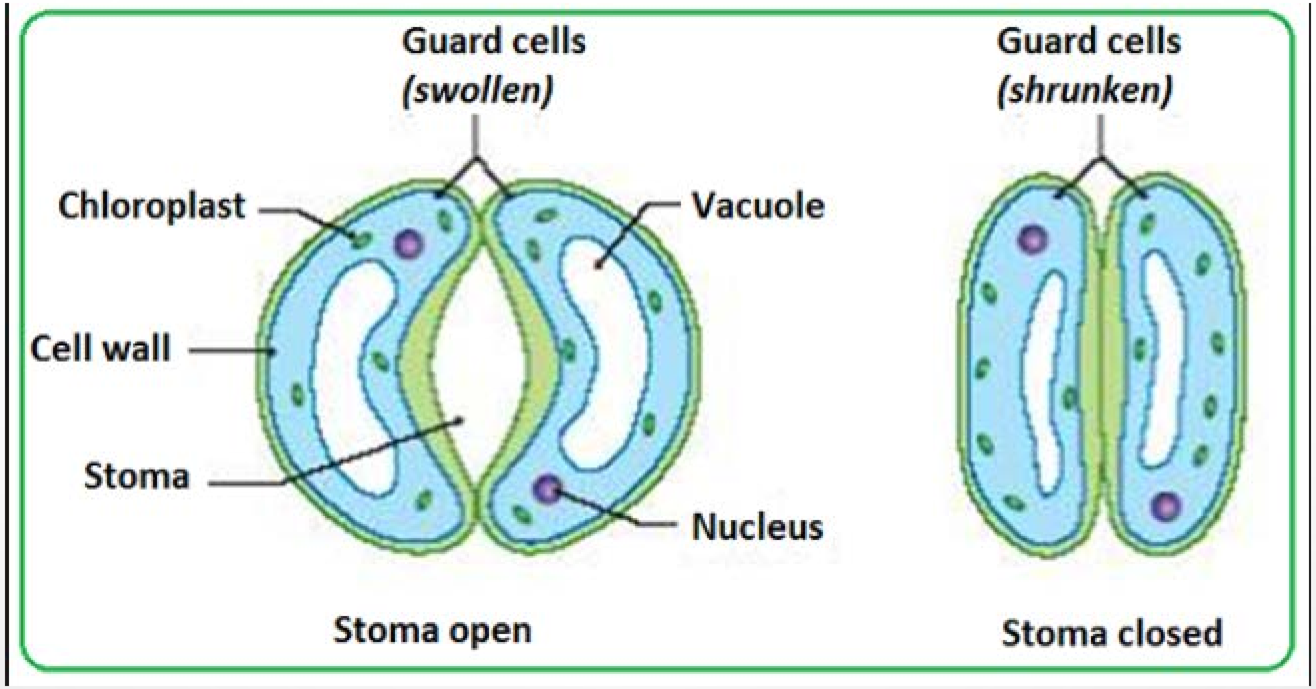


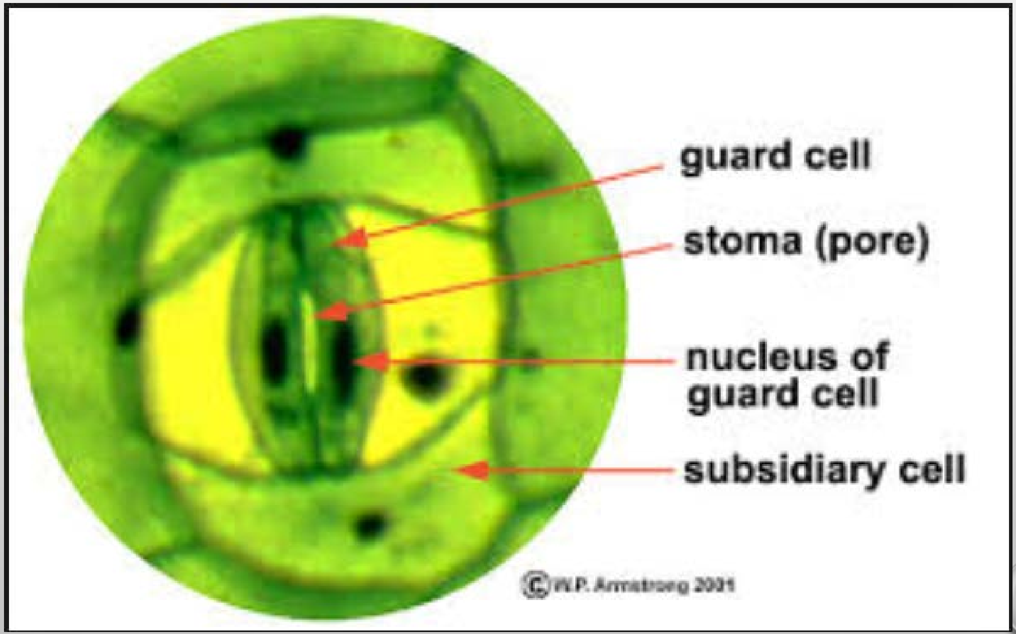


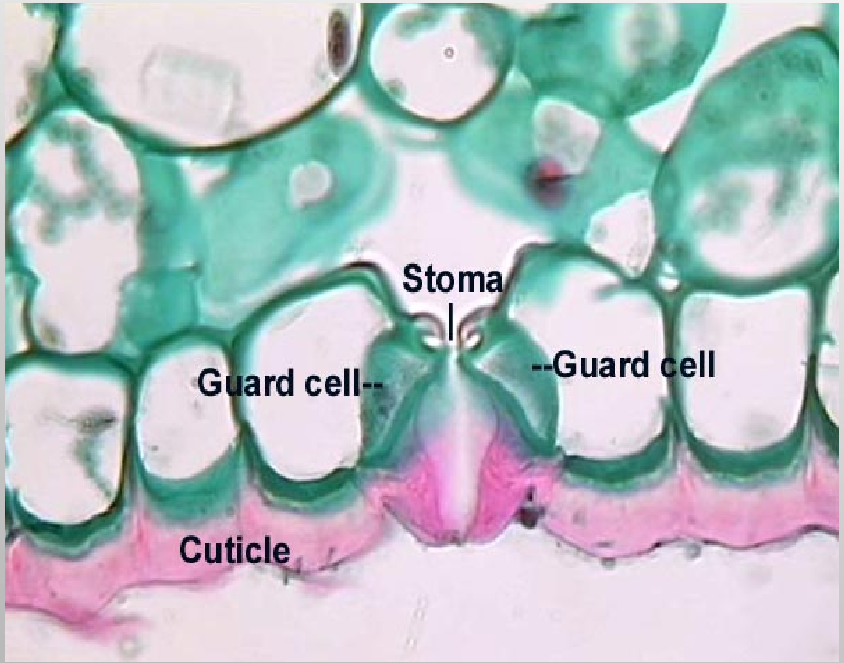
The radial alignment of the cellulose microfibrils in guard cells and epidermal cells of (A) a kidney-shaped stoma and (B) a grasslike stoma (*source: Taiz L., Zeiger E., 2010*)

The guard cells control the opening and closing of the stomata




Guard cells
(swollen)
Guard cells
(shrunken)
Chloroplast
Vacuole
Cell wall
Stoma
Nucleus
Stoma open
Stoma closed

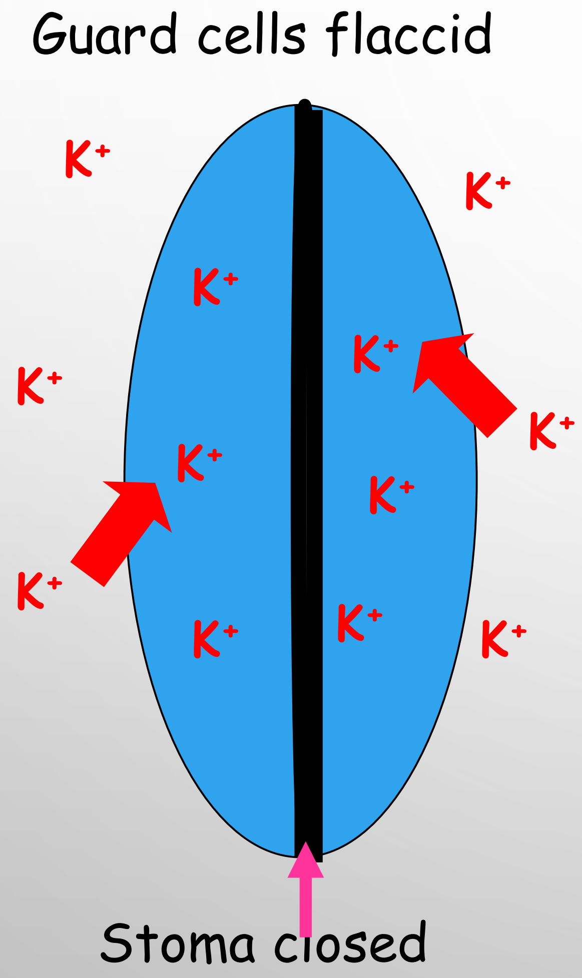

guard cell
stoma (pore)
nucleus of
guard cell
subsidiary cell


Stoma
Guard cell--
--Guard cell
Cuticle

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 (Ψs) 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 Ψs 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.

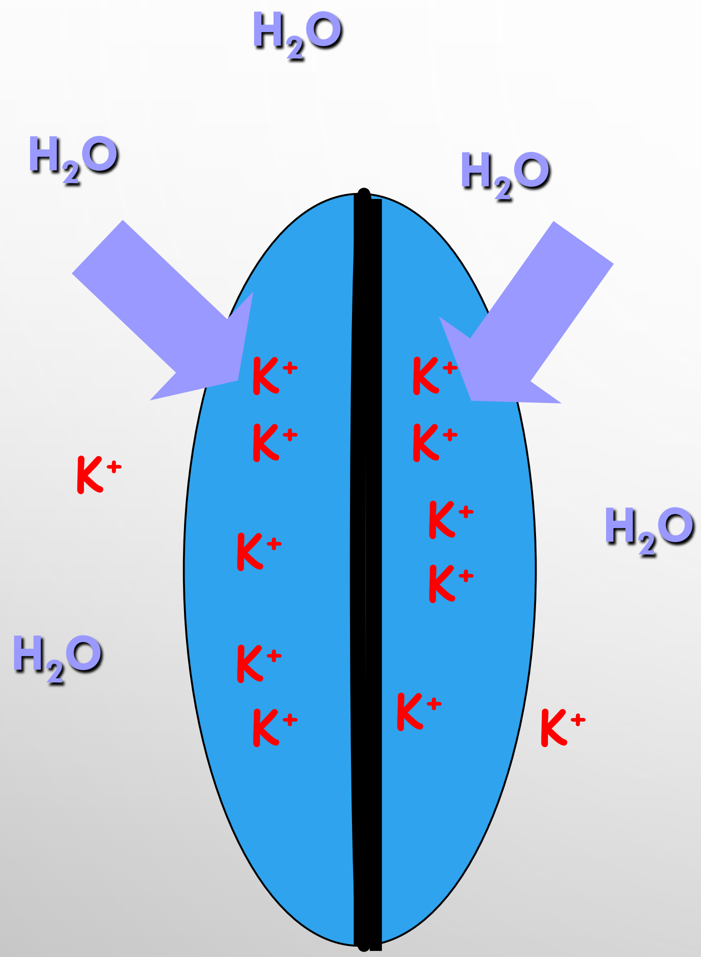
REGULATING STOMATAL OPENING:-THE POTASSIUM ION PUMP HYPOTHESIS



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

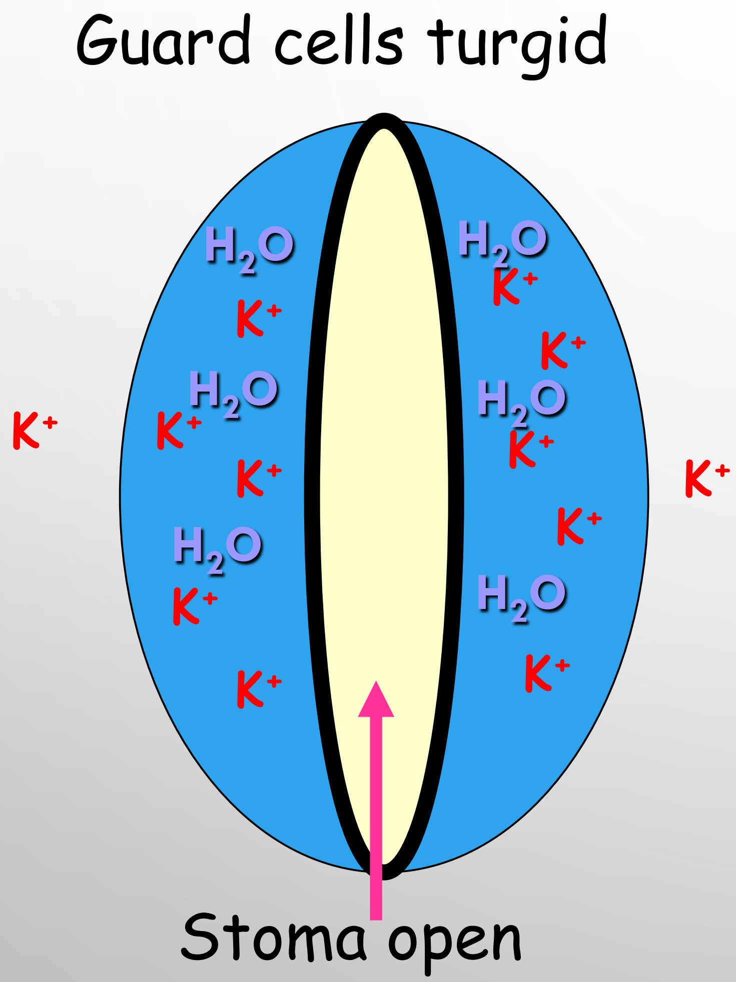
REGULATING STOMATAL OPENING:-THE POTASSIUM ION PUMP HYPOTHESIS



Increased concentration of K^+ in guard cells

Lowers the Ψ in the guard cells

Water moves in by osmosis, down Ψ gradient



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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.

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 (ψw) of the soil solution may approach zero, but drying can reduce the soil ψw 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°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	**Symptoms of Underwatering**
Organs swell, crack open	Growth Inhibition (Dwarfing)
Fungi thrive (Damp-off)	Leaves with brown tips and edges
Yellowing of leaves	Blueing of leaves
Root Death by Asphyxiation	Abscission of leaves
Wilting	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 den due to this pressure watery drops ooze out with the assistance of special structures which help in guttation called the hydathodes.

MECHANISM OF GUTTATION

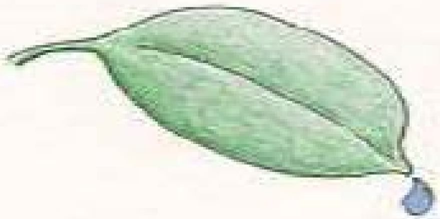
- Under certain conditions like soil flooded with overnight rain water and with high relative humidity of the day atmosphere, the root system of some plants like tomato, **potato,** etc., absorb excess of water by active uptake. As a result, hydrostatic pressure develops in the root system which actually 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.

HYDATHODES

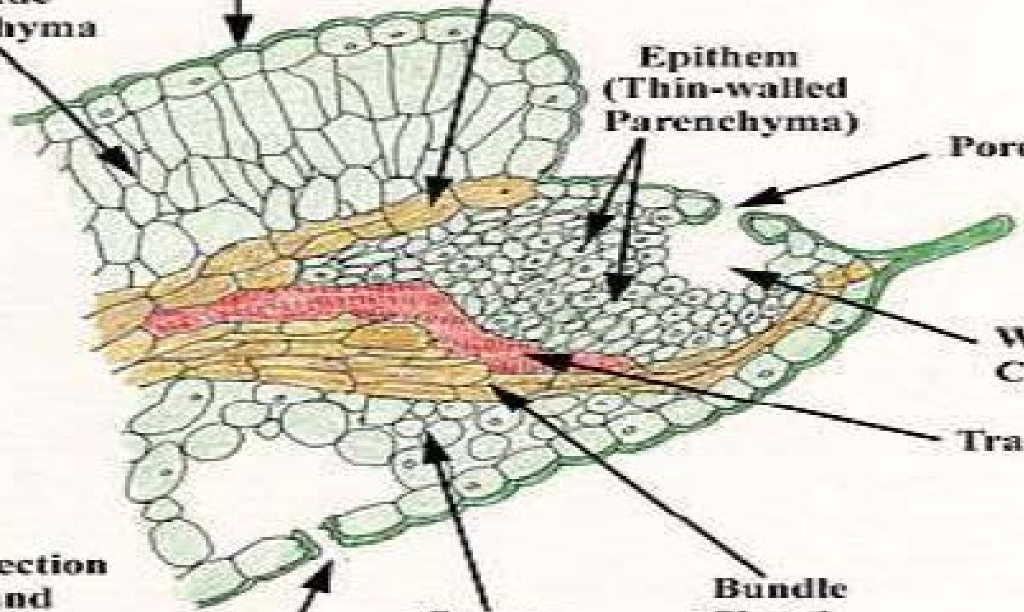
- A **hydathode** is a type of secretory tissue in leaves, usually of Angiosperms, that secretes water through pores in the epidermis or margin of leaves, typically at the tip of a marginal tooth or serration.
- They probably evolved from modified stomata. It is involved in guttation, where water is 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.

Hydathode



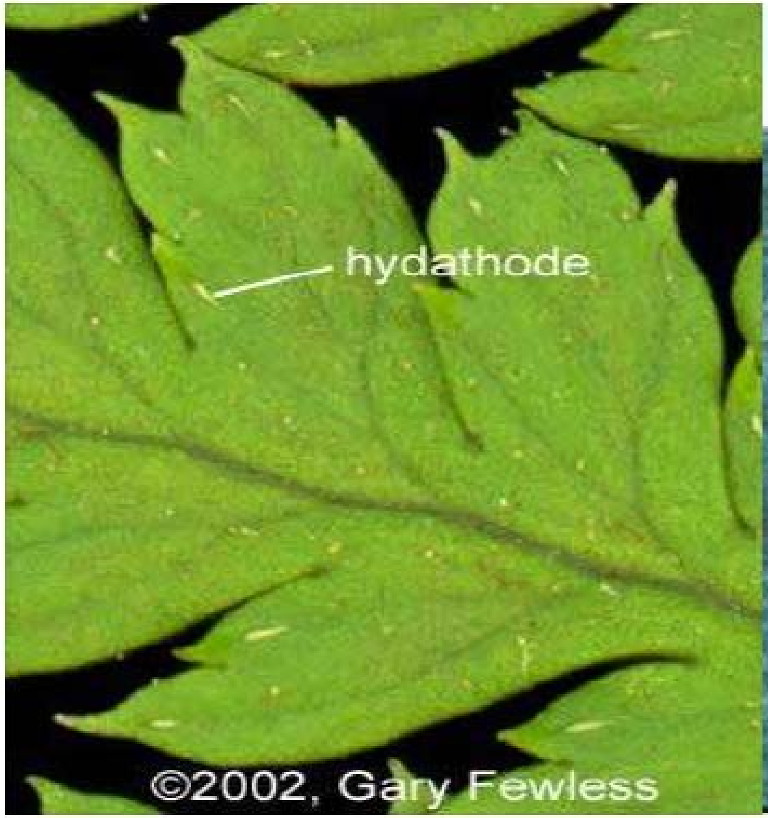
Leaf with guttation droplet from hydathode

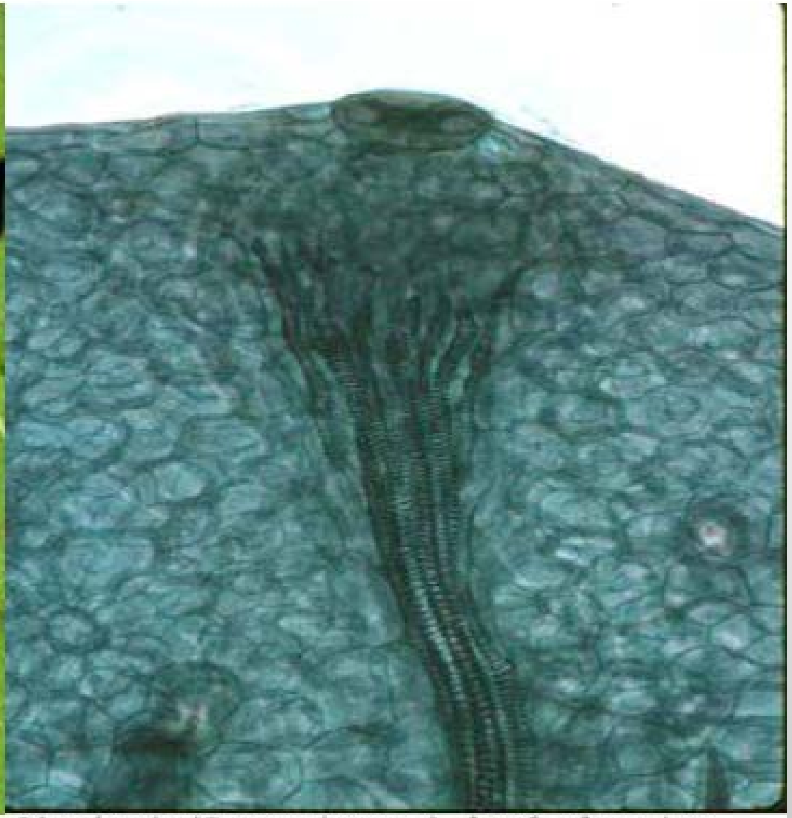
Guttation-exudation of water from hydathodes of leaf margins is caused by root pressure. It is often mistaken for dew in the morning because it occurs at night when water is not processed as quickly within the plant.



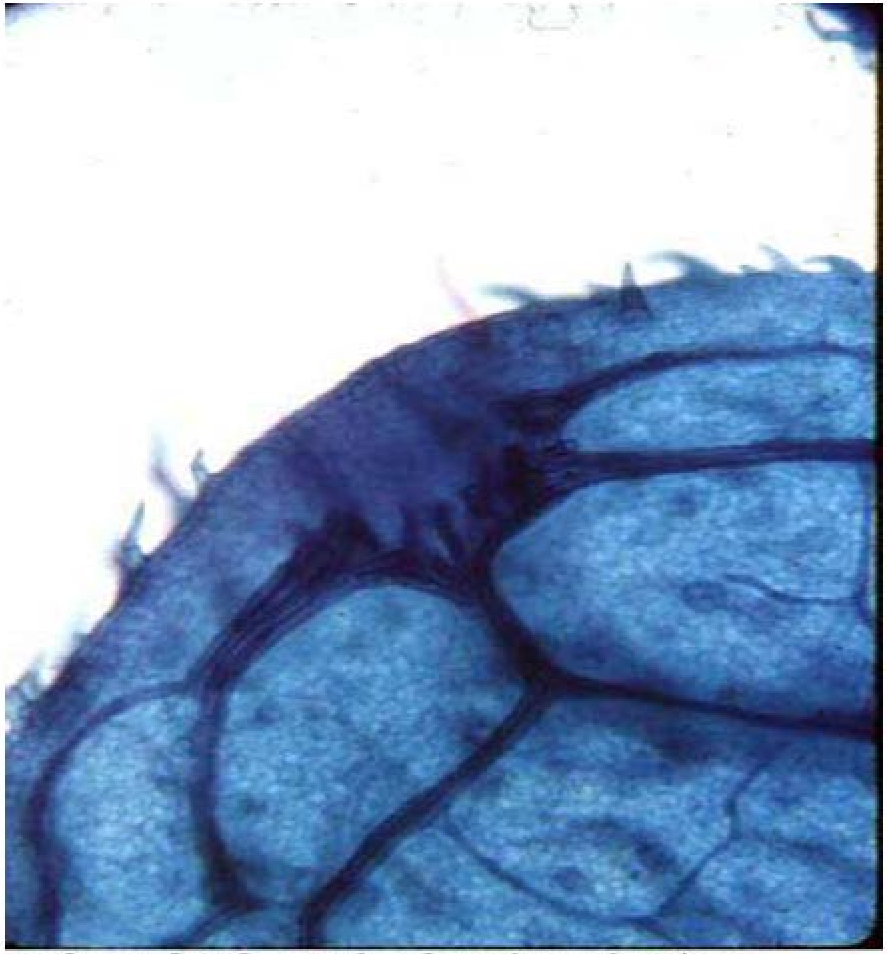
Longitudinal section of leaf apex and hydathode

Hydathodes

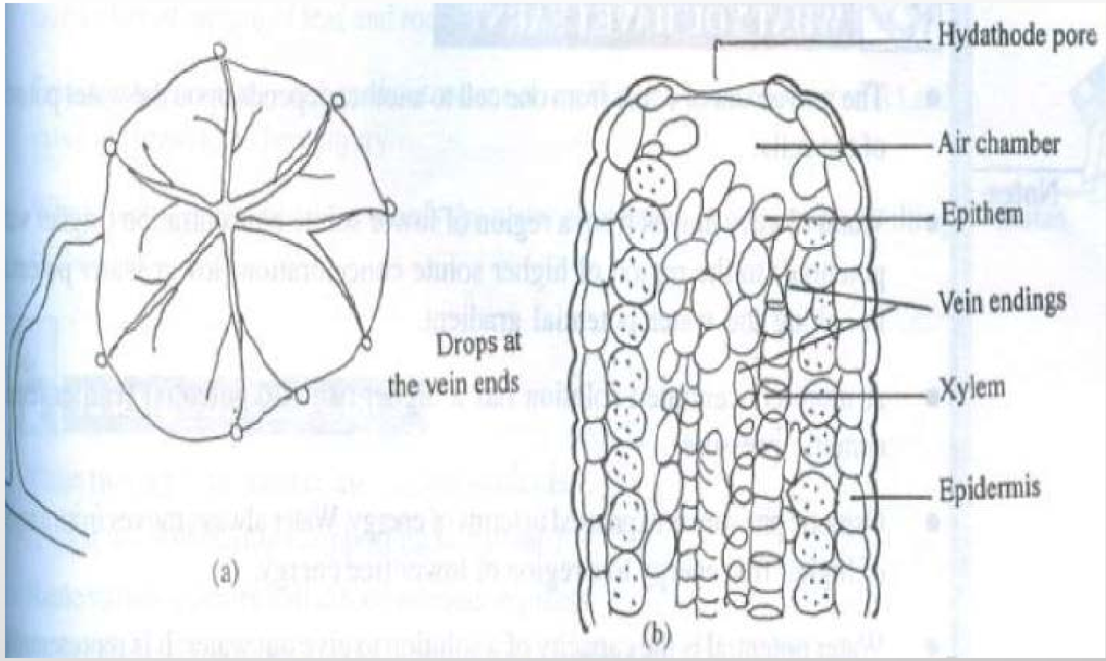




Sinningia(Gesneriaceae) leaf clearing focused on single water pore and vascular bundle end in hydathode.



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 benefial to plants as its maintains body tempreture 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.Subsidary 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)	√	