Unite V

Transpiration

Plant physiology

Transpiration

Transpiration is the loss of water from a plant by evaporation.

- What is the condition that allows the water to evaporate outside the plant body?

  Water can only evaporate from the plant if the **water potential** is **lower** in the **air** surrounding the plant than that of plant body.

- From which part of plant body the water evaporated?

  Most transpiration occurs via the leaves.

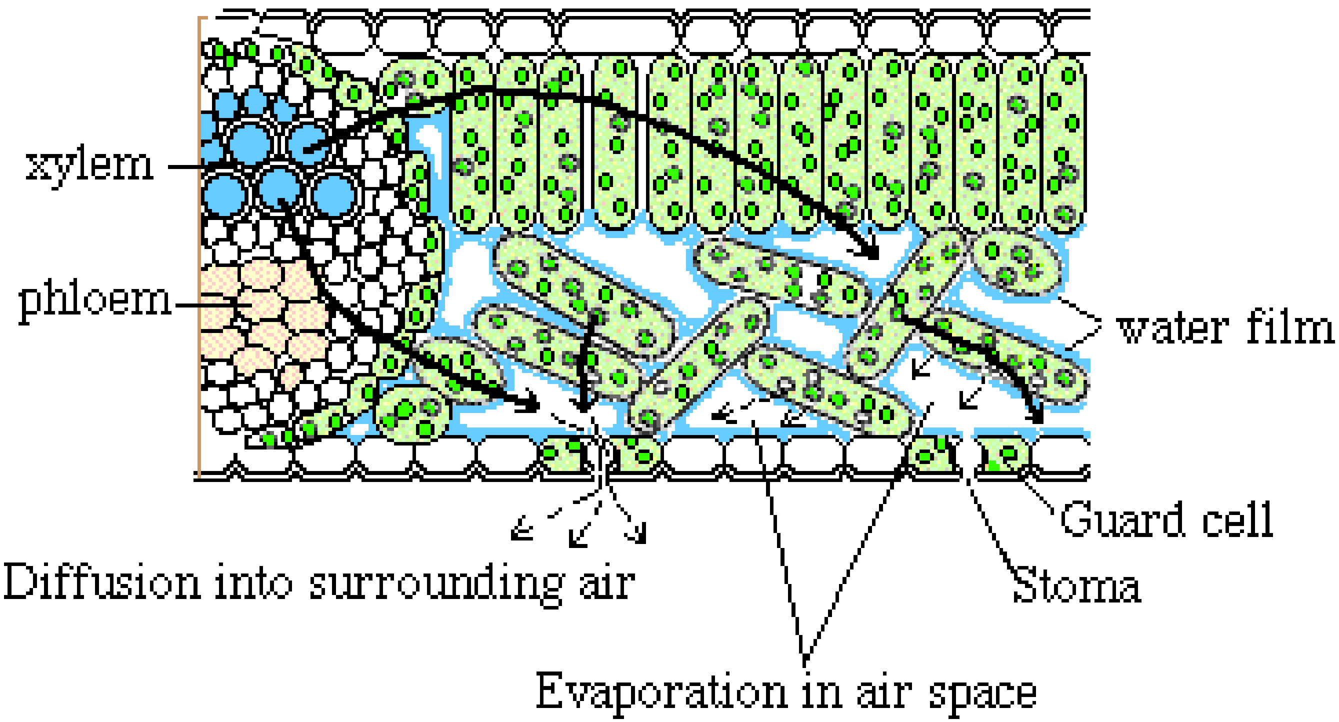
- From which part of leaves?

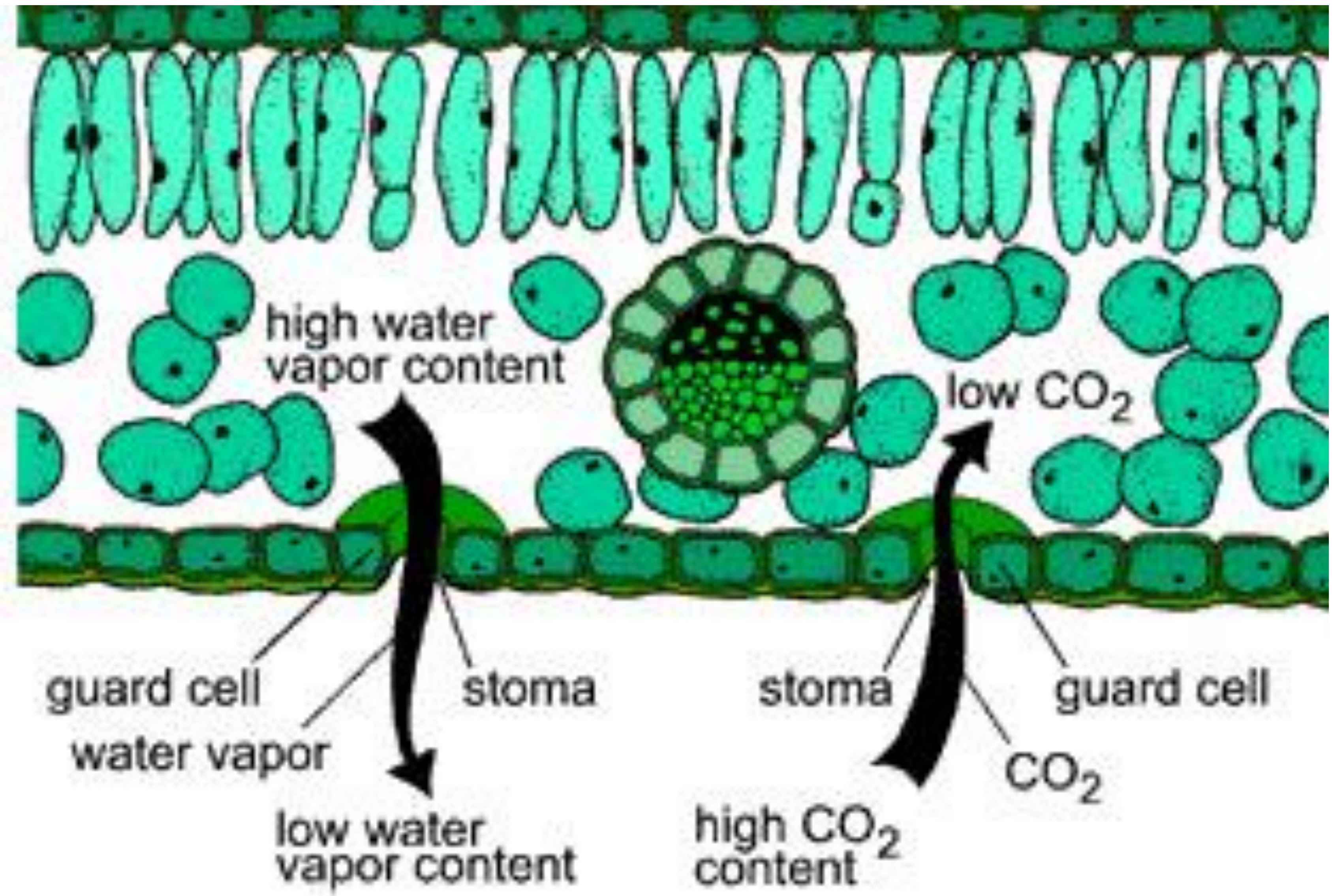
  Mostly via the stomata.

The mechanism of water evaporation through the stomata

Two stages in the process of transpiration are observed:-

1. Water evaporate from the walls of moist cells into the air chambers just behind the pore of stomata.
2. Water vapor diffuses from air chambers in to outside environment.



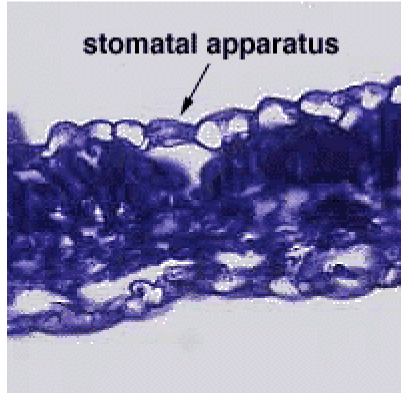

high water
vapor content
low CO_2
guard cell
stoma
stoma
guard cell
water vapor
CO_2
low water
vapor content
high CO_2
content

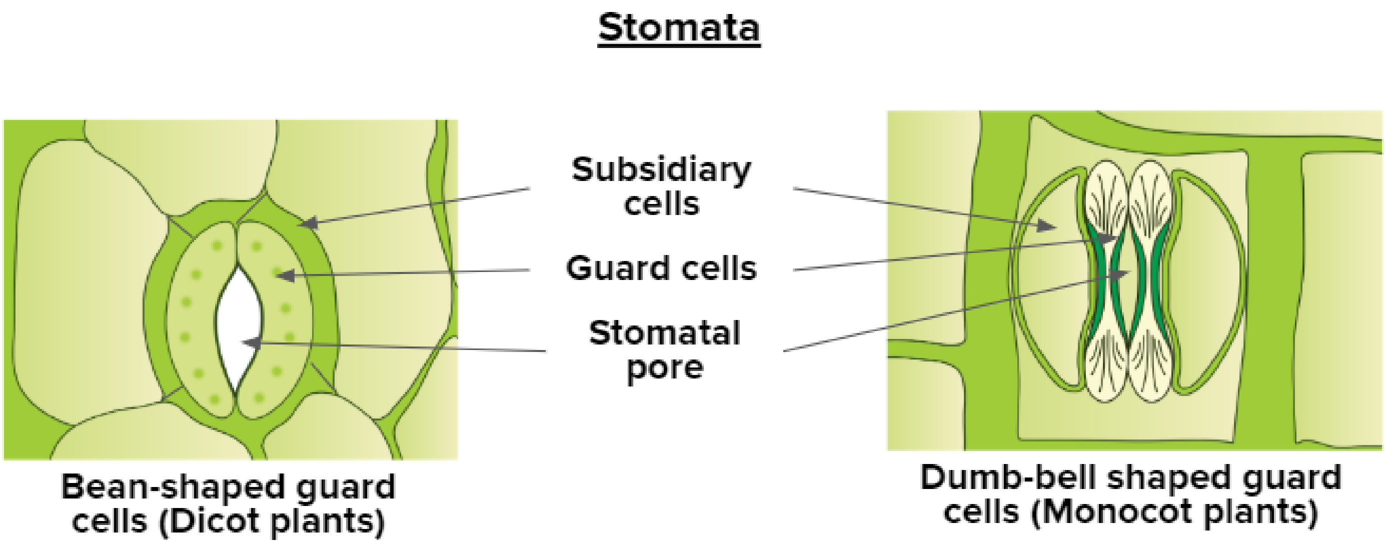
Distribution of stomata

- Usually stomata are distributed on both sides of plant leaves.
- But in general the number of stomata on the lower side or surface in higher the than of the upper side.
- Some times the stomata are present only on the lower side of leaf.
- Also there is a difference in the number of stomata from plant to another.

Principle components of stomata apparatus

1. Guard cells.
2. Stomatal opening (pore).
3. Subsidiary cells or accessory cells.
4. Sub-stomatal chamber.





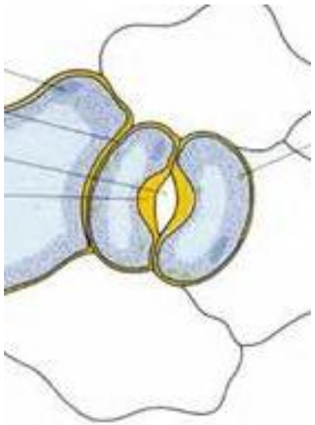
Stomata open and close mechanism

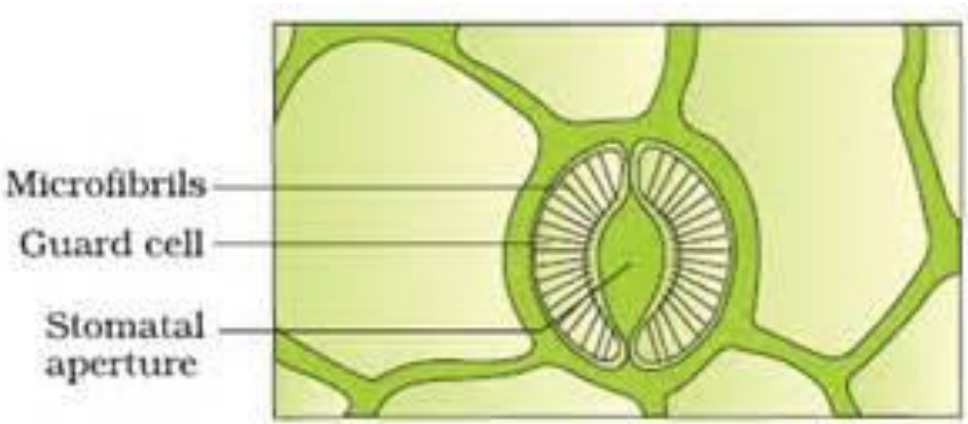
The turgidity is the driving force for opening and closing of stomata.

- Is there any other factors either than the turgidity play a role in stomata movement (open and close)?

- Defiantly yes,

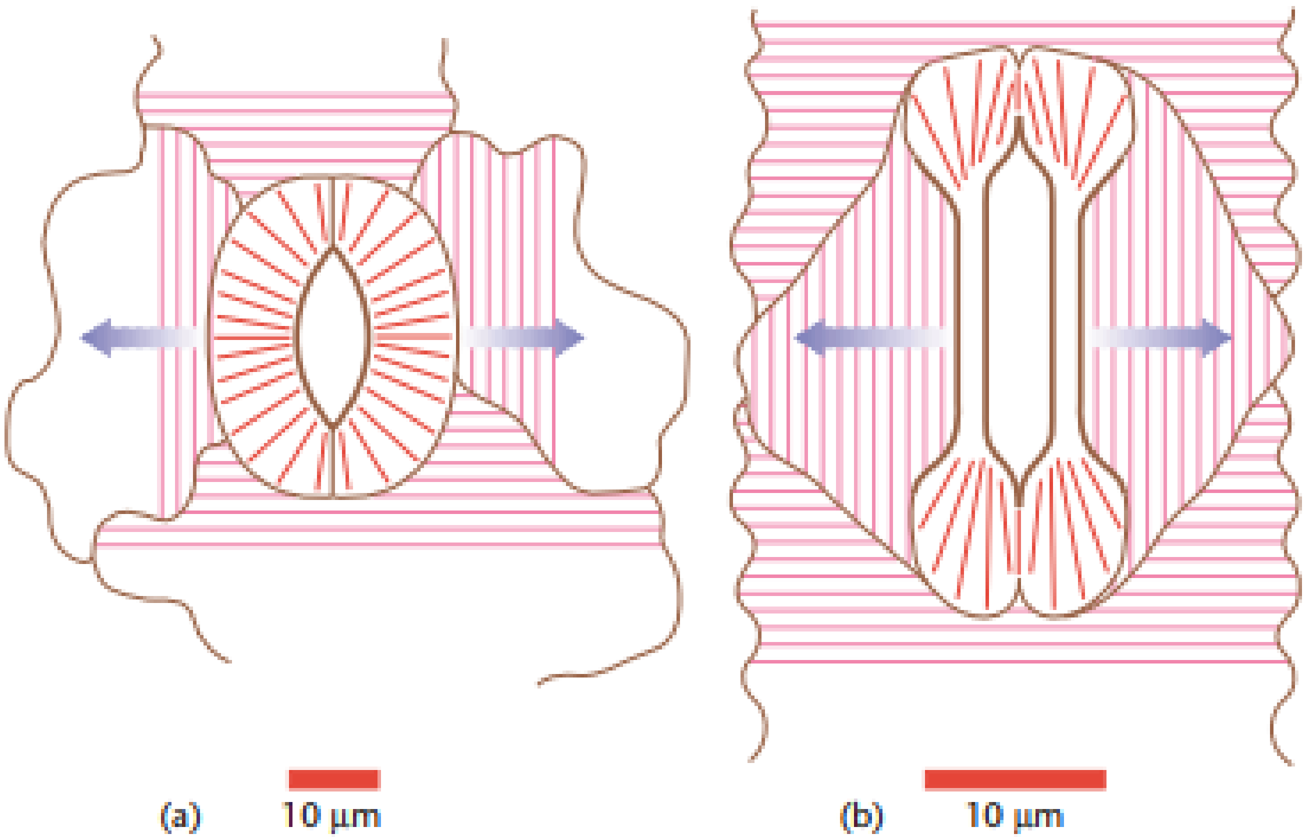
1. The uneven thickening in the cell walls next to the pore (stoma) and the cell adjacent to the epidermis.
2. The presence of the radially arranged cellulose microfibrils causes the opening of stomata when they are turgid.





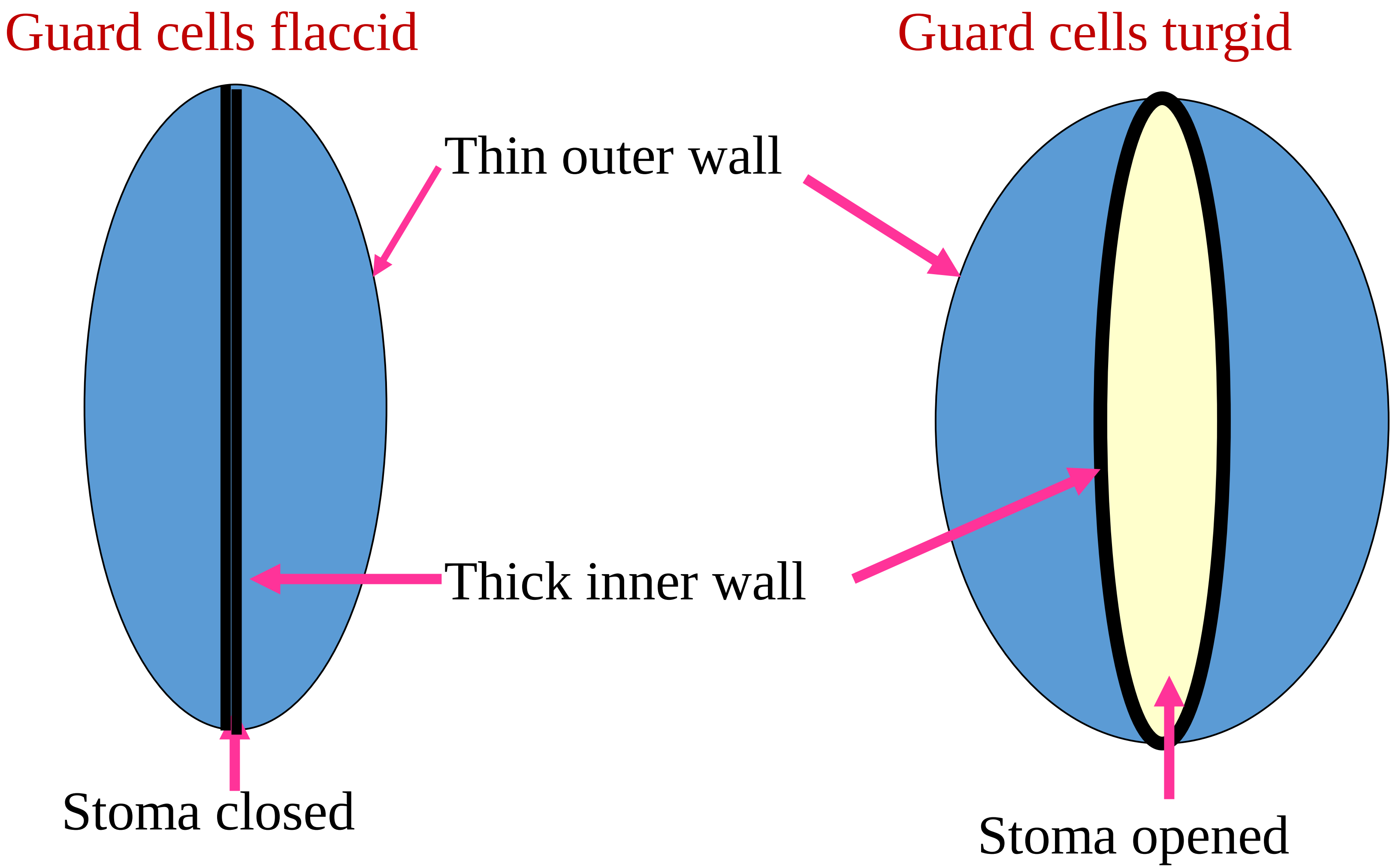
Stomata open and close mechanism

So, the cellulose microfibers alignment re-inforce all plant cell walls, as well as play a radical role in opining and closing of stomata.



The role of K+ ion in opening and closing of stomata

- Opening and closing of stomata controlled by turgidity.
- Turgidity of such cells depends basically on its contents of K+



The role of K+ ion in opening and closing of stomata

Two periods:-

- During the night / - In the morning.

During the night, also under water stress

↓

K+ exit from the guard cells

↓

Ψs of the guard cells become low

↓

Water exit from the guard cells → The guard cells become flaccid

↑

The pore closed

The role of K+ ion in opening and closing of stomata

Two periods:-

- During the night / - In the morning.

In the morning

↓

K+ moves into the guard cells

↓

Ψs of the guard cells become high

↓

Water enters in guard cells → The guard cells become turgid

↑

The pore opened

The role of K+ ion in opening and closing of stomata

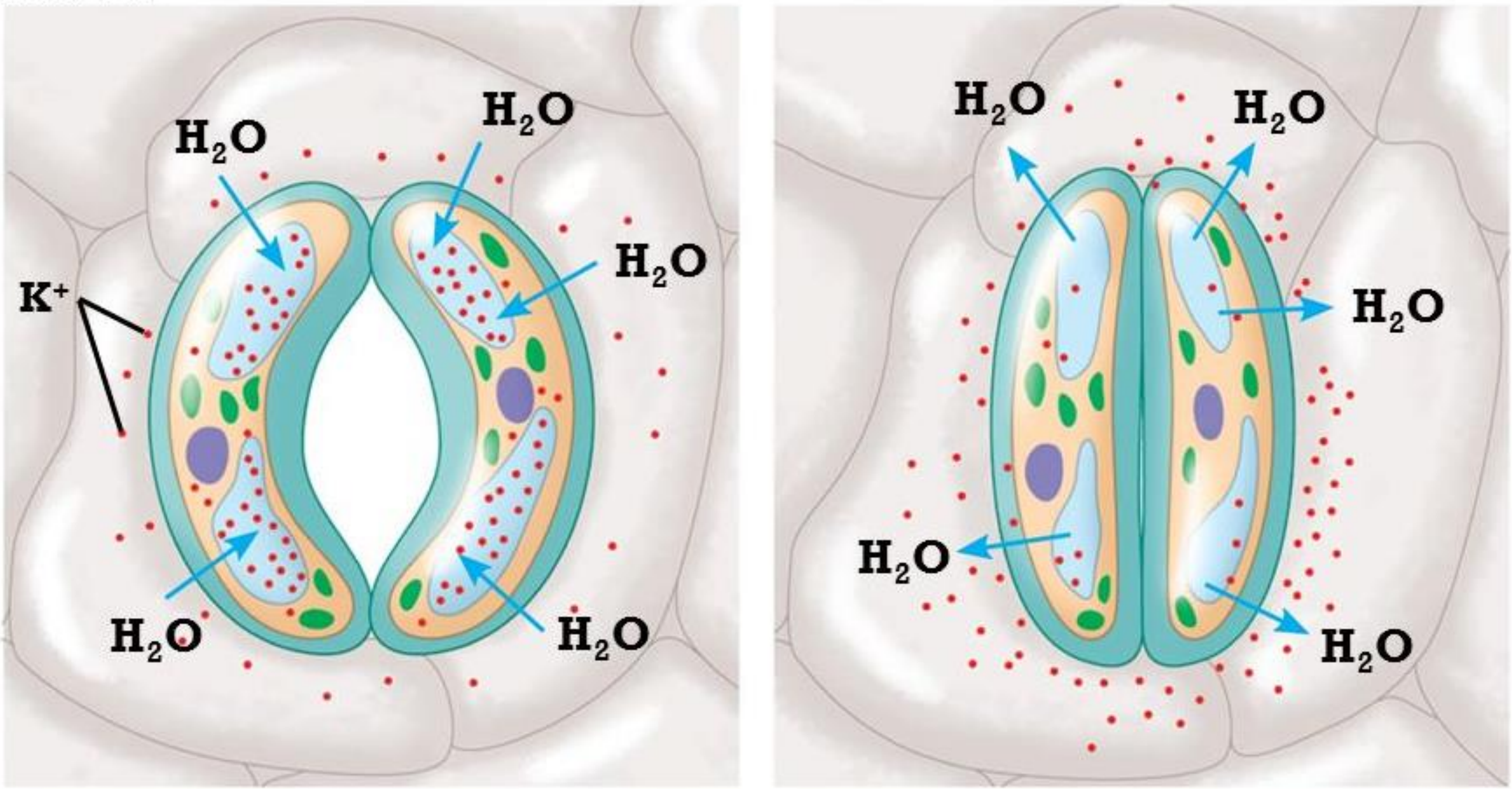
Two periods:-

In the morning

During the night

Guard cells turgid/Stoma open

Guard cells flaccid/Stoma closed



Role of potassium in stomatal opening and closing

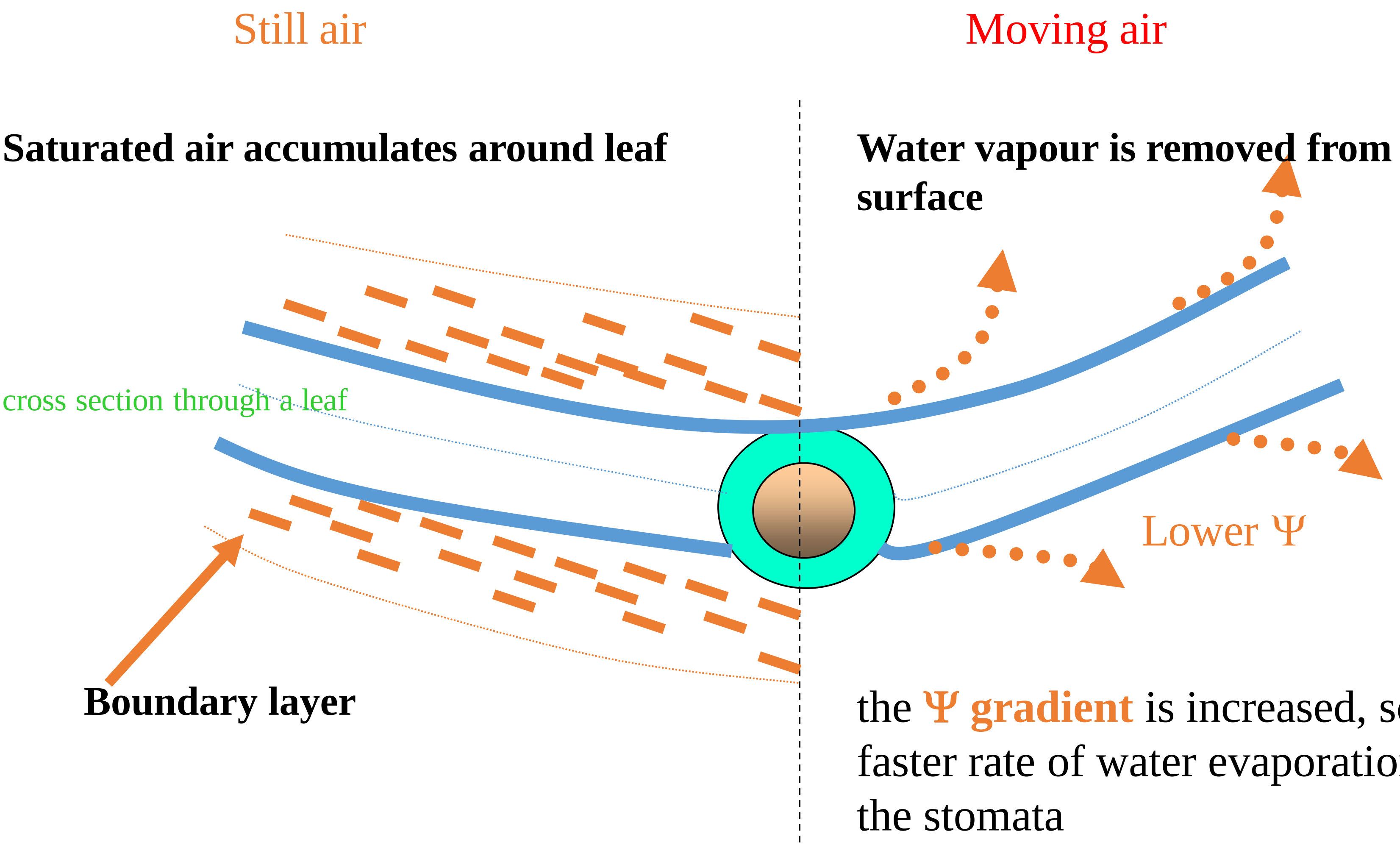
Environmental Factors Affecting Transpiration

1. **Relative humidity**:- air inside leaf is saturated (RH=100%). The lower the relative humidity outside the leaf the faster the rate of transpiration as the Ψ gradient is steeper

2. **Air Movement (winds)**:- increase air movement increases the rate of transpiration as it moves the saturated air from around the leaf so the Ψ gradient is steeper.

3. **Temperature**:- increase in temperature increases the rate of transpiration as higher temperature
   - Provides the latent heat of vaporisation
   - Increases the kinetic energy so faster diffusion
   - Warms the air so lowers the Ψ of the air, so Ψ gradient is steeper

Moving air removes the boundary layer of water vapour from the leaf



the **Ψ gradient** is increased, so faster rate of water evaporation via the stomata

4. Water stress:- increases the level of abscisic acid (ABA) in the vacuoles which causes the exit of K+ , subsequently lower the Ψs of the guard cells, and close the stomata.

5. CO_2 concentration:- If carbon dioxide concentration in the air increases, the plant will have its stomata open less. With the stomata open less, the amount of transpiration decreases. While when the concentration of CO_2 in the leaf tissue decreased lower than that of the surrounding air, the guard cells become turgid and the stomata opened. This is usually happed in the presence of light, during the photosynthesis, because of CO_2 reduction by photosynthesis. This explains why the stomata open during the day and close at the night.

6. Plant hormones:- ABA promotes Ca+ increase in cytosol which indirectly makes K+, Cl- flow out of guard cells and inhibits entrance of K+ into guard cells. Stomata closed.

7. Light plays a role in photosynthesis, permeability of membrane, temperature

Adaptation to reduce water loss in xerophytes

1. Thick waxy cuticle.
2. Reduced leaf area.
3. Hairy leaves.
4. Sunken stomata.
5. Rolled leaves.

Starch-sugar conversion theory

The enzyme starch phosphorylase (SPLase) plays an important role in stomata opening and closing.

pH> 5.0 hydrolysis activity.
pH<4.6 synthesis activity.

Light	Darkness
Photosynthesis in guard cells consumes CO_2	Respiration in guard cells produce CO_2
Cell pH ↑	Cell pH ↓
SPLase hydrolysis activity ↑	SPLase synthesis activity ↑
Starch becomes G-1-P	G-1-P to starch
Ψw ↓	Ψw ↑
Guard cells absorbs water and turgor ↑	Loss water and turgor ↓
Stomata opening ↑	Stomata closure ↓

Light / dark

↓

Guard cells photosynthesis / respiration

↓

ATP and malate

↓

ATPase hydrolysis ATP/ malate dissociates H+

↓

H+ pump out H+ of guard cells / K+ pump into guard cells

↓

Water potential

↓

Guard cells absorbs water and turgor

↓

Stomata opening

Role of transpiration

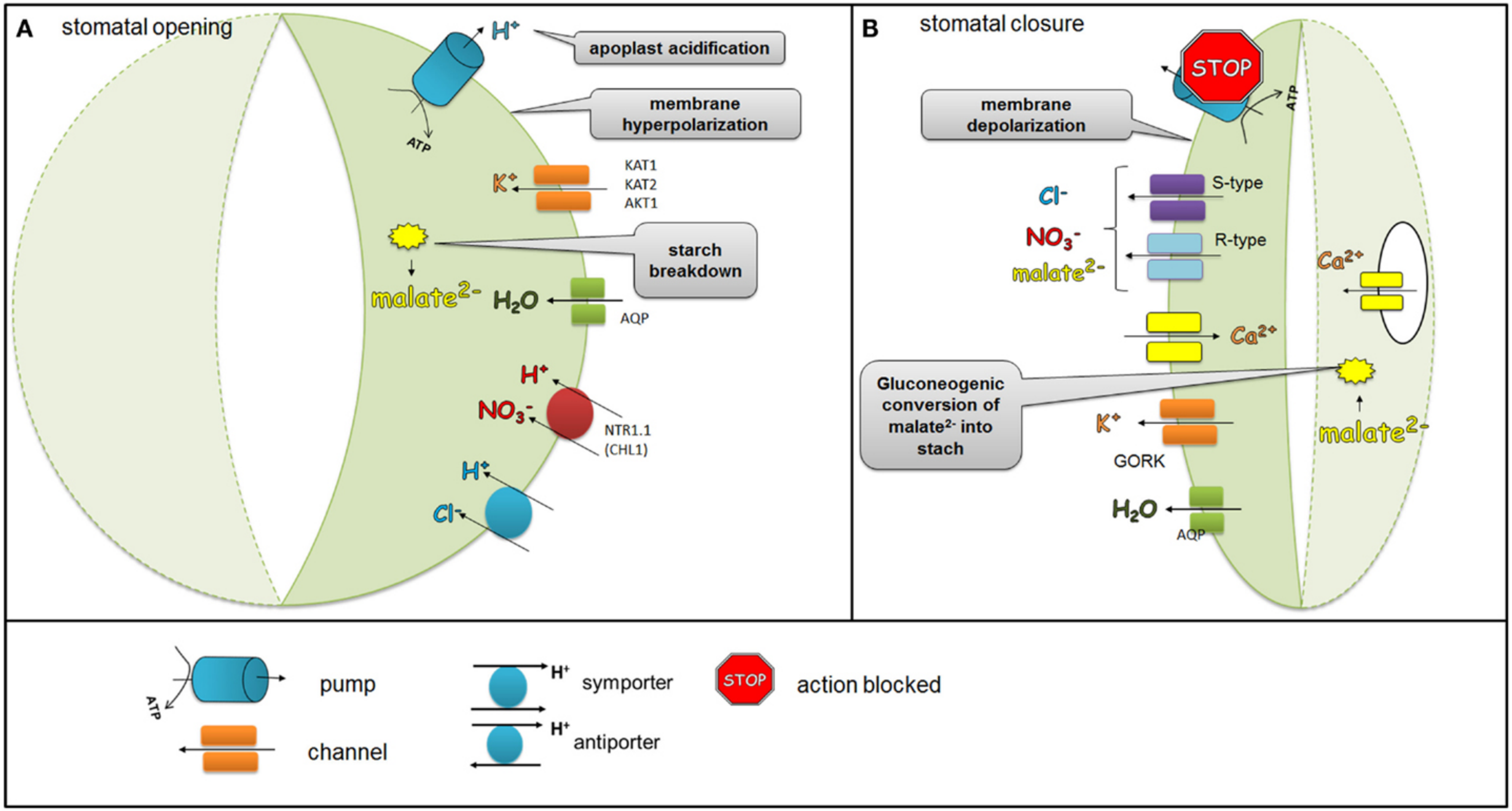
1. It decreases leaf temperature.
2. It is power for water absorption and transportation .
3. It enhances the transfer and distribution of mineral nutrition and other solution in plant body.

Regulation of stomata

1. Microfibrils mechanism.
2. Ion mechanism.
3. Blue-light receptor.

Botanical factors affecting transpiration

1. Leaf surface area.
2. Thickness of epidermis and cuticle.
3. Stomatal frequency.
4. Stomatal size.
5. Stomatal position.
6. The ratio of root to shoot
7. Distribution of stomata.
8. Presence of trachoma.



A
stomatal opening
H+
apoplast acidification
membrane hyperpolarization
ATP
K+
KAT1
KAT2
AKT1
starch breakdown
malate2-
H2O
AQP
H+
NO3-
NTR1.1
(CHL1)
H+
Cl-
B
stomatal closure
STOP
ATP
membrane depolarization
Cl-
S-type
NO3-
R-type
malate2-
Ca2+
Ca2+
Gluconeogenic conversion of malate2- into stach
K+
GORK
malate2-
H2O
AQP
pump
ATP
channel
H+
symporter
H+
antiporter
STOP
action blocked

Wilting

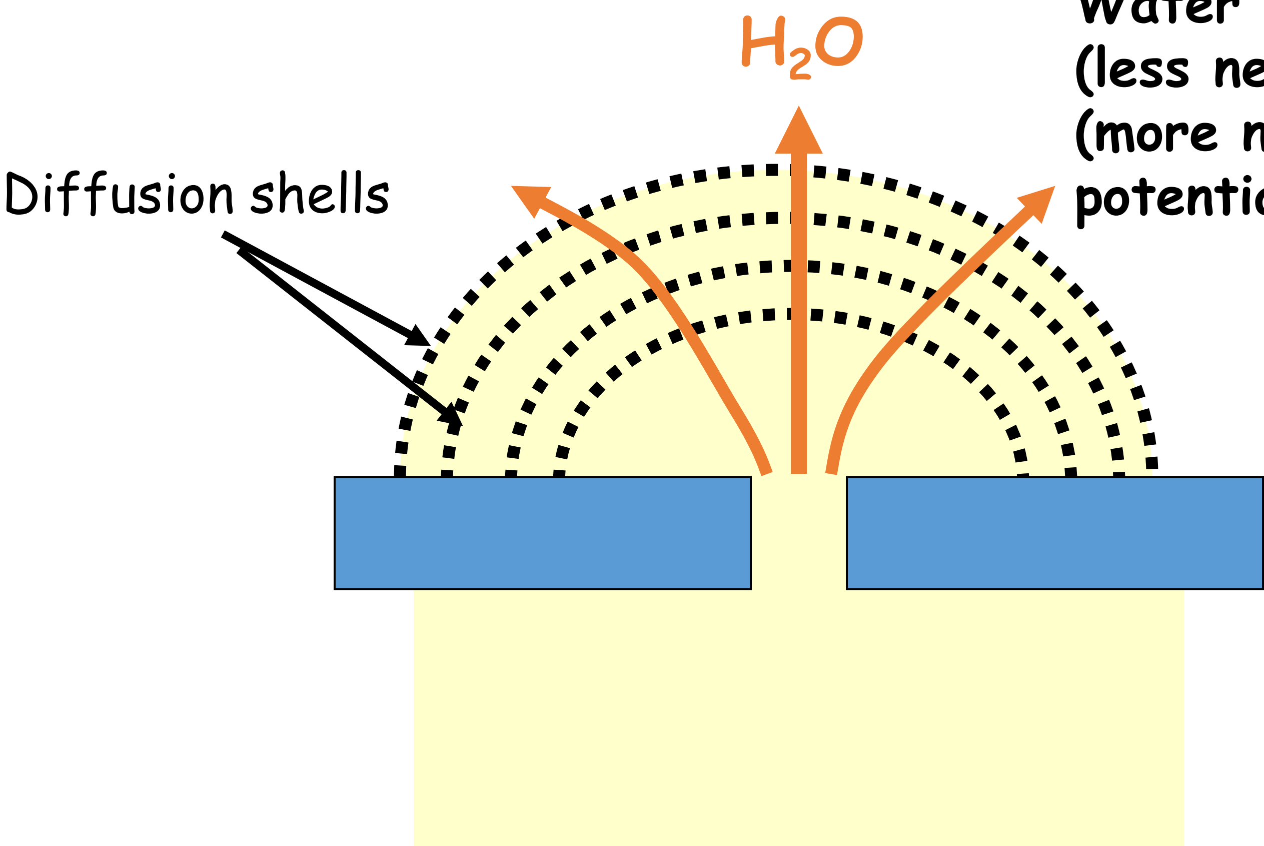
If water lost by transpiration is greater than water uptake via the roots the **plant cells** become **flaccid** and the plant wilts.

When the guard cells are flaccid the stomata close

ADVANCES

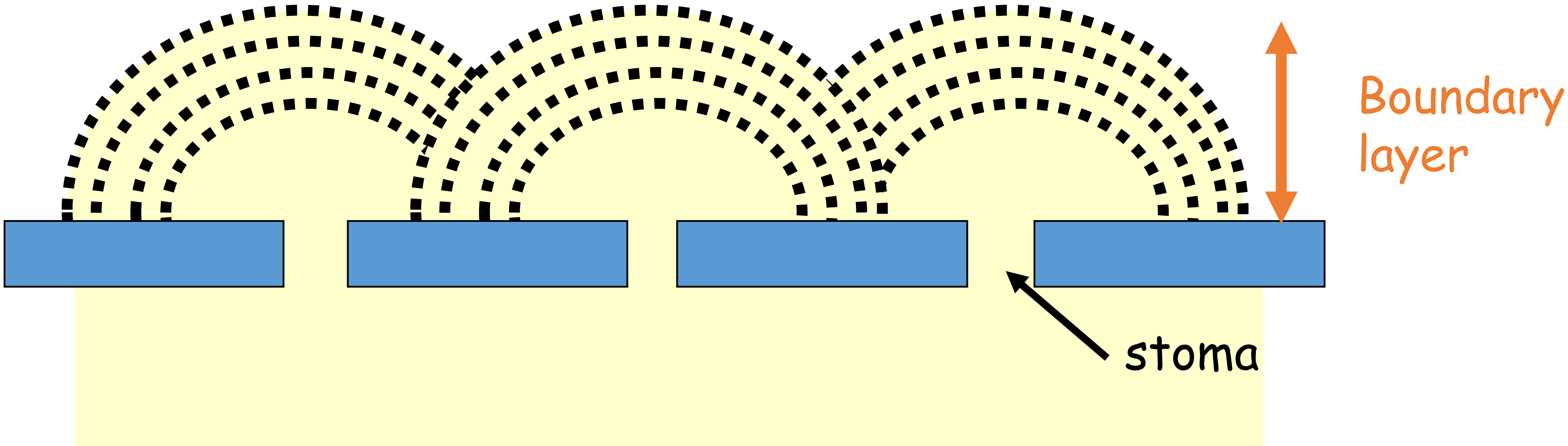
- Phototropin kinases activate the plasma membrane (PM) H^+-ATPase in guard cells, which provides driving force for the accumulation of K^+ through K^+_{in} channels in the PM.
- ABA suppresses blue light-induced activation of PM H^+-ATPase and K^+_{in} channel via ABA receptor components PYR/PYL/RCAR-PP2Cs-SnRK2s in guard cells.
- The novel protein kinase BLUS1 acts as a phototropin substrate and transduces blue light signal to the PM H^+-ATPase via the type 1 protein phosphatase and its regulatory subunit PRSL1.
- A Raf-like kinase BHP interacts with BLUS1 and mediates blue light signaling between BLUS1 and PM H^+-ATPase.
- Degradation of starch in guard cell chloroplasts is required for phototropin-mediated signaling downstream of PM H^+-ATPase activity and contributes to stomatal opening through malate synthesis.
- PP2C-Ds directly dephosphorylate the penultimate threonine of PM H^+-ATPase in etiolated seedlings and are potentially involved in dephosphorylation of PM H^+-ATPase in guard cells.

Movement of Water Through the Stomata



Water moves from a higher (less negative) to a lower (more negative) water potential

Increase in stomatal frequency increases the rate of transpiration



If the distance between the stomata is less than 10 X the pore diameter the diffusion shells overlap

So increasing the number of stomata per unit area will have no further effect on transpiration

Adaption to reduce water loss in xerophytes

1. **Thick waxy cuticle** to reduce the evaporation**.**
2. **Reduced leaf area** **e.g.** needles leaf.
3. **Hairy leaves**, the hairstrap a layer of saturated air.
4. **Sunken stomata**, the pits above the stomata become saturated.
5. **Rolled leaves**, this reduces the area exposed to the air and keeps the stomata on the inside so increasing the water vapour in side the roll.

Increasing the water vapour around the stomata reduces the water potential gradient so slows water loss

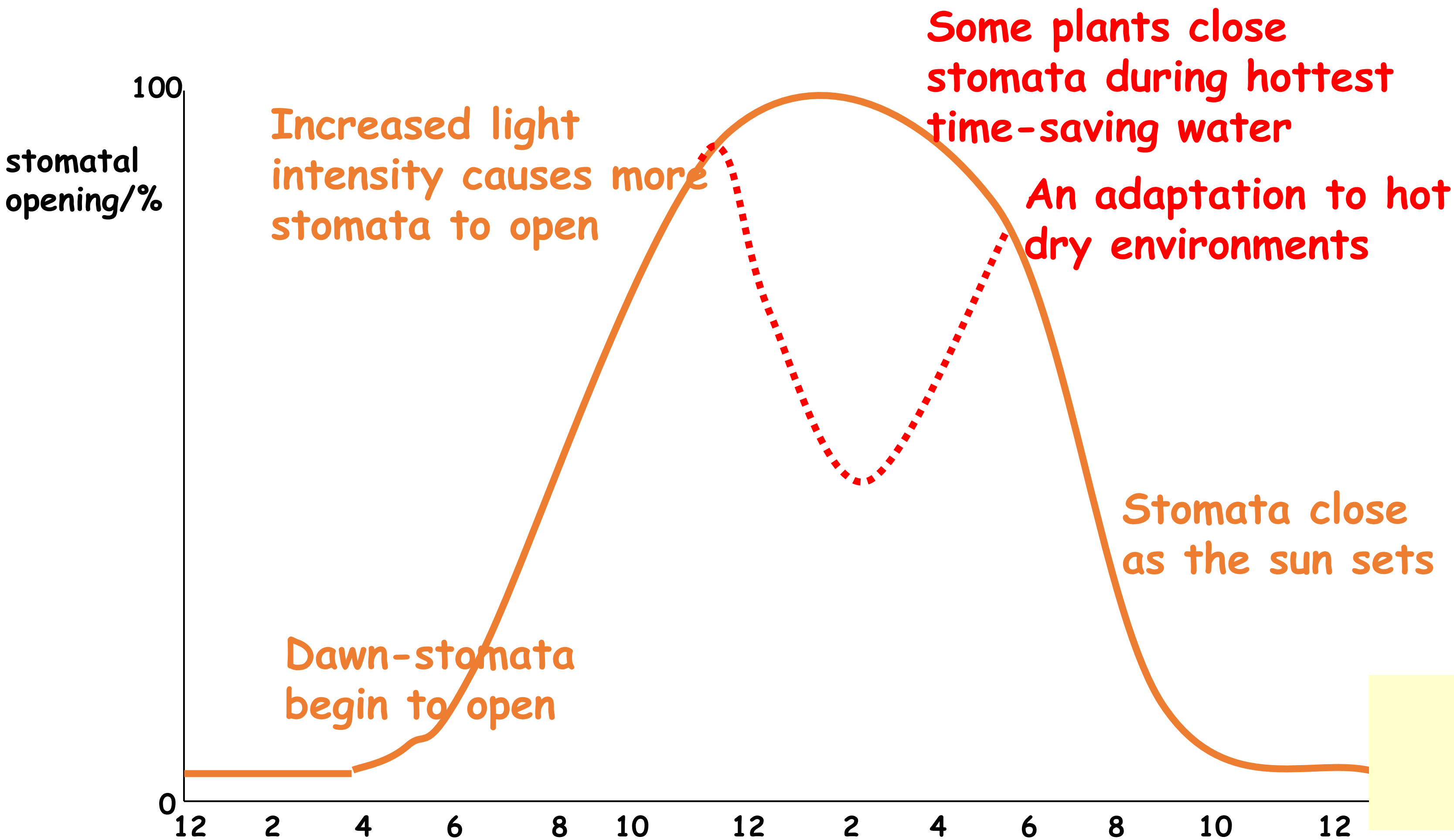
The adaptation to increase water uptake in xerophytes

1. **Deep extensive root**, system to maximize water uptake.

2. **Accumulation of solutes in the root**, system to reduce the Ψ, so making Ψ gradient from the soil to root cell steeper.

1. **Some very shallow roots to absorb** dew which condenses on the soil at night.

Graph to show stomatal opening over 24 hours



24h Cycle of Stomatal Opening and Closing

Why is this cycle an advantage to most plants?