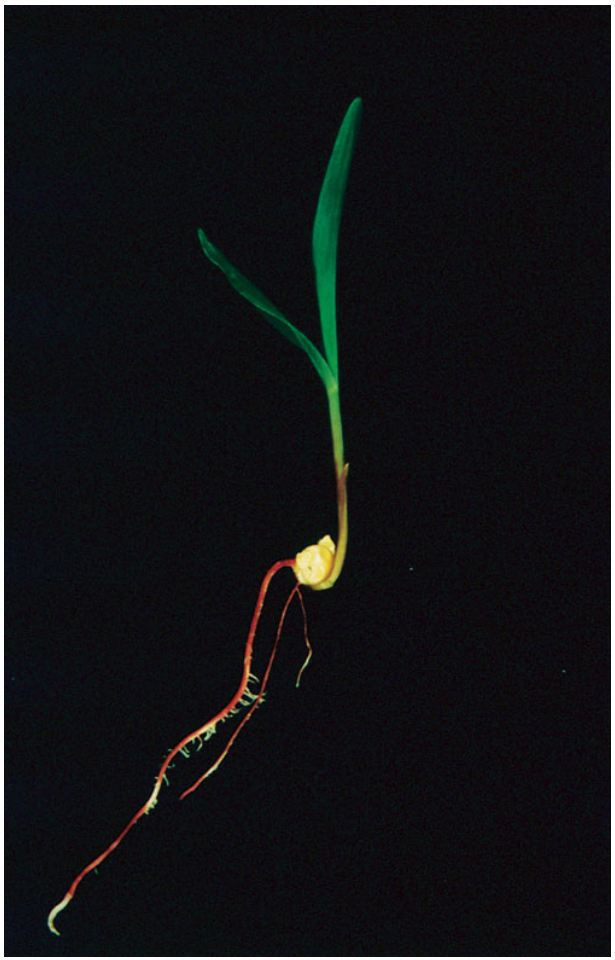
Phytochrome

- Overview of photomorphogenesis
- Chemistry
- Phytochrome responses
- Mode of Action

TABLE 17.2
Some plant photomorphogenic responses induced by high irradiances

Synthesis of anthocyanin in various dicot seedings and in apple skin segments
Inhibition of hypocotyl elongation in mustard, lettuce, and petunia seedlings
Induction of flowering in henbane (*Hyoscyamus*)
Plumular hook opening in lettuce
Enlargement of cotyledons in mustard
Production of ethylene in sorghum

Photomorphogenesis

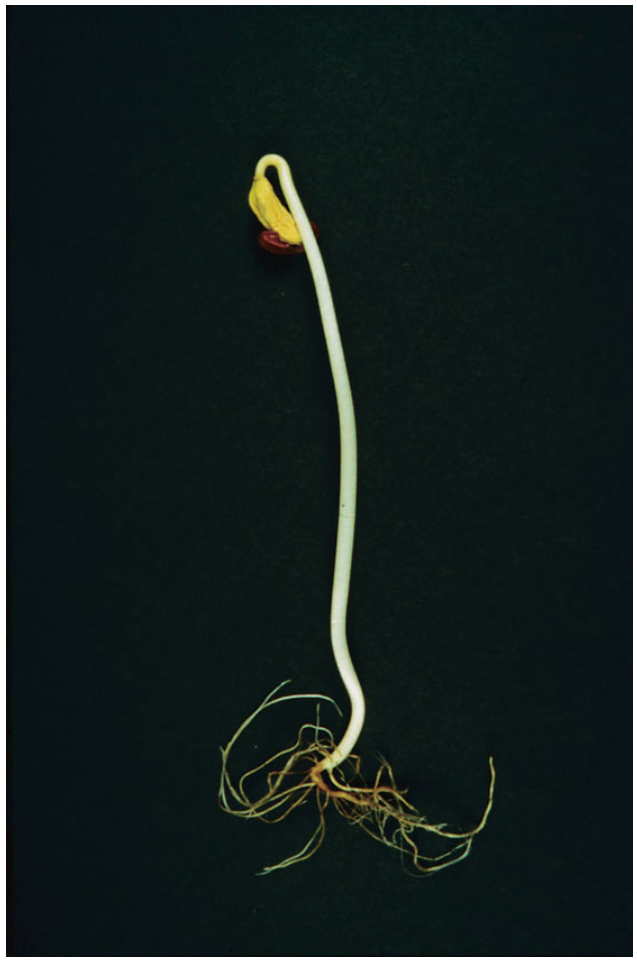


Light grown corn

Dark grown corn

Photomorphogenesis

Light grown bean



Dark grown bean

Photoreversibility

TABLE 17.1 Photoreversible control of germination. Lettuce seeds were imbibed for 3 hours prior to irradiations. Irradiation times were: red, 1 min; Fr, 3 min. Germination was scored after 48 h in darkness at 20 °C.

Irradiations	Germination (%)
R	88
R, Fr	22
R, Fr, R	84
R, Fr, R, Fr	18
R, Fr, R, Fr, R	72
R, Fr, R, Fr, R, Fr	22

Data from a student experiment.

- studied in flowering/seed germination
- photoreversible phenomena
- shown that they all had same action spectra

Lettuce Seed Germination

Dark

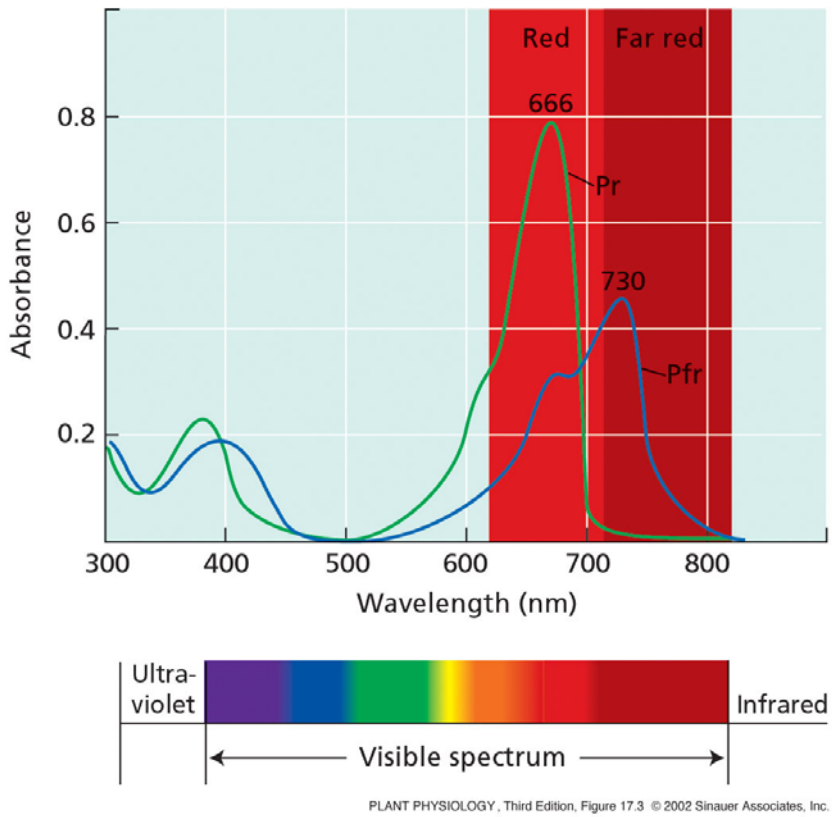
Red

Red-Far Red

Red-Far Red-Red

Phytochrome

- P_{660}/P_{730}
- red/far red absorbance
- peaks in red and blue
- studied by difference spectra
- reach photoequilibrium because of overlap of spectrum
- 85% red/15% far red



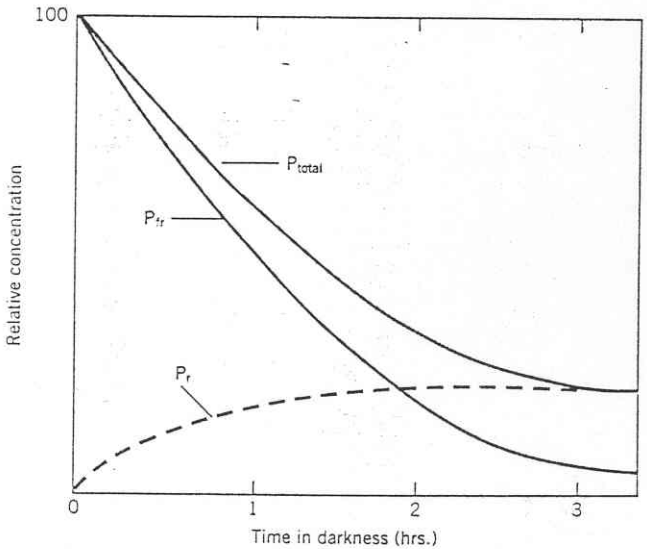


FIGURE 17.4 Typical photochrome transformations in etiolated seedling tissue. Dark-grown tissue is given a short exposure to low fluence red light at time 0, then monitored spectrophotometrically for total pigment and Pfr in the ensuring dark period. Pr is calculated as the difference.

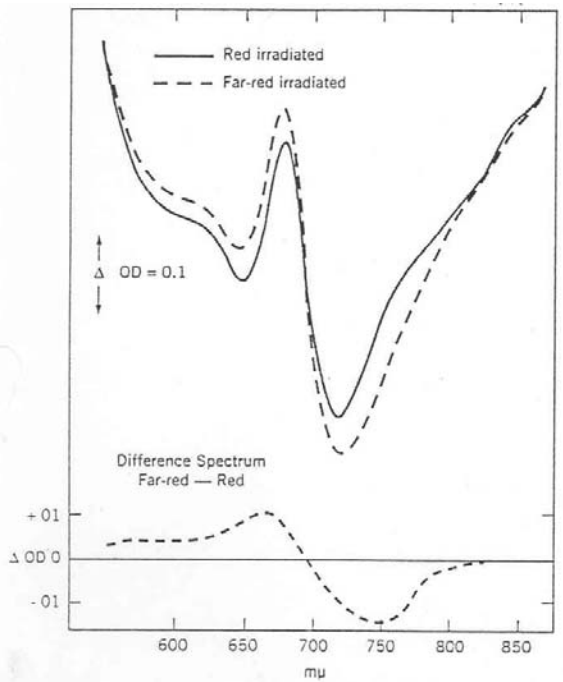
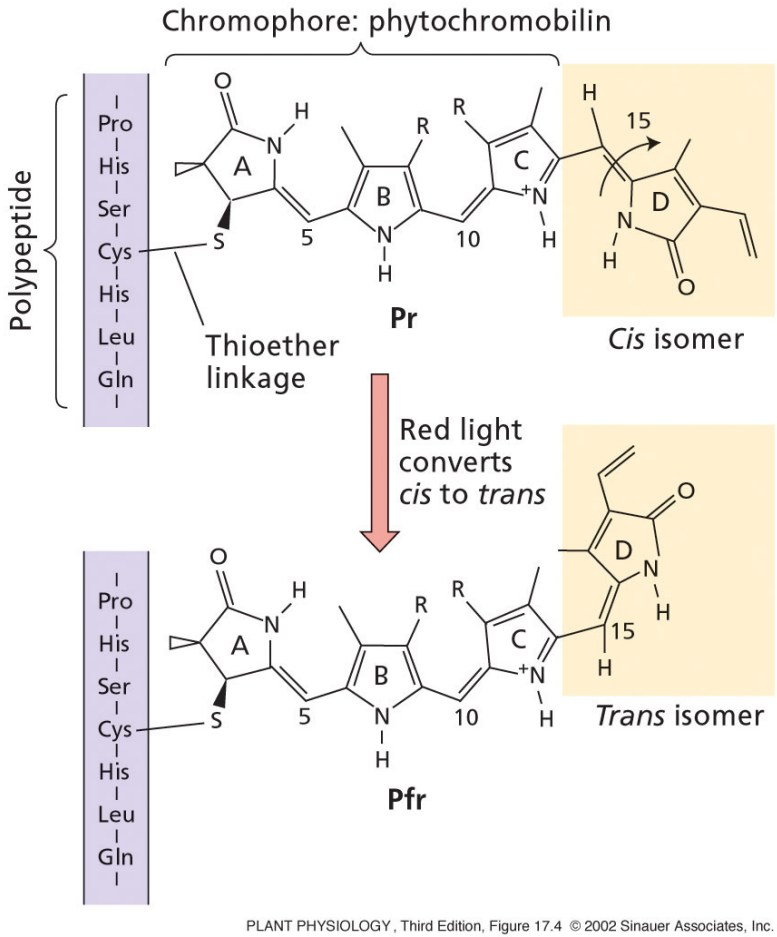


FIGURE 17.2 Absorbance curves for maize shoots following red or far-red irradiations. Note that these curves represent the absorbance of whole tissue, not just the pigment. Note also that conversion of the pigment from Pfr (solid curve) to Pr (dashed curve) causes an increase in absorbance in the red and a decrease in the far-red regions of the spectrum. The difference spectrum effectively represents the absorption spectrum of the Pr form. (From W. Butler et al., *Proceedings of the National Academy of Sciences USA* 45:1703–1708, 1959. Reprinted by permission.)

Phytochrome

- protein
- chromophore: open chain tetrapyrrole
- dimer



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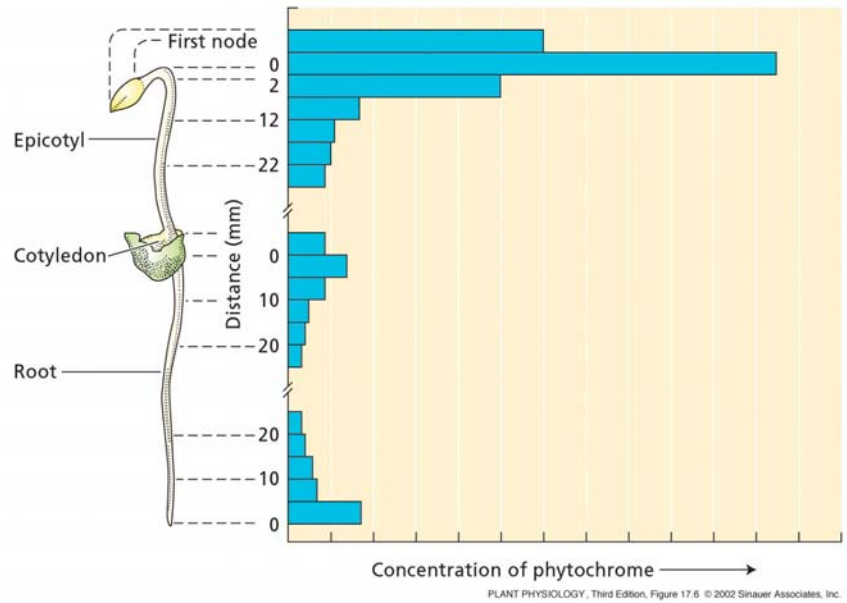
Expression in Different tissues

- highest levels in hypocotyl region/root



Multi-gene family

- phytochrome A in etiolated plants
- phytochrome B light grown plants
- 5 genes

Phytochrome responses

- angiosperms and gymnosperms
- seed germination
- hypocotyl hook opening
- internode extension
- photoperiodism
- flower induction
- anthocyanin synthesis
- bud dormancy
- sun/shade plant responses in natural settings

TABLE 17.1
Typical photoreversible responses induced by phytochrome in a variety of higher and lower plants

Group	Genus	Stage of development	Effect of red light
Angiosperms	*Lactuca* (lettuce)	Seed	Promotes germination
	Avena (oat)	Seedling (etiolated)	Promotes de-etiolation (e.g., leaf unrolling)
	Sinapis (mustard)	Seedling	Promotes formation of leaf primordia, development of primary leaves, and production of anthocyanin
	Pisum (pea)	Adult	Inhibits internode elongation
	Xanthium (cocklebur)	Adult	Inhibits flowering (photoperiodic response)
Gymnosperms	*Pinus* (pine)	Seedling	Enhances rate of chlorophyll accumulation
Pteridophytes	*Onoclea* (sensitive fern)	Young gametophyte	Promotes growth
Bryophytes	*Polytrichum* (moss)	Germling	Promotes replication of plastids
Chlorophytes	*Mougeotia* (alga)	Mature gametophyte	Promotes orientation of chloroplasts to directional dim light

Mode of Action

- synthesized in Pr form which is inactive
- Pfr biologically active form
- red causes change to Pfr form
- causes response
- far red burst will reverse the response

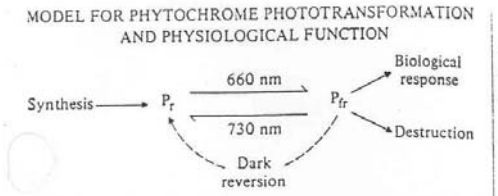


FIGURE 20.5 Simplified model to show the phototransformation of phytochrome and physiological function. The P_r form is the form that is synthesized. Red light (660 nm) converts the P_r form to the P_{fr} form, and far-red light converts the P_{fr} form to the P_r form. In dicots the P_{fr} form can revert back to the P_r form in the dark. The P_{fr} form is considered to be the active form and either brings about the physiological response or is inactivated by metabolic destruction.

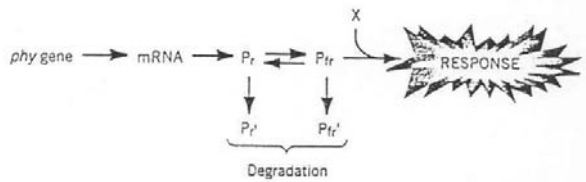
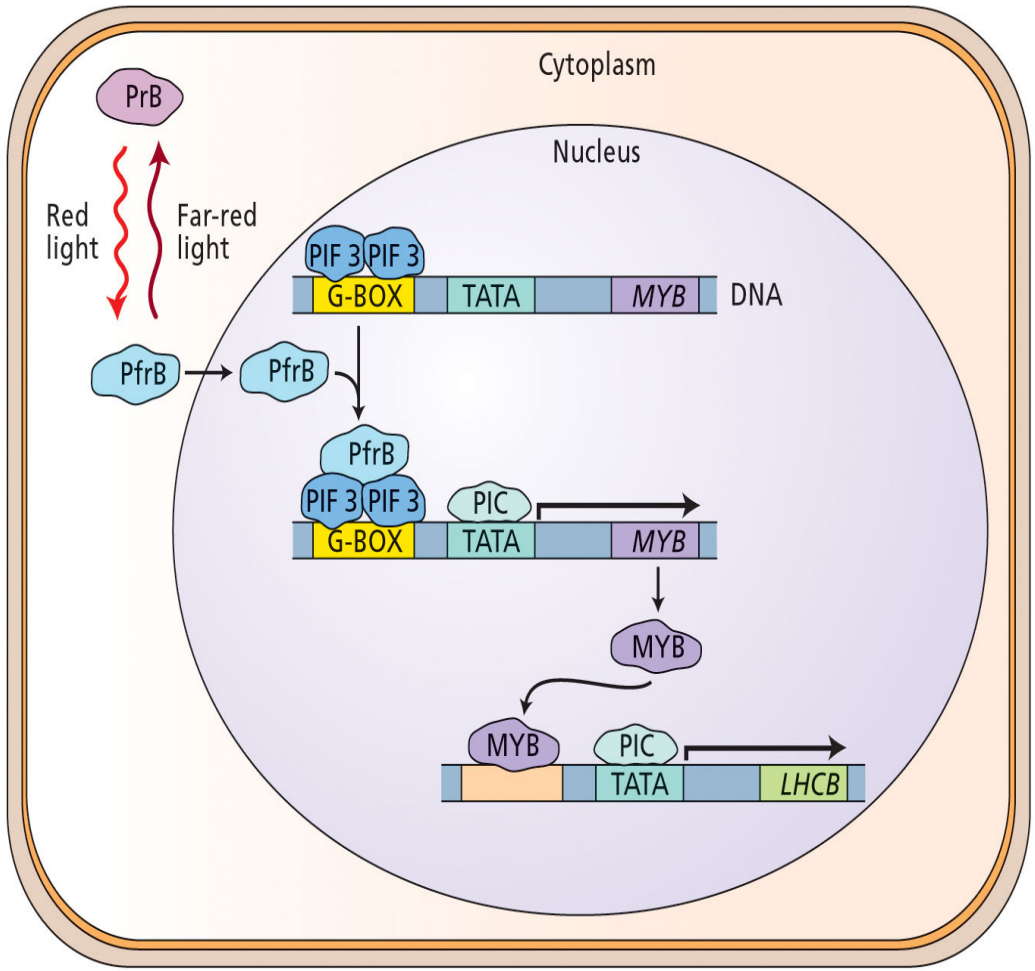


FIGURE 17.5 The photochrome system. The pigment is synthesized as the physiologically inactive red-absorbing form (Pr), which accumulates in dark-grown seedlings. Red light (660 nm) drives a phototransformation to the far red-absorbing form (Pfr). Absorption of far red light (735 nm) returns the pigment to the Pr form. Pfr, the active form, enters into some unknown reaction (X) to give a response. Pr′ and Pfr′ represent inactive degradation products of Pr and Pfr, respectively.

Transduction Pathway

- found in cytoplasm then aggregates when hit with far red light
- receptor protein
- moves to nucleus
- binds to DNA
- activate LRE
- upregulate transcription of genes
  - examples
  - small sub-unit of rubisco
  - cab genes
- downregulate
  - phytochrome genes



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Activation of genes

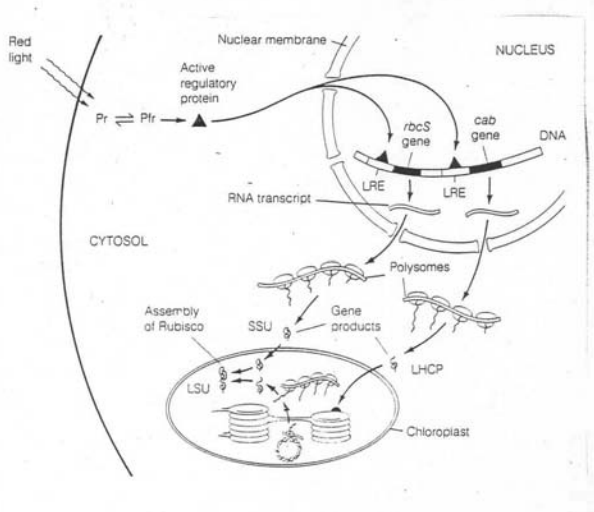

FIGURE 20.18. Model for phytochrome regulation of *rbcS* and *cab* genes. Red light converts to Pr to Pfr, initiating a sequence of biochemical events that leads to the activation of one or more regulatory proteins in the cytosol. The regulatory proteins migrate to the nucleus, where they bind to specific light-regulated elements (LREs) in the promoter region of the *rbcS* and *cab* genes. Transcription is stimulated, leading to enhanced synthesis of the gene products, the small subunit (SSU) of Rubisco and the light harvesting chlorophyll *a*/*b* protein (LHCP). These proteins contain transit peptides that facilitate their entry into the chloroplast. Once inside the chloroplast, SSU combines with LSU (the large subunit of Rubisco) to form the holoenzyme. LHCP is incorporated into photosystem II on the thylakoid membrane. (Adapted from Schäfer et al., 1986.)

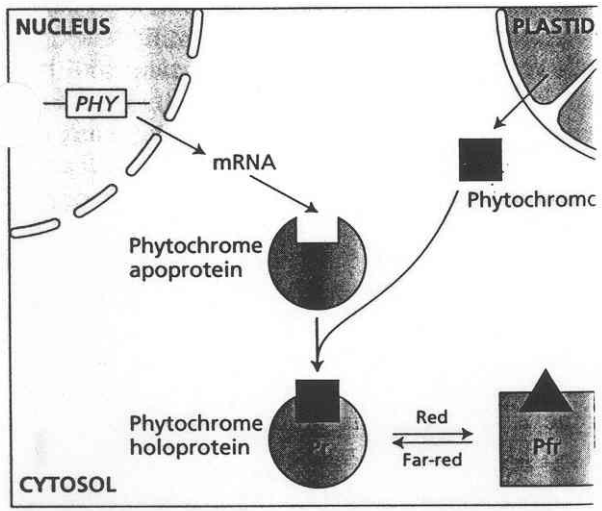

Figure 17.6 Phytochromobilin is synthesized in plastic released into the cytosol, where it assembles with the tochrome apoprotein. (After Kendrick et al. 1997.)

Sun-Shade plants

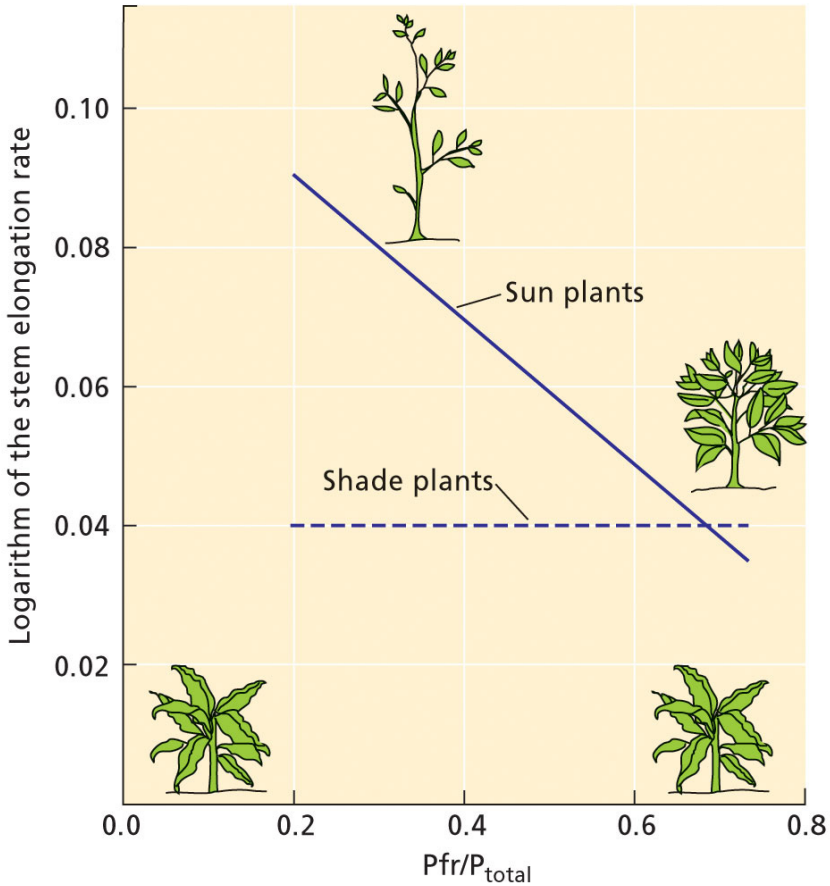

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TABLE 17.3
Ecologically important light parameters

	Photon flux density ($\mu mol\ m^{-2}\ s^{-1}$)	R/FR[a]
Daylight	1900	1.19
Sunset	26.5	0.96
Moonlight	0.005	0.94
Ivy canopy	17.7	0.13
Lakes, at a depth of 1 m		
Black Loch	680	17.2
Loch Leven	300	3.1
Loch Borralie	1200	1.2
Soil, at a depth of 5 mm	8.6	0.88

Source: Smith 1982, p. 493.

Note: The light intensity factor (400–800 nm) is given as the photon flux density, and phytochrome-active light is given as the R:FR ratio.

[a]Absolute values taken from spectroradiometer scans; the values should be taken to indicate the relationships between the various natural conditions and not as actual environmental means.

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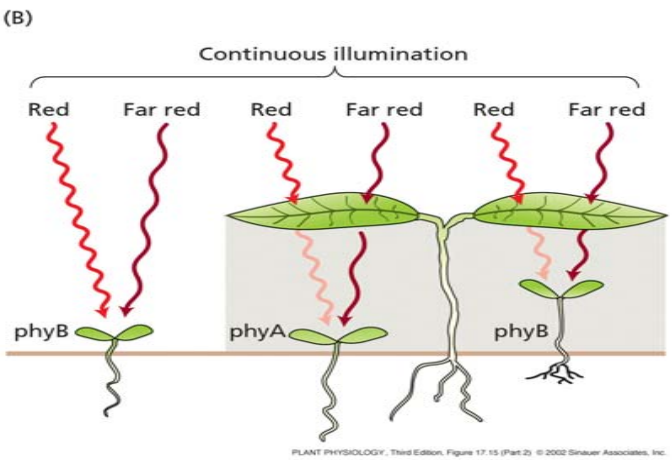
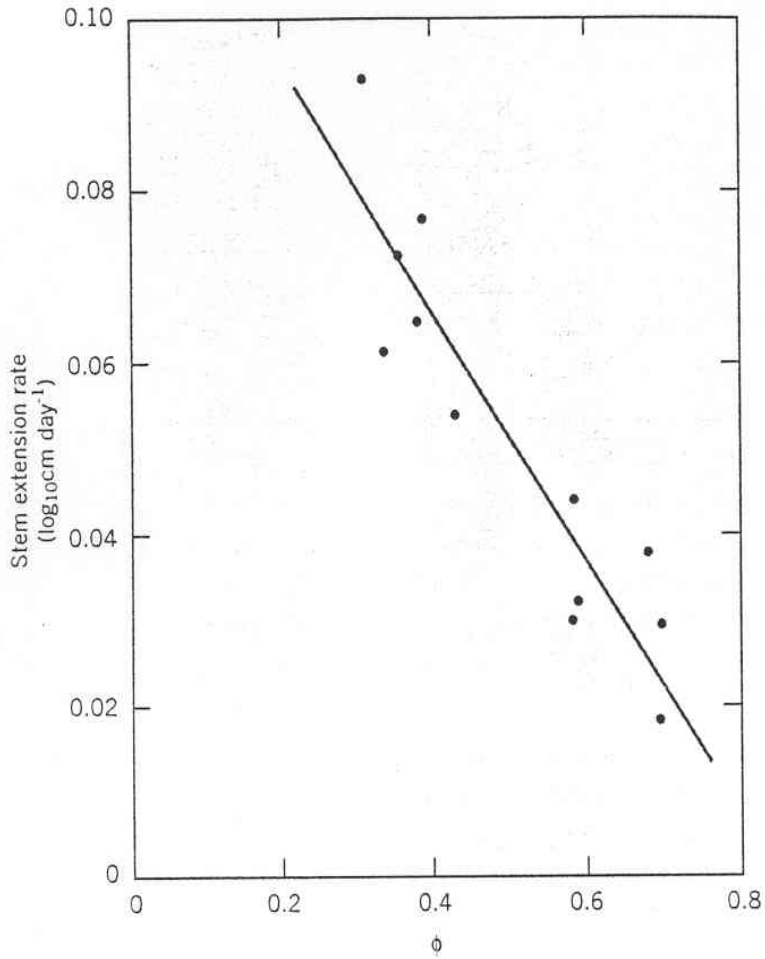
Stem elongation

TABLE 17.5 Coaction of phytochrome and a blue light receptor in photocontrol of anthocyanin biosynthesis in milo (Sorghum vulgare) seedlings. Treatments were begun five days after sowing. Anthocyanin content is expressed as absorbance at 510 nm.

Treatment	Anthocyanin content
27 hrs R	0.0
27 hrs Fr	0.0
3 hrs B + 24 hrs dark	0.19
3 hrs B + 5 min R + 24 hrs dark	0.19
3 hrs B + 5 min Fr + 24 hrs dark	0.05
3 hrs B + 5 min Fr + 5 min R + 24 hrs dark	0.19

Data from Drumm and Mohr, 1978.





A.