Photomorphogenesis

1. **Phytochrome can sense light changes during the day.**

2. Where is phytochrome located?
3. How can phytochrome sense and induce so many responses ?
There are multiple phytochromes: phy A, B, C, D, E

3. How can we identify the signaling intermediates?
a. Genetic approach. E.g. how do mutants behave? det2, cop1
b. Cell Biol.-measure changes in [Ca], electrical potentials
c. Biochem. Changes in enzyme activity, metabolites (kinase, pase, lipase)
d. Molecular: changes in target gene expression
e. Combination of all methods

4. Model: mode of action.

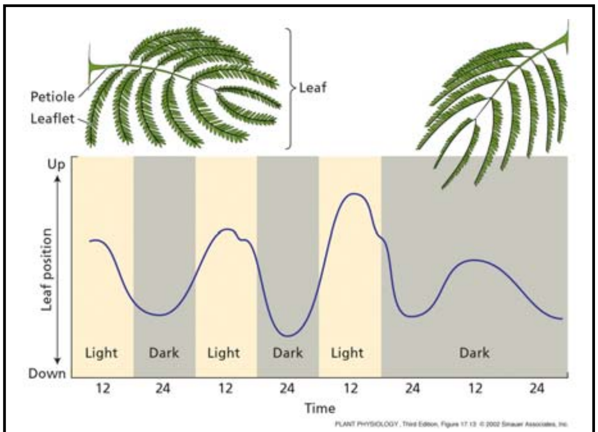
a. Change ion flux
b. Regulate metabolic pathway
c. Change cytoskeleton
d. Regulate gene expression

5. **Blue light-induced responses**
a. E.g.: Phototropism, inhibition of hypocotyl elongation, guard cell movement
b. Several receptors act to mediate different responses

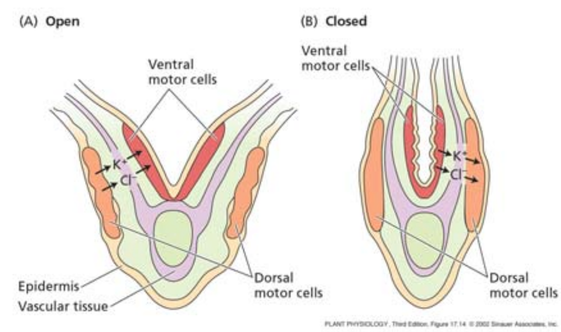
Table 17-3 Taiz. Phytochrome can sense light changes and enable plant to adapt to changes.

	($\mu mol/m^2/s^{-1}$) Photon flux density	**R/FR**
Unfiltered daylight	1900	1.19
Canopy filtered light	18	0.2-0.3 green leaves absorb R
Sunset	26	0.96
Moonlight	0.005	0.94
Soil (0.5 cm below)	8.6	0.88
Lakes: 1 m	300-1200	1.2 , 3.1

a. Photon (light energy)- quantity
b. Shade vs. sunlight
c. dawn, noon, dusk changes: rhythms



17-14. Leaf movement results from turgor changes in ventral and dorsal cells. Light alters ion fluxes.

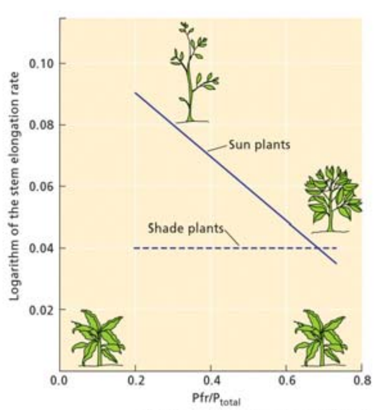


17-11. Sun plants can sense shade versus sunlight.

How?

Why?

Ratio of Pr/Pfr



Mode of Action

How is light sensed and how is that signal transduced to give the final response?

How can one identify receptors and signaling intermediates ?

1. **Cell Biology/physiol.**: morphology, growth changes, ion flux

2. **Biochemical**: protein level, enzyme activity changes. e.g. kinase, pase

3. **Genetic Approach (powerful)**:

•Find **mutants** that do not respond to R or FR.
E.g. hy1-6 suggests these gene products play a role in signaling

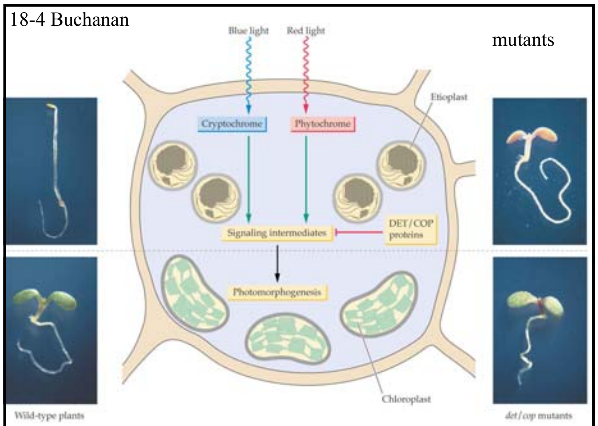
•Find **mutants** that are constitutively in "light-grown" form. Cop, det

•Overexpress components of pathway.

A [Receptor] --> B ---> C ---> D ----> E ----> F Response

18-4 Buchanan

mutants



Det2 mutant cannot synthesize BR hormone which stimulates cell elongation

Etiolation is a result of cell elongation. (long hypocotyl)

BR (Brassinosteroid), a hormone, stimulates cell elongation.

If synthesis of BR is blocked, then cells do not elongate.

Det2 has a mutation in an enzyme required for BR synthesis.

Suggest: Dark somehow enhances BR synthesis.

Light inhibits BR synthesis.

Box 17-4. Taiz. Det2 encodes enzyme needed for Brassinosteroid {BR} synthesis

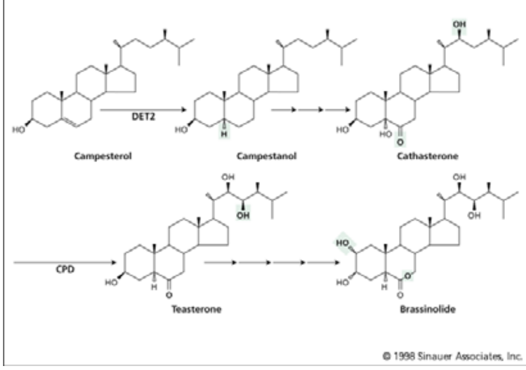
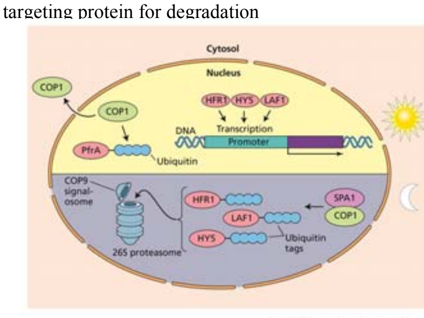
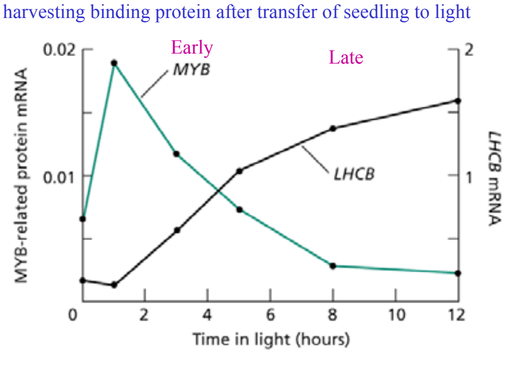


Fig 17-15. Taiz. COP1 represses expression of light-regulated genes by targeting protein for degradation



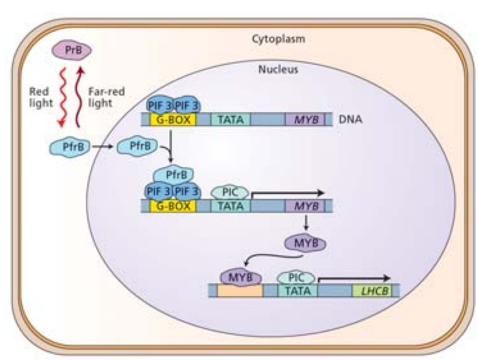
Cop1 = E3 Ubiquitin Ligase that targets proteins (Hy5) for degradation
Hy5 is a TF that binds to light-inducible promoters.
In Dark, COP1 targets Hy5 for degradation.
In light, COP1 leaves the nucleus. Hy5 binds and activates light-regulated genes.

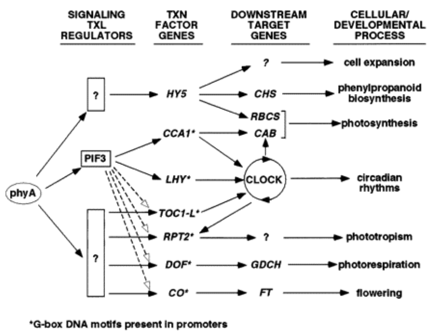
17-18. Taiz. Induction of mRNA for Myb and Light-harvesting binding protein after transfer of seedling to light



17-20. PhyB directly regulates gene expression in nucleus

PIF3 is a master TF = [master switch]





Master TF regulate multiple TF

Fig. 4. Simplified schematic of postulated phyA-regulated transcriptional network. It is proposed that the phyA-regulated transcription (TXN)-factor genes identified here are primary targets of phyA signaling via "signaling transcriptional (TXL) regulators" constitutively present before light signal perception, and that these TXN-factor genes encode a master set of regulators, each of which regulates one or more major branches of cellular or developmental activity by controlling the expression of specific downstream target genes. (Tepperman et al 2001 PNAS)

Summary- mode of action

1. Plant growth and developments is regulated by light.
2. Phytochrome is an important photoreceptor.
   Phy A: Pr -->Pfr
   Phy B is stable; senses P_{fr}/P_{total}
3. Mode of action
   a. Fast responses- changes in ion fluxes
   [no gene expression;
   activated by protein modification

b. Changes in gene expression
   Early response genes: 1-5 min after stimuli
   mostly TF

   late response genes: seen later 3-10 min

Blue light induced responses

(see "Plants in Motion" by Roger Hangarter)

1. How do we know plants respond to blue light?
2. What responses do blue light induce? Action spectra

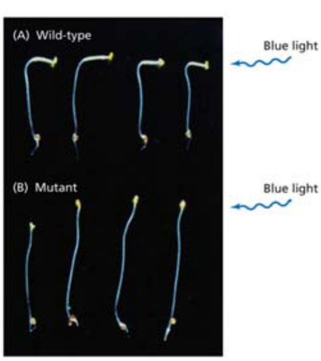
   Phototropism
   Inhibits hypocotyl elongation of seedling
   Induces stomatal opening
   Sleep movements of leaflets in Samanea

3. What is the identity of BL receptor?
What are the functions of multiple BL receptors?

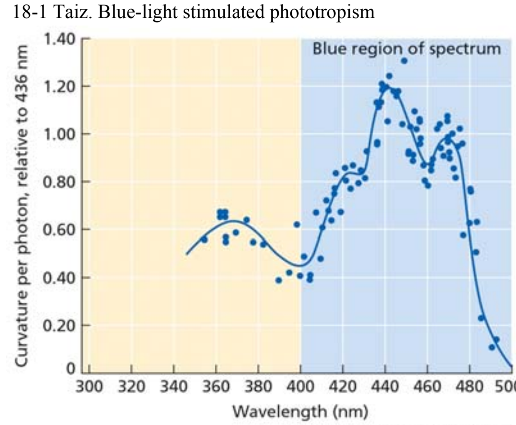
4. How is BL signal received and then passed on to give a final response(s)?

Blue light responses

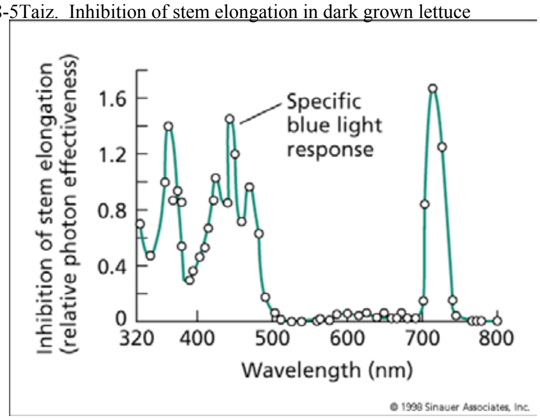
Phototropism: directional growth towards light

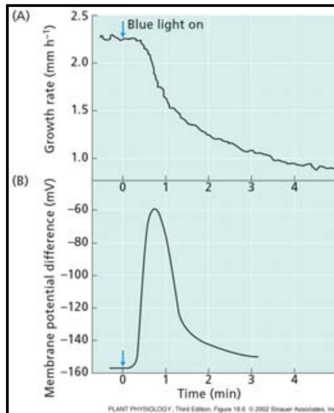


18-1 Taiz. Blue-light stimulated phototropism



18-5Taiz. Inhibition of stem elongation in dark grown lettuce





?? How does blue light induce inhibition of growth?

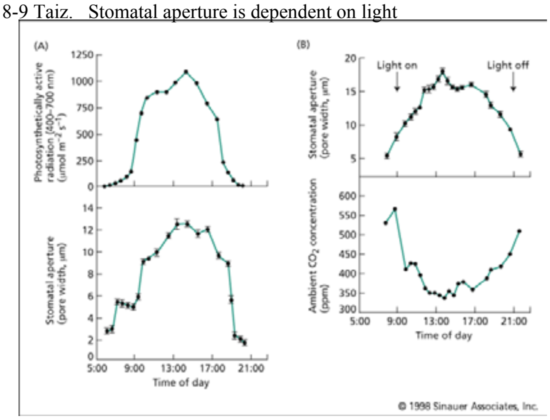
Hypothesis: ion transport is altered.

Test: Measure membrane potential with an electrode

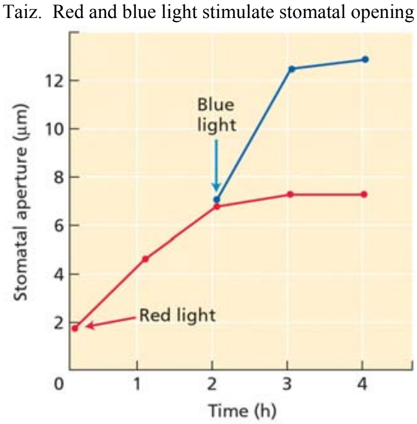
Result:
18-6 Taiz. Blue light inhibited elongation of dark grown seedling is preceded by a membrane depolarization.

Light causes stomatal opening

18-9 Taiz. Stomatal aperture is dependent on light

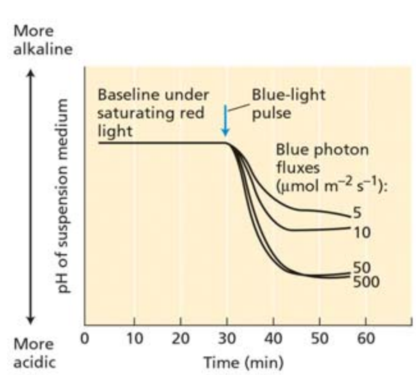


18-10 Taiz. Red and blue light stimulate stomatal opening



18-13. Taiz. How does blue light cause stomatal opening?

Blue light increase acidity of medium with guard cell protoplast.



?? interpret

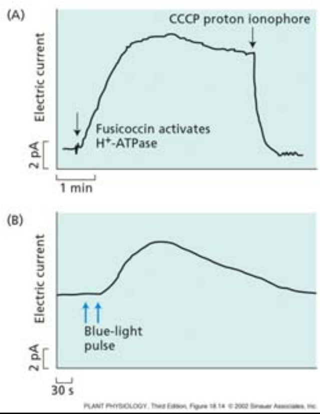
18-16. Taiz. Blue light stimulates PM H+-pumping ATPase in guard cells

patch clamp

Whole cell protoplast.

Outward current

Why and how?



What are BL receptors?

Several Blue Light Receptors have been identified:

Different receptors affect different responses

Cry1: photolyase inhibit stem elongation

Cry2 cotyledon expansion, clock, flower induction

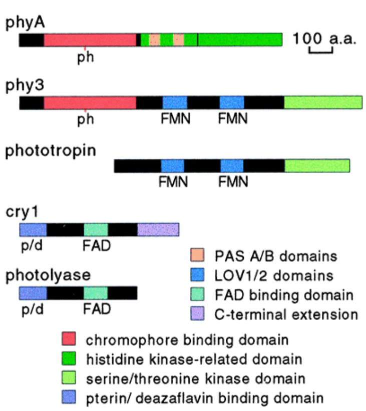
Nph1 or Phot1: PM protein phototropism

NPL1 or Phot2: chloroplast, high light avoidance response.

Flavins

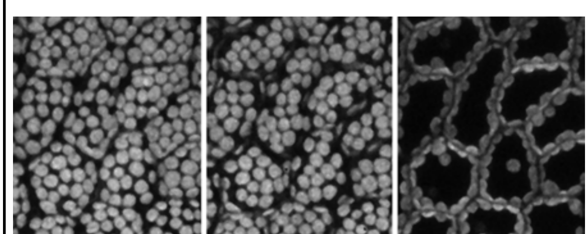
Carotenoids

Cryptochromes found in retina of mammals have role in circadian rhythm



Domain organization of the three classes of known plant photoreceptors and a typical prokaryotic photolyase.
PhyA, Arabidopsis phytochrome A; Phy3, Adiantum capillus-veneris phy3; Phototropin, Arabidopsis phototropin (nph1);
Cry1, Arabidopsis cry1.
Chromophores: ph, phytochromobilin; FMN; FAD; d, deazaflavin; p, pterin.
[from Briggs + Olney, 2001, Jan. Pl Physiol

Fig 9-5. Chloroplasts of duckweed



Dark Weak Blue Blue strong

Summary:
1. Plants growth and development is regulated by light. Red and Blue. Different intensities of light induce different responses.

2. Plants have several red light receptors: **Phytochrome**
Phy A accumulates in dark as a stable Pr form, and is converted to Pfr by red light. Pfr is considered the active form and is unstable
Phy B 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 : pump and channel
b) Change/regulate gene expression
Early response genes are most likely **transcription factors**
Late response genes are specific target genes.

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

Takatoshi Kagawa, et al 2001. Science

Chloroplasts relocate their positions in a cell in response to the intensity of incident light, moving to the side wall of the cell to avoid strong light, but gathering at the front face under weak light to maximize light interception. Here, Arabidopsis thaliana mutants defective in the avoidance response were isolated, and the mutated gene was identified as NPL1 (NPH-like 1), a homolog of NPH1 (nonphototropic hypocotyl 1), a blue light receptor used in phototropism. Hence, NPL1 is likely a blue light receptor regulating the avoidance response under strong light.