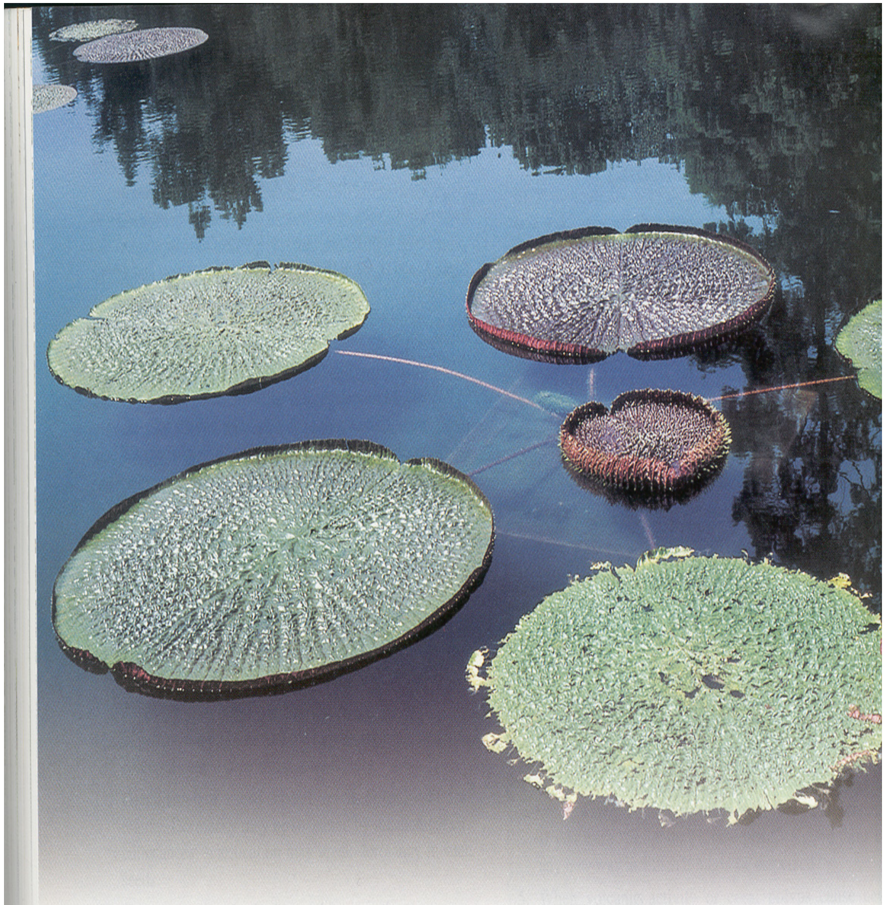
Stomata & Guard Cells

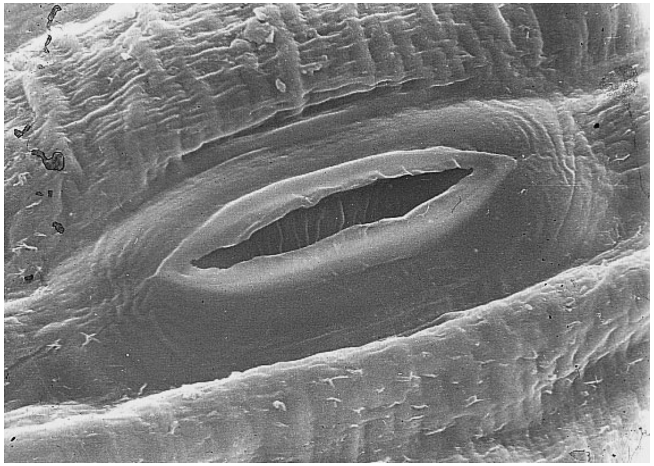
- Overview
- Stomata: morphology
- Physiology of stomata
- Environmental factors



Floating leaves of a giant water lily (*Victoria amazonica*), which sometimes attain a diameter of 2 meters (6.5 feet). The larger leaves are capable of supporting, without sinking, the weight of a child.

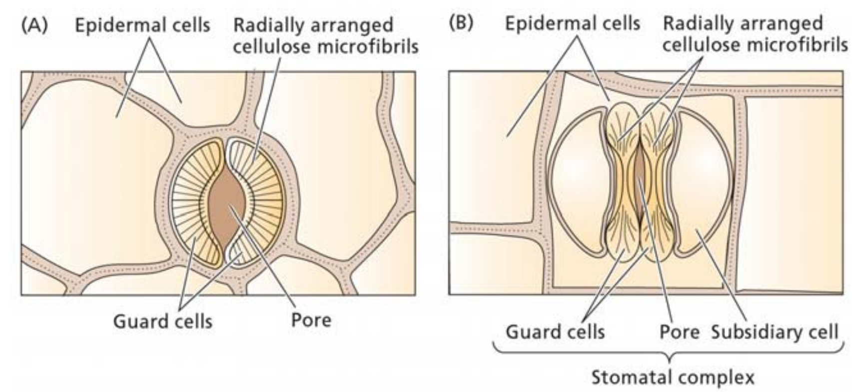
Overview

- Located in epidermal tissue
- Have chloroplasts
- Found in stems, floral parts, fruits



Stomatal morphology

- Guard cells
- Subsidary cells
- Radial micellation
- Substomatal cavity



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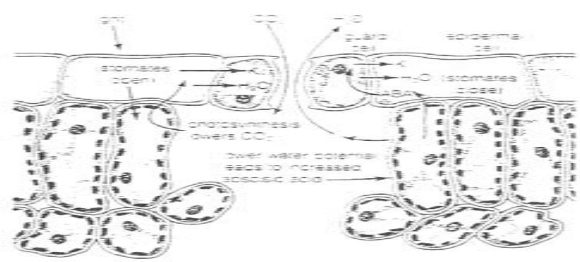


Figure 3-10 Two important feedback loops, one for CO_2 and one for H_2O, that control stomatal action. The left part of the drawing illustrates the effects of light. Light promotes photosynthesis, which lowers CO_2 levels in the leaf; the leaf's response is to cause more K^+ to move into guard cells, and water follows osmotically, causing stomates to open. (There is also a direct effect of light on stomatal opening, independent of CO_2 levels.) The right-hand side shows the effects of water stress: When more water exits than can enter from the roots, abscisic acid (ABA) is released or produced from mesophyll cells, which leads to movement of K^+ out of guard cells; water follows osmotically, so stomates close. If the rate of drying is extremely rapid, water is lost from the guard cells directly, bypassing the ABA step but still leading to closure. (From W. A. Jensen and F. B. Salisbury, Botany, 1984, p. 260.)

Stomatal

- 1% of leaf area
- Found on upper surface
- Lower surface
- Both amphistomatous
- Floating leaves: epistomatous

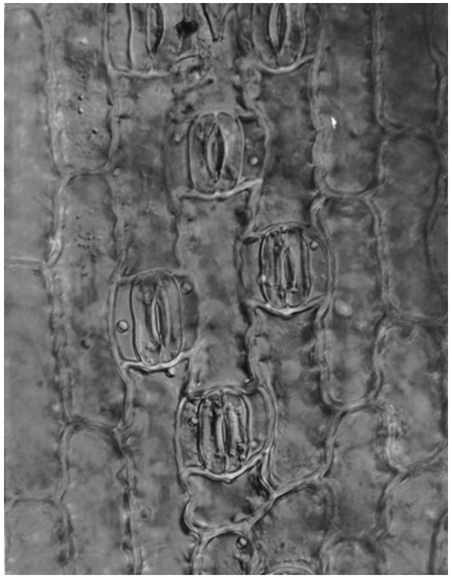


TABLE 5.1 Stomatal frequencies on the upper and lower surfaces of leaves.

Genus	Number of Stomata mm^{-2} Upper Surface	Lower Surface
Monocotyledonae		
Allium (onion)	175	175
Hordeum (barley)	70	85
Triticum (wheat)	50	40
Dicotyledonae		
Herbacious species		
Helanthus (sunflower)	120	175
Medicago (alfalfa)	169	188
Pelargonium (geranium)	29	179
Woody species		
Aesculus (horse chestnut)	—	210
Quercus (oak)	—	340
Tilia (linden)	—	370

Data from Meidner and Mansfield, 1968.

Stomatal Dimensions

TABLE 5.2 Dimensions of stomata from some common plants

Plant	Stomata per cm^2	Aperture* (diameter in μm)	Spacing† (stomatal diameters)
Bean	28,100	5.4	12.6
Begonia	4,000	15.6	11.5
Castor bean	17,600	7.6	11.2
Coleus	14,100	7.9	12.0
English ivy	15,300	8.3	10.9
Geranium	5,900	15.9	9.2
Maize	6,300	13.9	9.9
Oat	2,300	27.5	8.6
Sunflower	15,600	16.5	5.5
Tomato	13,000	10.4	9.5
Wheat	1,400	27.4	11.0
Average	11,327	14.2	10.2

*Aperture is calculated from length × width and assumes a perfect circle.

†Spacing, expressed in relative stomatal diameters, is calculated from the ratio of the absolute center-to-center distance to the maximum pore diameter. If stomata are 100 μm apart and the aperture is 10 μm, the relative spacing is 10 (100 μm/10 μm).

Data from Verduin (1949).

TABLE 5.3 Frequency of stomata and assumed open area of leaf when stomata are open

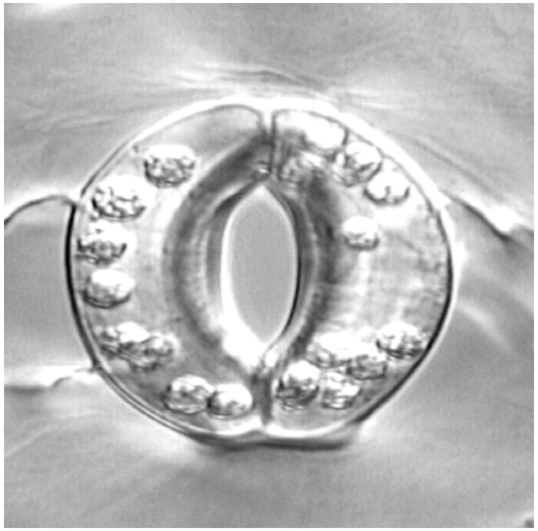
Species	Stomata per cm^2 Upper	Stomata per cm^2 Lower	Open Space, %
Pinus sylvestris	12,000	12,000	1.2
Larix decidua	1,400	1,600	0.15
Allium cepa	17,500	17,500	2.0
Zea mays	9,800	10,800	0.7
Tilia europea	—	37,000	0.9
Helianthus annuus	12,000	17,500	1.1
Vicia faba	6,500	7,500	1.0
Sedum spectabilis	2,800	3,500	0.32

Open pore area calculated by assuming 6 μm maximum aperture.

Data from Meidner and Mansfield (1968).

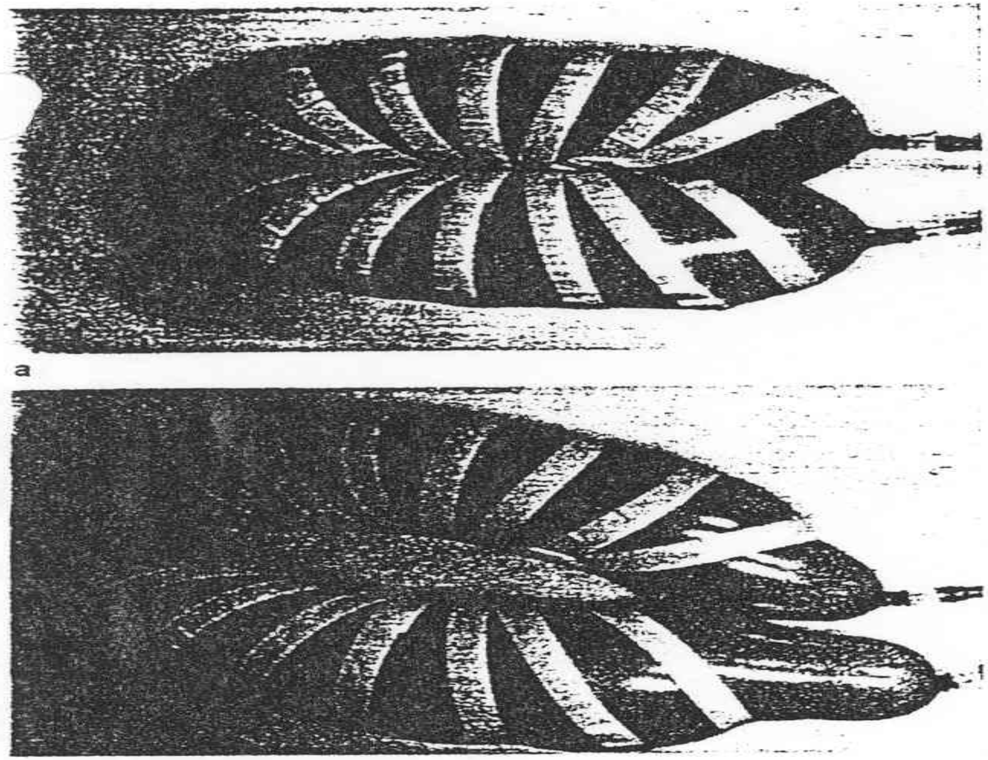
Physiology: Opening and closing

- Light receptors
- Movement of ions
- Turgor pressure changes: movement of water
- Evidence



Vicia faba

Guard cell opening

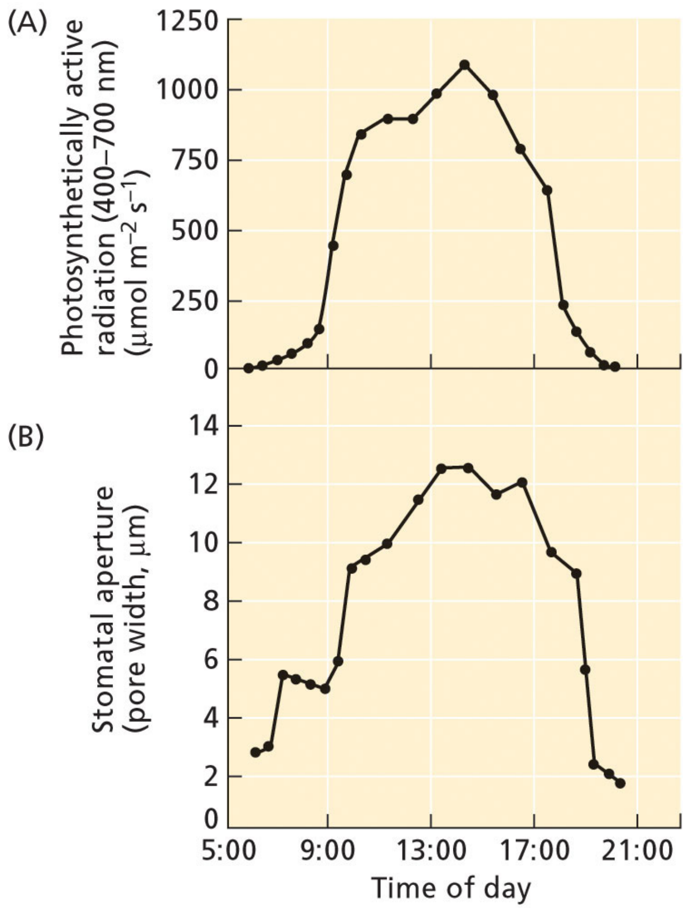


a

b

Figure 3-7 Two balloons representing a guard-cell pair. (**a**) Balloons in their "relaxed" state with masking tape applied represent both the "radial micellation" and the thickening long part of the ventral walls. (**b**) The balloon pair in an inflated state. Balloons were glued together at the ends with rubber cement before inflating (which weakened the rubber and caused eight pairs to burst when inflated before achieving success with the pair shown!).

Opening



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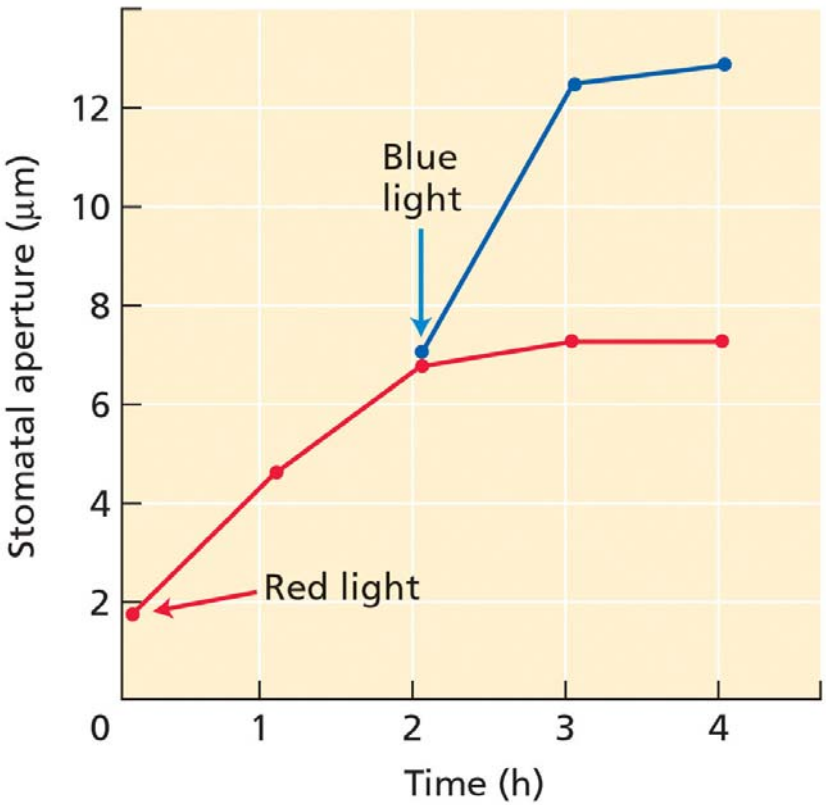

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Ion Exchange

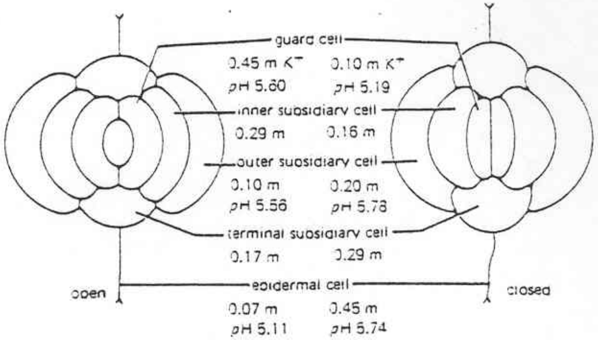


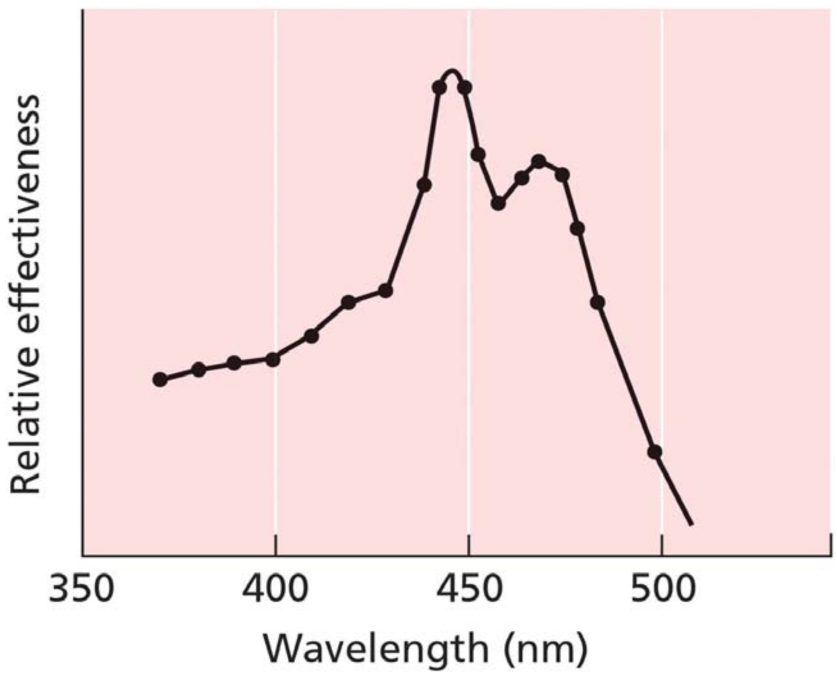
Figure 3-9 Quantitative changes in K^+ concentrations and *p*H values of the vacuoles in several cells making up the stomatal complex of *Commelina communis*. Values are given for the open and closed conditions of the stomatal pore. (Data of Penny and Bowling, 1974 and 1975.)

TABLE 5.3 Potassium content of open and closed guard cells.

	K^+ Content			
	pmol/Guard Cell		mM	
Species	Open	Closed	Open	Closed
Vicia faba	2.72	0.55	552	112
Commelina communis	3.1	0.4	448	95

Data from MacRobbie, 1987.

Blue Light Receptors



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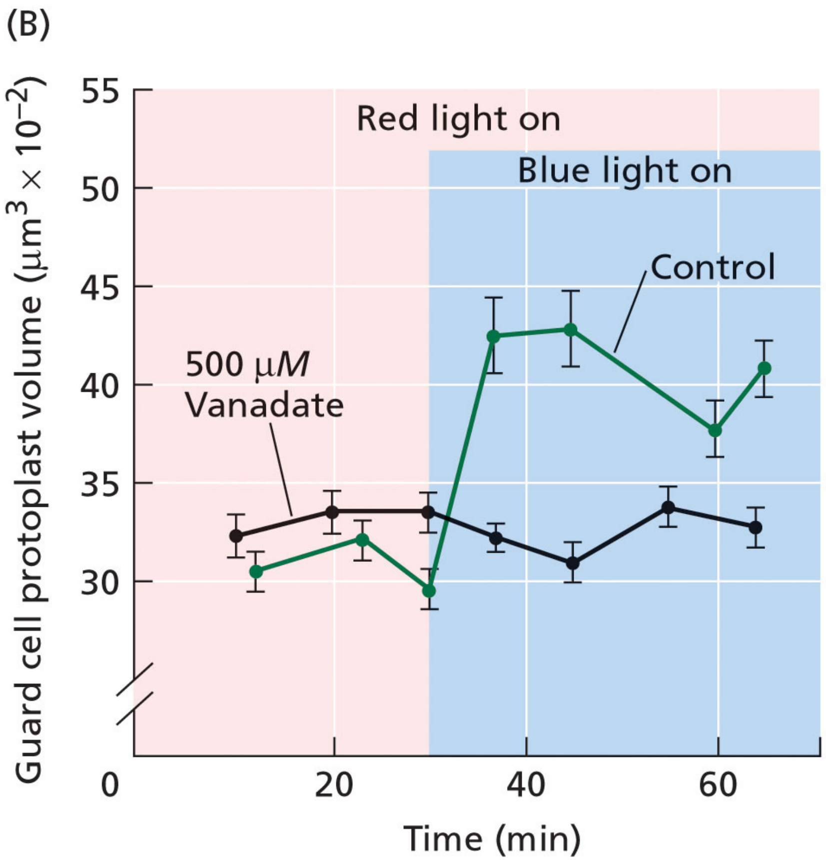

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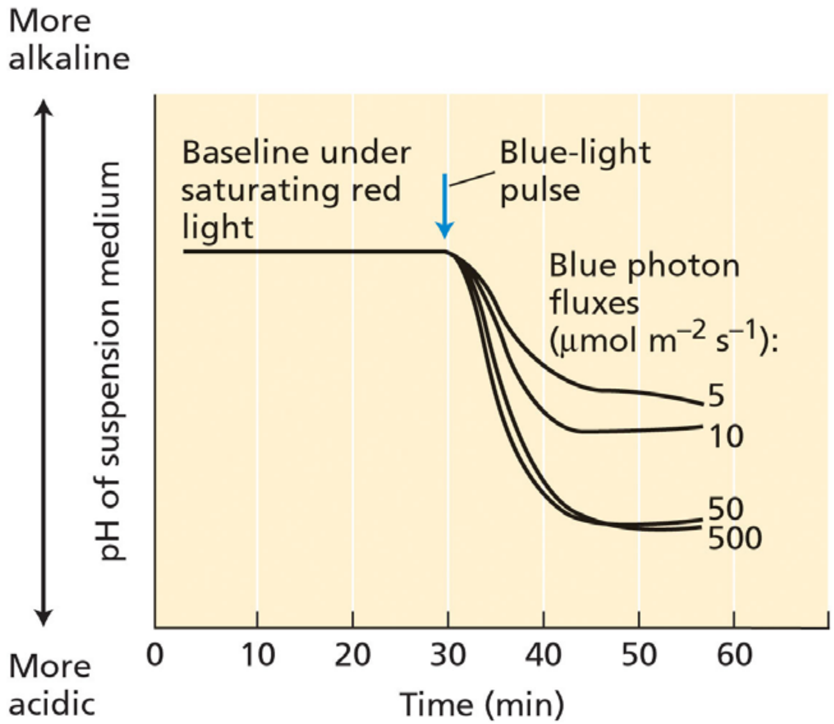
Proton Pump



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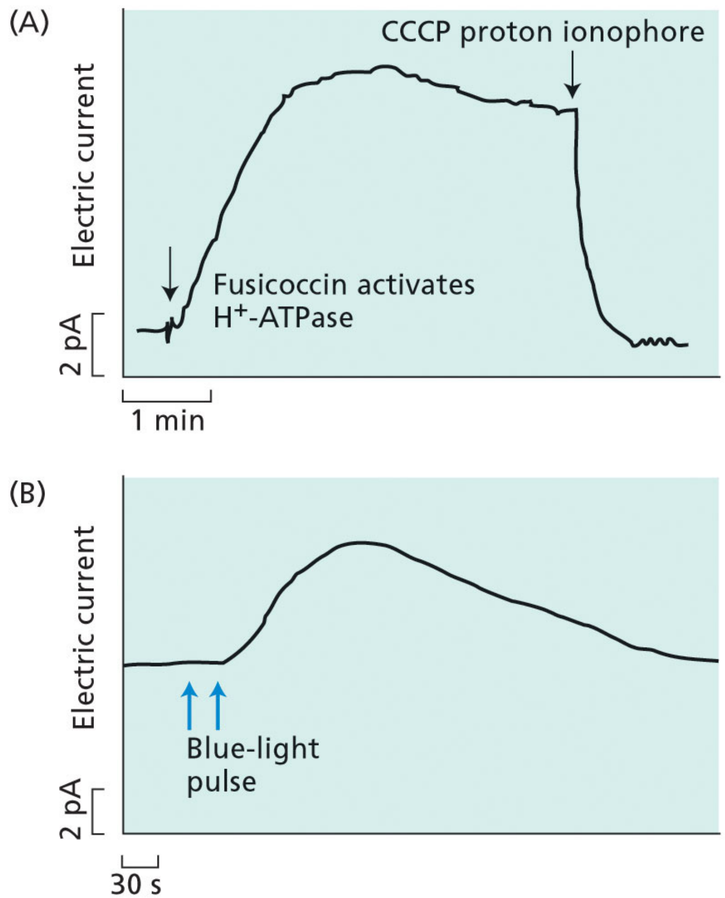

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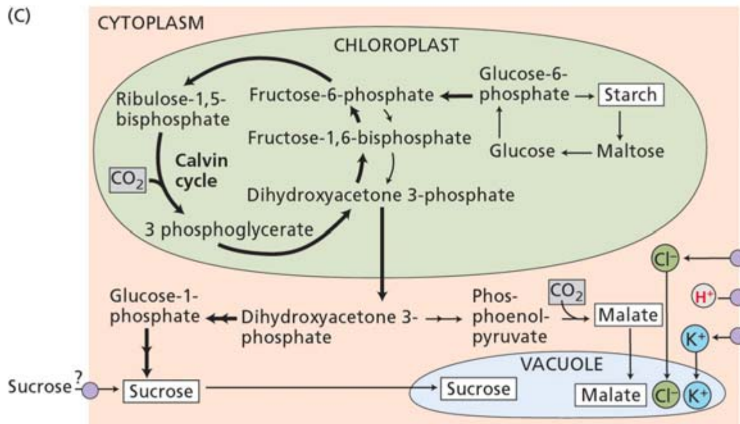
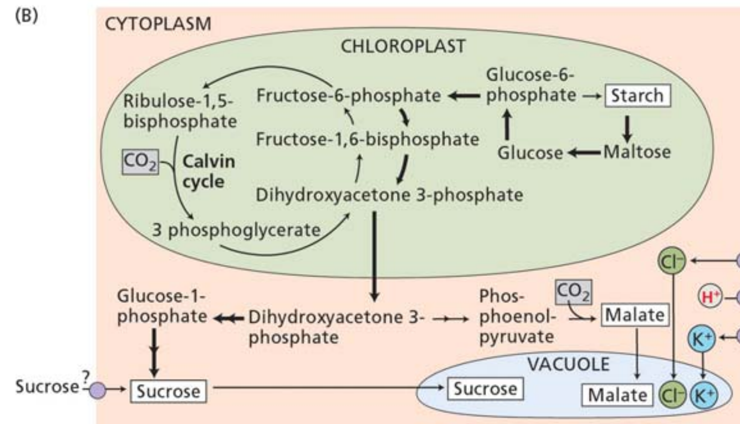
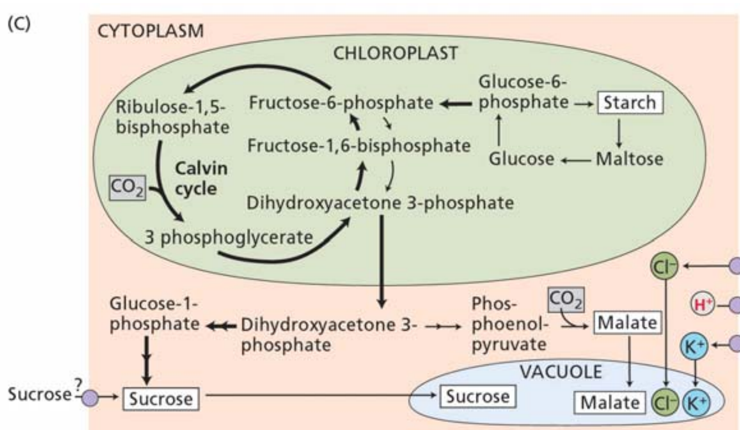
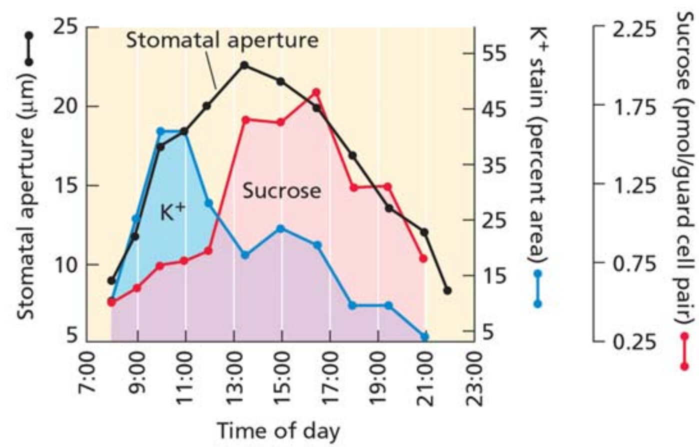
Osmotic Regulation

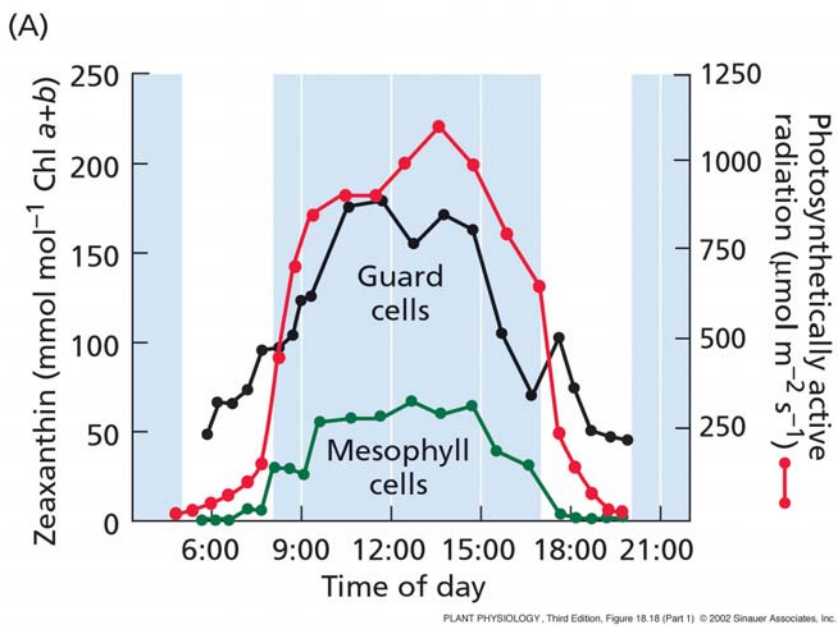








Receptor


(A)
Zeaxanthin (mmol mol−1 Chl a+b)
250
200
150
100
50
0
1250
1000
750
500
250
Photosynthetically active radiation (μmol m−2 s−1)
Guard cells
Mesophyll cells
6:00 9:00 12:00 15:00 18:00 21:00
Time of day
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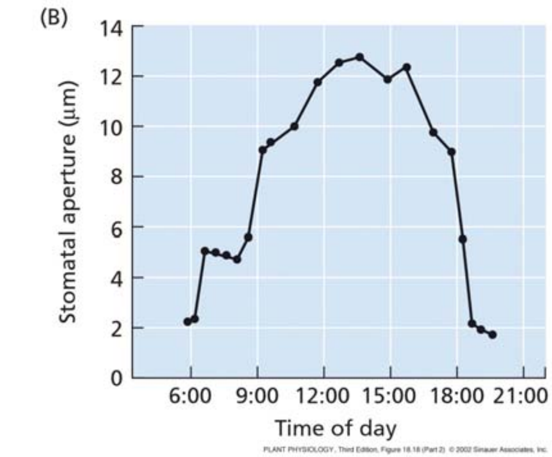
(B)
Stomatal aperture (μm)
14
12
10
8
6
4
2
0
6:00 9:00 12:00 15:00 18:00 21:00
Time of day
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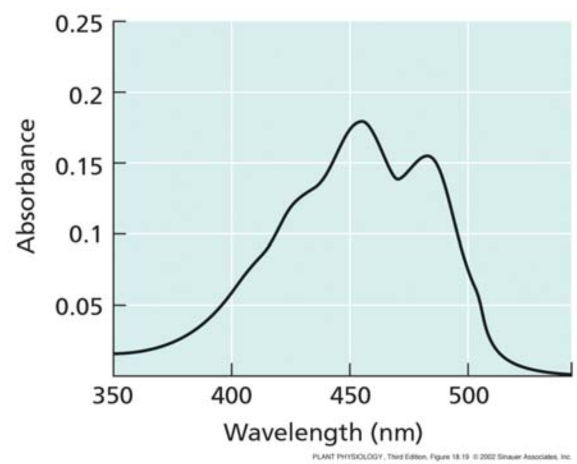
Absorbance
0.25
0.2
0.15
0.1
0.05
350 400 450 500
Wavelength (nm)
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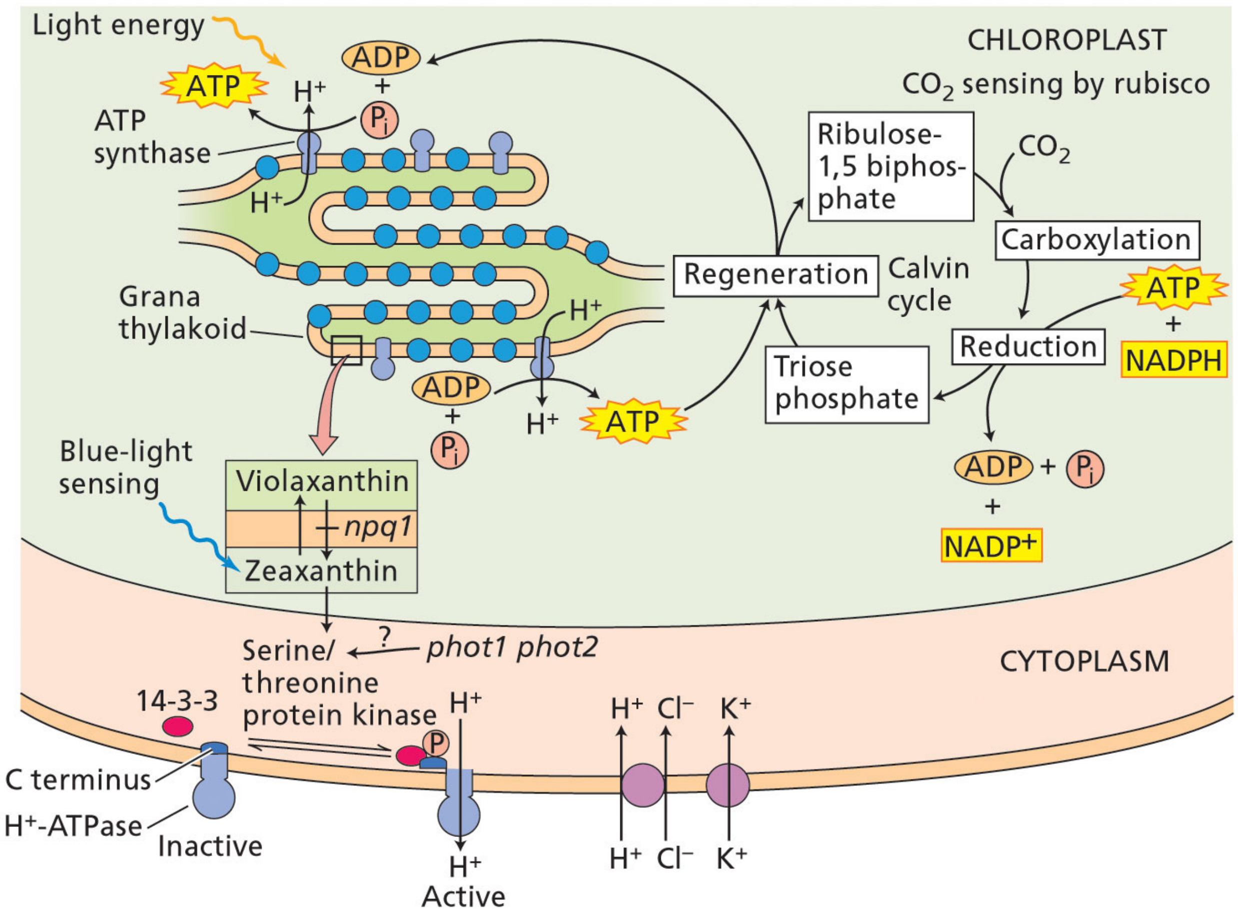
Signal pathway



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Diurnal curves of stomatal opening

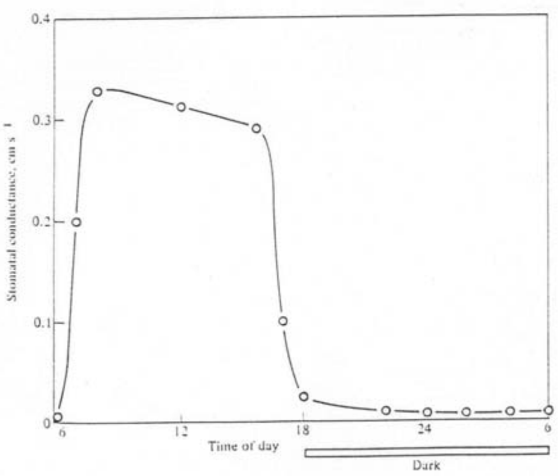

FIGURE 5.6 The diurnal curve of stomatal opening. The data are expressed as stomatal conductance (cm s^{-1}), an indication of the capacity for diffusion through stomata and an indirect measure of stomatal opening. The stomata open rapidly in the light and close at the end of the daylight period. Stomata remain closed throughout the dark period. The data are from *Peperomia*, and were obtained by the author in 1978 at the University of California, Riverside.

FIGURE 5.7 The diurnal curve of stomatal opening for a Crassulacean acid metabolism (CAM) succulent. The data are expressed as stomatal conductance (cm s^{-1}). Refer to Fig. 5.6. The data are from a cactus obtained by Dr.