Blue Light and Photomorphogenesis

Q:

1. How do we know plants respond to blue light?
2. What are the functions of multiple BL receptors?
3. How is BL signal received and then passed on to give final response(s)?

Figure 18.3 Blue light responses - phototropsim of growing Corn Coleoptile

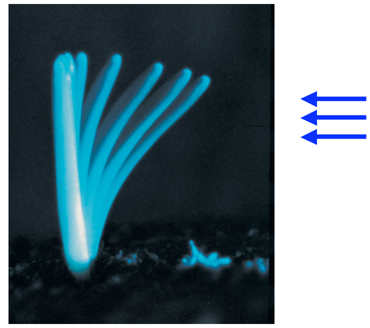


Figure 18.4 Phototropism: directional growth towards light in *Arabidopsis*

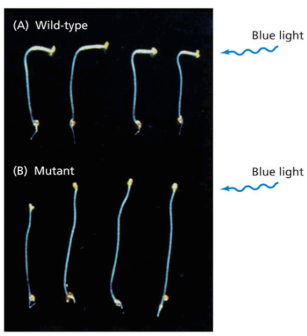


Figure 18.5 How do plants sense the direction of light? - light gradient affects auxin distribution

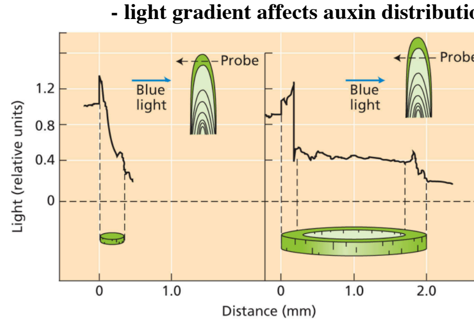
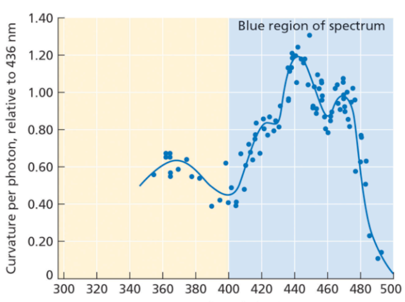


Figure 18.1 Blue-light stimulated phototropism

Receptors:

UV-A

Blue



Blue light Inhibits seedling hypocotyl elongation

Dark Blue

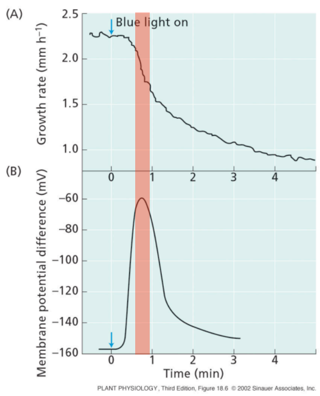


Figure 18.6

Q: How does blue light induce inhibition of growth?

Hypothesis: ion transport is altered.

Test: Measure membrane potential with an electrode

Result:
Figure 18.6 Blue light inhibited elongation of dark grown seedling is preceded by a membrane depolarization.

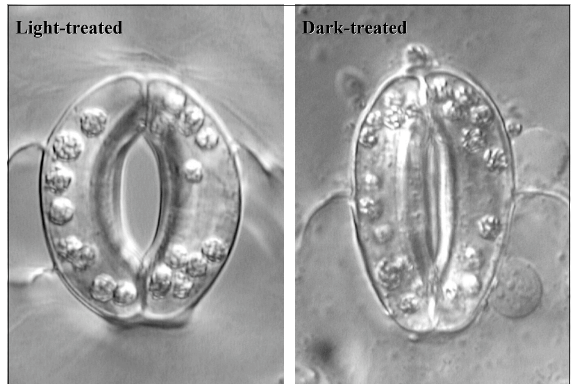


Figure 18.8 Light causes stomatal opening

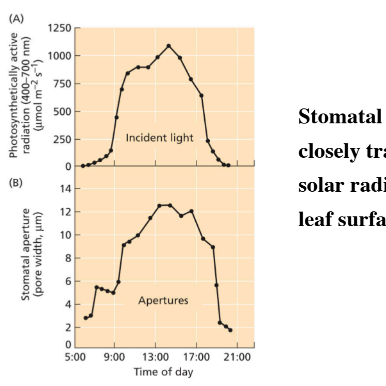


Figure 18.9

Stomatal movements closely track incident solar radiation at the leaf surface

Figure 18.10 Red and blue light stimulate stomatal opening

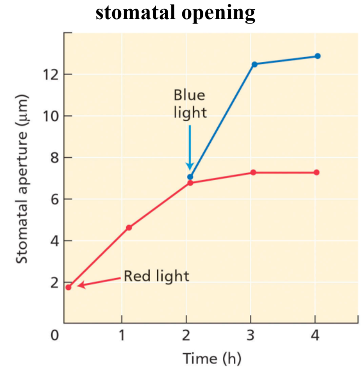
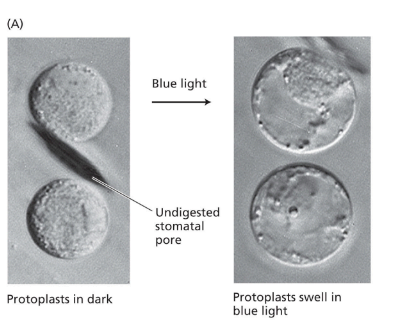


Figure 18.12 Blue light-stimulated swelling of guard cell protoplasts



Vanadate, an inhibitor of the H⁺-ATPase, inhibits the swell

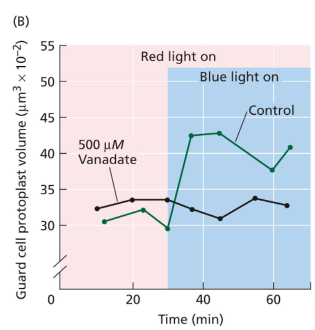


Figure 18.14 Blue light stimulates PM H+-pumping ATPase in guard cells

Patch clamp experiment

Whole cell protoplast.

Outward current

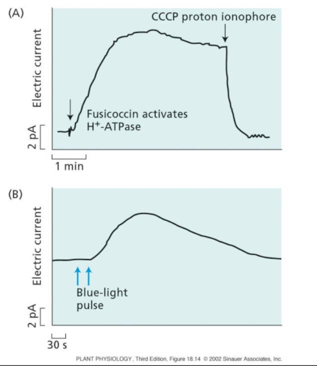
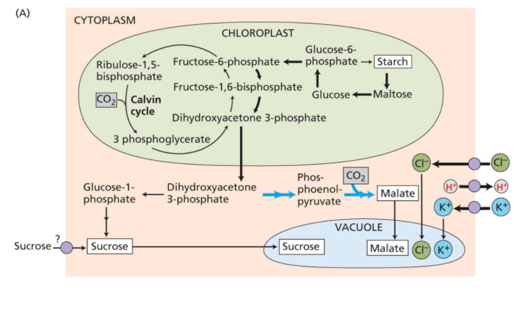
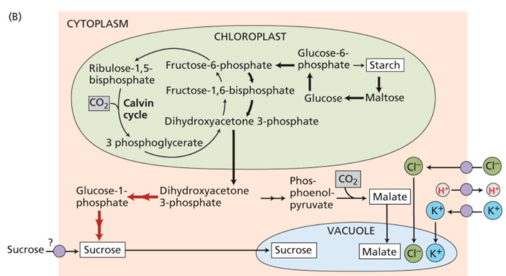


Figure 18.15 Osmoregulatory Pathways

a. Potassium and its counterions.



b. Accumulation of sucrose from starch hydrolysis.



c. Accumulation of sucrose from photosynthesis.

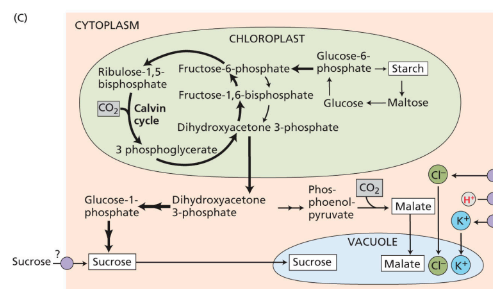
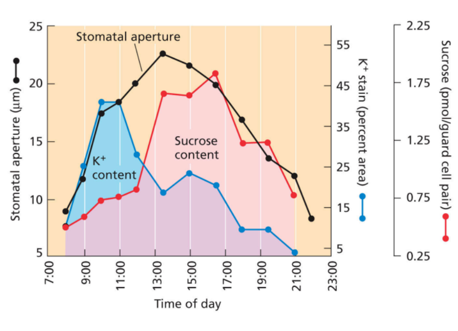


Figure 18.16 Changes in osmotic potential are required for stomatal opening



Arabidopsis NPL1: A Phototropin Homolog Controlling the Chloroplast High-Light Avoidance Response

Takatoshi Kagawa, et al 2001. Science

Chloroplasts move

Toward weak light

Away from strong light

Blue Light Receptors

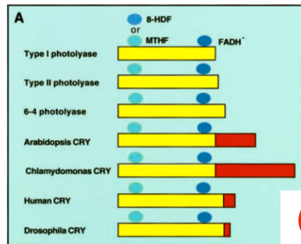
Cryptochromes: CRY1, CRY2, CRY3

- inhibit hypocotyl elongation
- promote cotyledon opening and expansion;
- promote anthocyanin accumulation
- set the circadian clock, flower induction
- Cryptochrome homologs regulate the circadian clock in *Drosophila, mouse and human.*

Phototropins: PHOT1 (NPH1), PHOT2

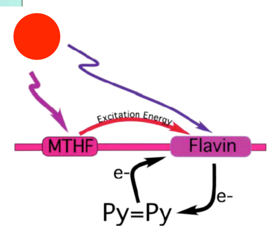
- mediate blue light-dependent phototropism and chloroplast movements
- PHOT1: low-intensity blue light (0.01-1 µmol $m^{-2}s^{-1}$)
- PHOT2: high-intensity blue light (1-10 µmol $m^{-2}s^{-1}$)

Carotenoid zeaxanthin - in guard cells , mediates stomatal opening



Mode of Action of Photolyase

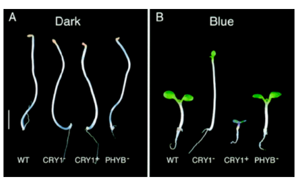
- Cashmore AR. Cell 2003.



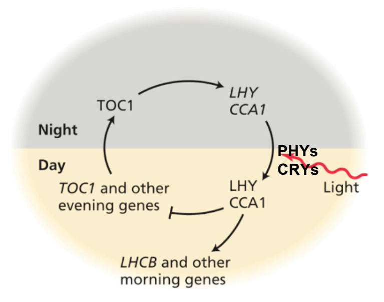
Cryptochromes and bacterial photolyases share the same conserved sequence and structure.

- Cashmore AR, *et al.* Science. 1999.

CRY1 is the predominant blue light receptor
-stable in the light



CRY2 is degraded in the light. Induce flowering.



UV Light and Photomorphogenesis

UVC	UVB	UVA
< 280 nm	280-320 nm	320-400 nm
Absorbed by ozone layer	environmental stress developmental signal	absorbed by blue light receptors

Receptor unknown

Approaches:

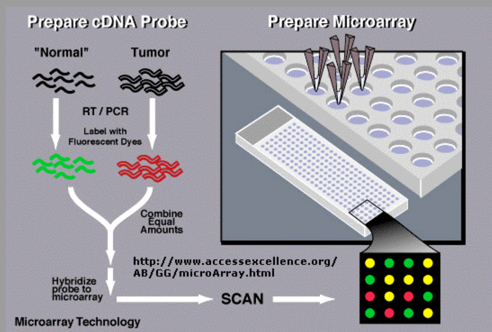
Genetic screen - mutagenesis
Transcriptome profiling - microarray

Mutagenesis

Mutagens: physical (X-rays, γ-rays, β-rays or UV);
chemical (ethylmethane sulfonate/EMS);
Biological (T-DNA of *Agrobacterium tumefaciens*)

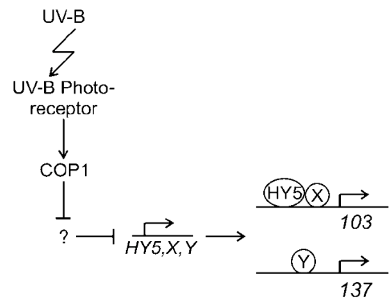
mutagen + seeds — M1 ⟶ M2 seeds
↓
screen mutant for

- Hypersensitivity: low intensity
- Insensitivity: high intensity



- from google images

Early function of COP1 and HY5 in UVB signaling.



- Oravecz, A. *et al.* The Plant Cell, 2006.

cop1 **mutants:**

Constitutive photomorphogenesis 1
-Short hypocotyls and opened cotyledons in both dark and light, except for chlorophyll synthesis happening only in light.

COP1 function:

In the dark: labels TFs with ubiquitin tags → protein degradation in 26S proteasome
With light: nucleus → cytosol, TFs are released and mediate photomorphogenesis related gene expression.

Summary:

1. **Plants growth and development is mainly regulated by light - R/FR and Blue.**
   Different light intensities induce different responses.
2. **Plants have several R/FR light receptors: Phytochromes**
   PHYA accumulates in dark as a stable Pr form, and is converted to Pfr by red light. Pfr is unstable.
   PHYB is stable, found in green plants, senses ratio of Pfr/total
3. **Plants have several Blue light receptors.**
4. **Many light-induced effects are controlled by both blue and red light**
5. **Responses due to light perception:**
   a). Change ion transport : pumps and channels
   b) Change/regulate gene expression
   Early response genes are most likely transcription factors
   Late response genes are specific target genes.

Q1: ***How do we know plants respond to blue light?***

(Action spectra)

Phototropism

Inhibition of hypocotyl elongation of seedlings

Stomatal opening

Q2: ***What are the functions of multiple BL receptors? (Slide 19)***

Q3: ***How is BL signal received and then passed on to give final responses?***

Quick response: to change the membrane potential.
Slow response: to regulate gene expression.