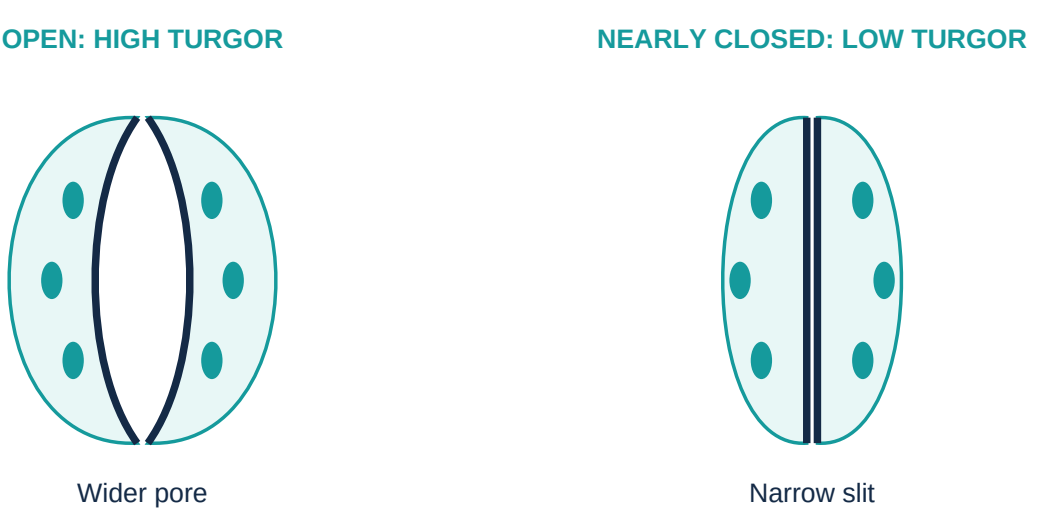
A pore balances two needs

Stomata allow carbon dioxide to diffuse into a leaf for photosynthesis. The same openings allow water vapour to escape during transpiration.

1. TWO GUARD CELLS CONTROL EACH PORE



Surface-view schematics; not to scale. Dark edges face the pore; teal ovals = chloroplasts.

2. STRUCTURE TURNS TURGOR INTO MOVEMENT

Guard cells contain a nucleus, chloroplasts and a large vacuole. Their pore-facing walls are typically thicker than the outer walls. Wall geometry and cellulose organisation constrain swelling, so higher turgor makes the pair bow apart rather than simply expanding into the pore.

3. CLOSURE CONSERVES WATER, BUT HAS A COST

A smaller aperture reduces water-vapour diffusion from the leaf. It also restricts carbon dioxide entry and may reduce photosynthesis. Stomatal control balances carbon gain against water conservation; closure does not increase carbon dioxide uptake.

Stoma = one pore; stomata = several pores. Aperture means the size of the opening. Guard cells change shape; the pore itself is not a cell.

Gas exchange and water loss: OpenStax, Biology 2e 30.5.
Guard-cell wall mechanics: Carter et al., Current Biology (2017).

Scope: Cambridge Biology 9700, section 14.2, outcomes 1-4, p. 38.

Solutes first, then water and turgor

Water moves by osmosis across partially permeable membranes. Guard cells alter their solute content, changing water potential and therefore water movement.

1. COMPARE OPENING AND CLOSING

OPENING	CLOSING
Solutes accumulate	Solutes are lost
↓	↓
Water potential initially falls	Water potential initially rises
↓	↓
Water enters by osmosis	Water leaves by osmosis
↓	↓
Turgor increases	Turgor decreases
↓	↓
Guard cells bow apart	Guard cells become less curved
↓	↓
Aperture increases	Aperture decreases

Water-potential changes are relative to surrounding cells at the onset of water movement.

2. ION TRANSPORT ENABLES OPENING

Light, especially blue light, promotes proton-pump activity in guard-cell membranes. ATP-powered H^+ export favours K^+ entry through channels. Potassium and accompanying anions, including chloride and malate, contribute to solute accumulation. Sugars also contribute. Water enters; the vacuole enlarges and turgor rises.

3. DAILY RHYTHMS ARE MODIFIED BY CONDITIONS

In many plants, stomata tend to open during daylight and close at night. An internal circadian clock contributes to these rhythms, alongside light and internal carbon dioxide signals. Water stress can promote daytime closure. This is not universal: CAM plants commonly open stomata at night.

Potassium movement: Humble and Hsiao, Plant Physiology (1970).
Endogenous daily rhythms: Gorton et al., Plant Physiology (1989).

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ABA signals water stress

Abscisic acid (ABA) is a plant hormone. During water shortage, increased ABA signalling promotes stomatal closure and helps limit further water loss.

1. TRACE THE CLOSURE RESPONSE

ABA IS PERCEIVED
ABA binds to receptors and initiates signalling in guard cells.

CALCIUM RELAYS THE SIGNAL
Cytosolic Ca^{2+} can rise through influx and release from internal stores.

ION CHANNELS RESPOND
Ca^{2+} acts as a second messenger, helping regulate channel activity.

NET SOLUTE LOSS
Anions leave; membrane depolarisation favours K^{+} efflux.

WATER AND TURGOR DECLINE
Water potential initially rises; water leaves by osmosis.

THE PORE CLOSES
Guard cells lose turgor, decreasing aperture and transpiration.

2. DISTINGUISH SIGNAL FROM OSMOTIC EFFECT

ABA is the hormone signal; calcium ions relay information inside the cell. The small signalling increase in cytosolic calcium is not the main cause of osmotic water entry. Net loss of potassium salts and other osmolytes is what favours water loss and reduced turgor.

3. USE THE COMPLETE CAUSAL CHAIN

Do not stop at "ABA closes stomata". Link hormone perception to ion movement, water potential, osmosis, turgor and aperture. This is a simplified pathway: ABA also uses calcium-independent signalling, so a calcium rise is not obligatory for every closure response.

ABA and calcium responses: Siegel et al., The Plant Journal (2009).
Signalling network and alternative branches: Munemasa et al. (2015).

Scope: Cambridge Biology 9700, section 14.2, outcomes 1-4, p. 38.