OUTLINE

- Plant cell, tissues, organs: basic structure and function
- Transport and translocation of water and solutes
- Photosynthesis and Respiration
- Plant growth and development
- Plant and light response
- Plant hormone and plant tissues culture
- Plant – environment interactions

OUTLINE

- Plant cell, tissues, organs: basic structure and function
- Transport and translocation of water and solutes
- Photosynthesis and Respiration
- Plant growth and development
- Plant and light response
- Plant hormone and plant tissues culture
- Plant – environment interactions

Bachelor 2: Plant physiology

Lesson 6:

PLANT AND LIGHT RESPONSE

Instructor: LE Thi Van Anh

le-thi-van.anh@usth.edu.vn

Learning outcome

By the end of this course, students are able to:

- List the name pigments that regulating light response of plant: phytochrome, cryptochrome, phototropin and zeaxanthin
- Analyze structure of phytochrome correlates to physiological response to red light and far-red light
- Analyze plant responses to blue light under reaction of blue light receptor
- Study by them self to analyze the articles related to the phytochrome effects

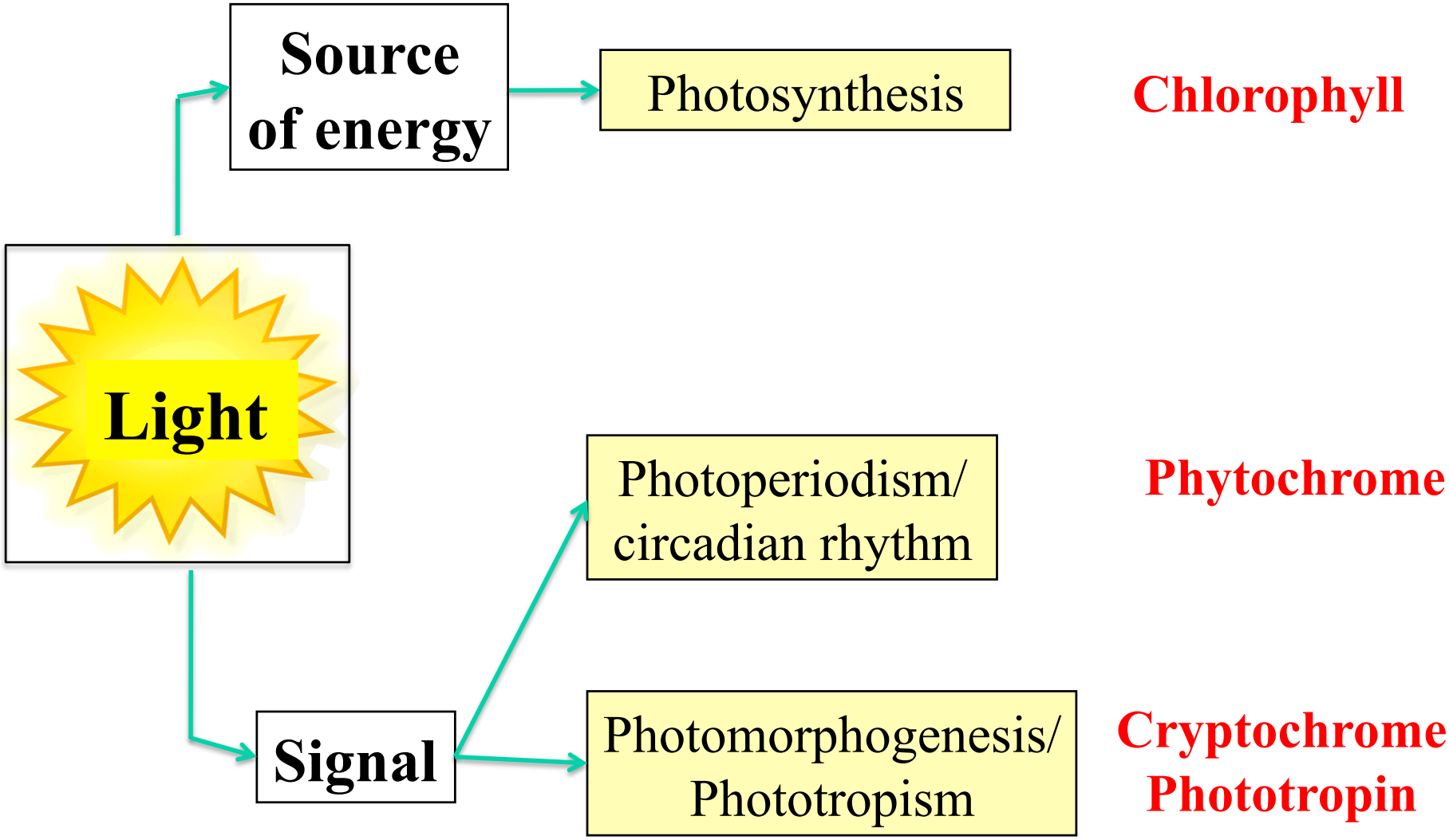
Concept

"phototropism"
growth toward light

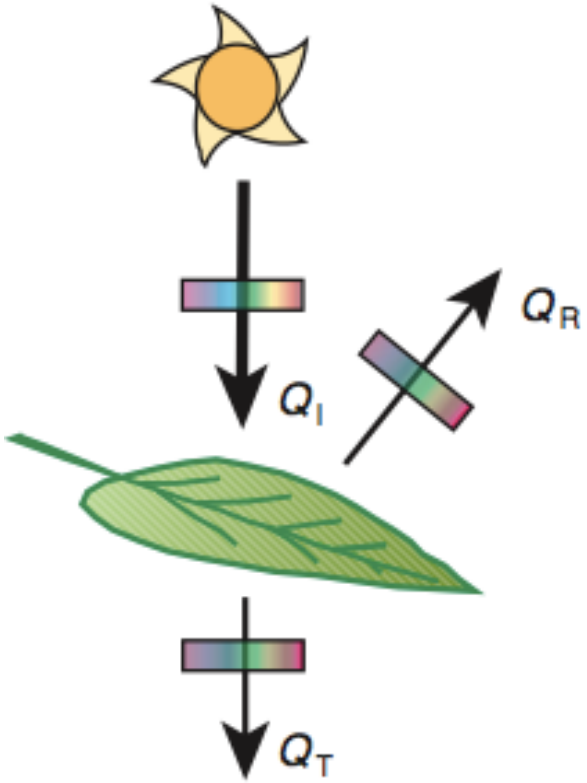
"etiolation symptoms"
No greening, smaller leafs,
longer hypocotyl

Light as a signal

Concept

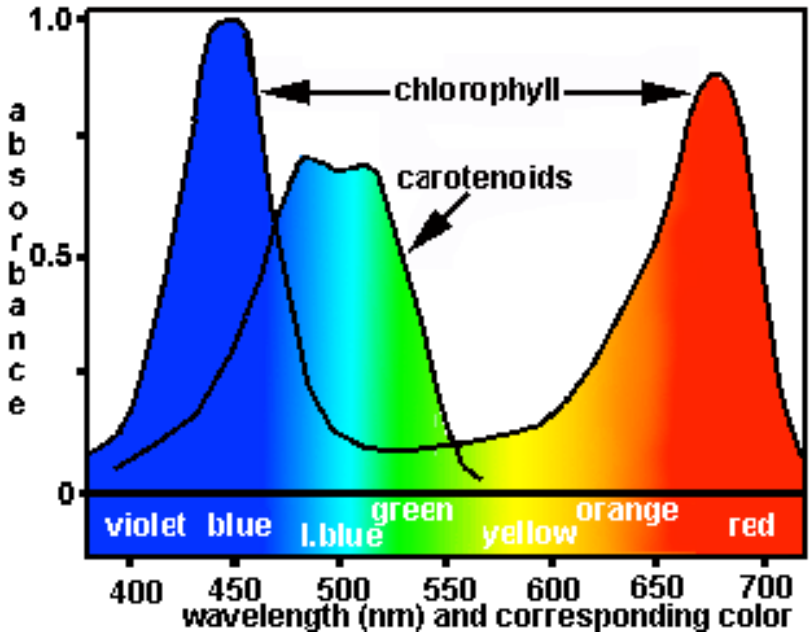

Source of energy
Photosynthesis
Chlorophyll
Light
Photoperiodism/ circadian rhythm
Phytochrome
Signal
Photomorphogenesis/ Phototropism
Cryptochrome
Phototropin

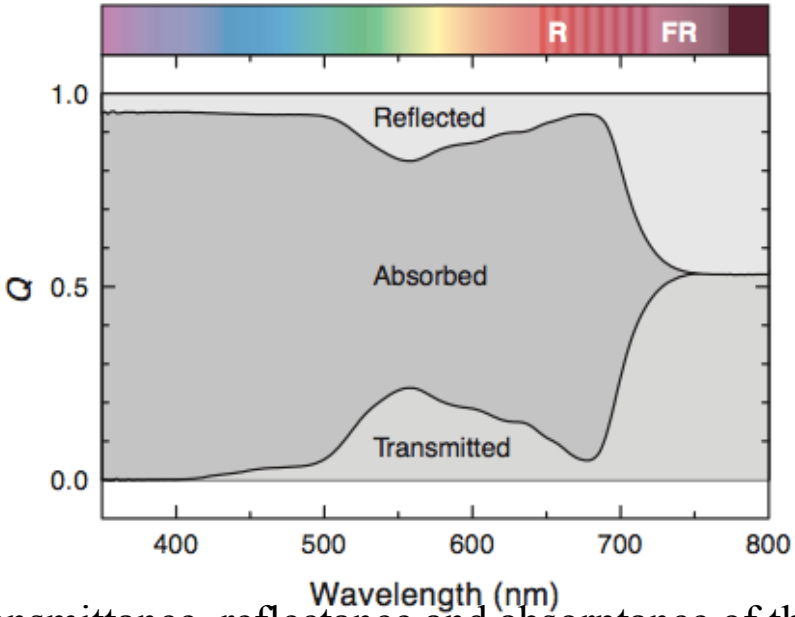
Concept



Incident light is partly reflected, transmitted and absorbed

Concept



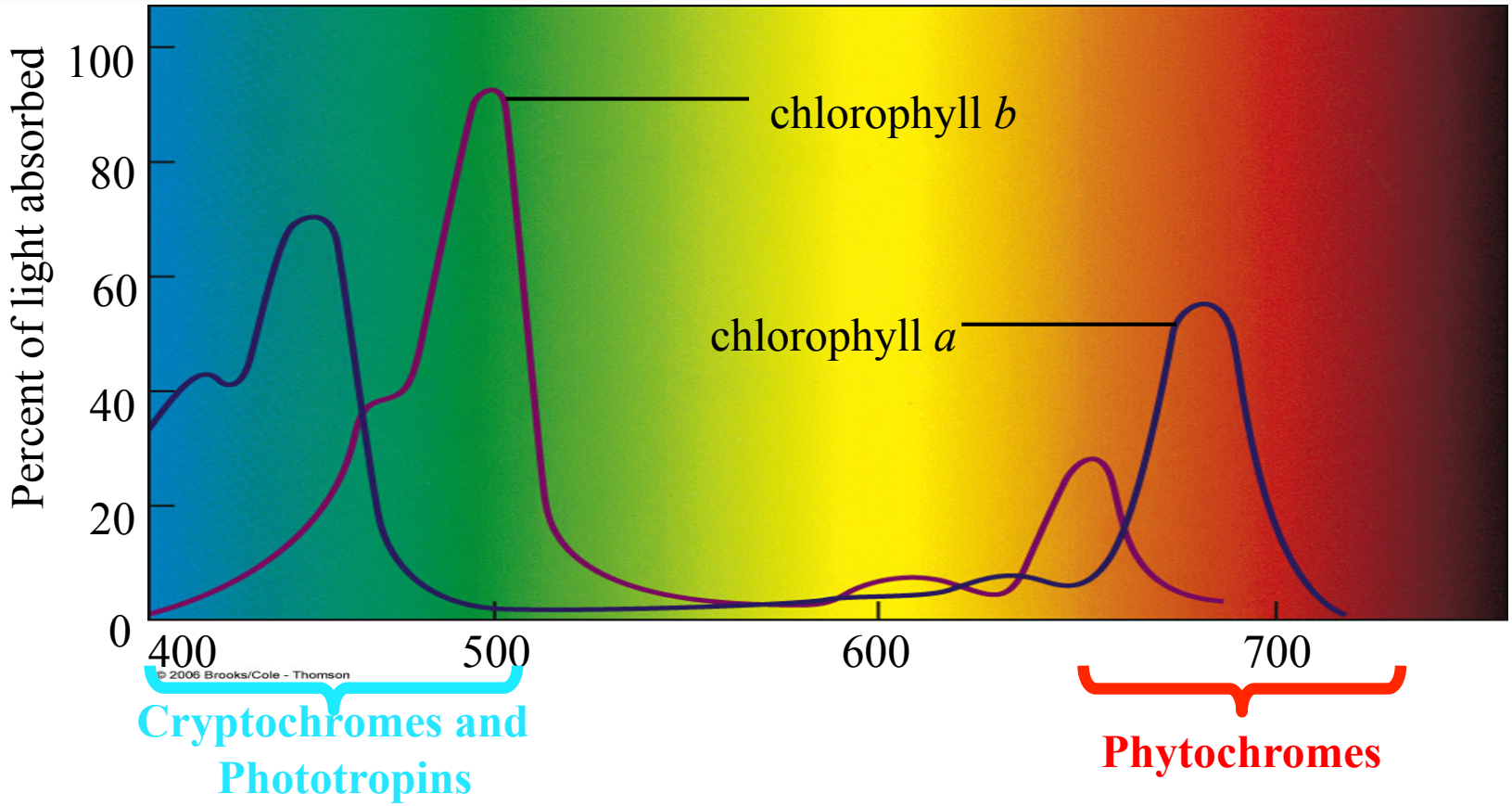


Transmittance, reflectance and absorptance of the adaxial surface of a young fully expanded leaf of a silver birch (Betula pendula Roth.) seedling (Pedro J. Aphalo and Tarja Lehto, unpublished).

Blue and red (far-red) light is absorbed or transmitted.
Green light is reflected. That's why almost leaves are green in human eyes

Concept:

Light wavelengths detected by plant light receptors

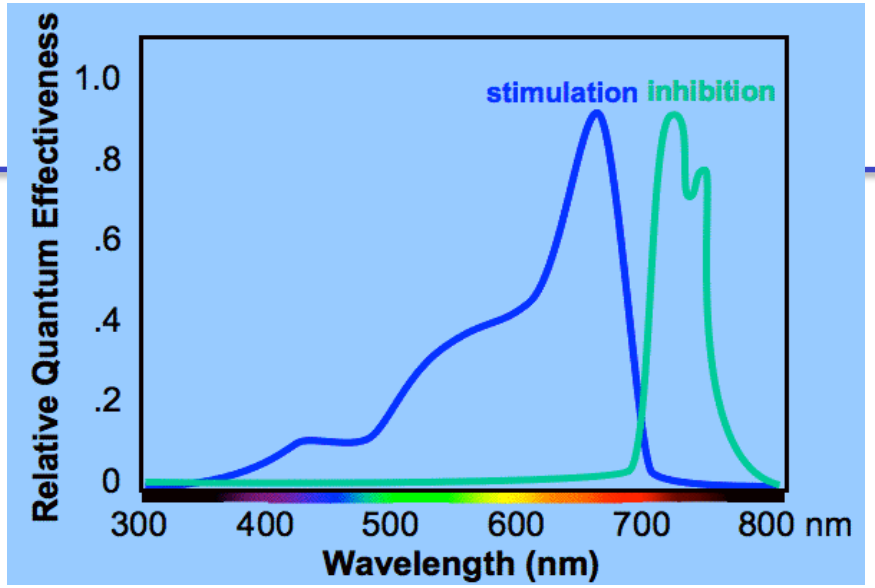


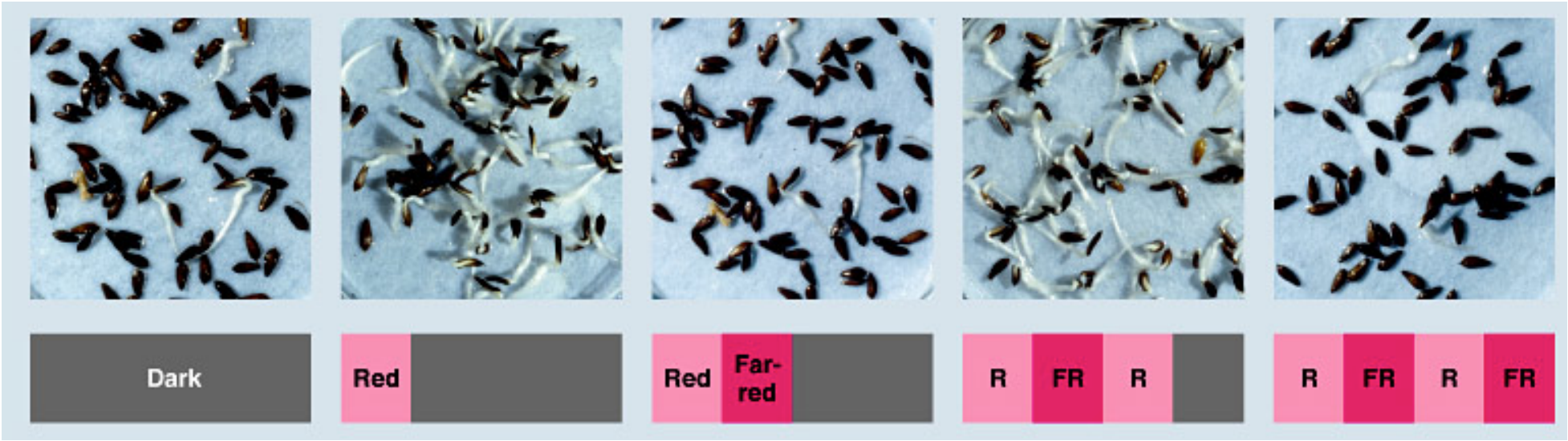
Red light detection:

Phytochromes

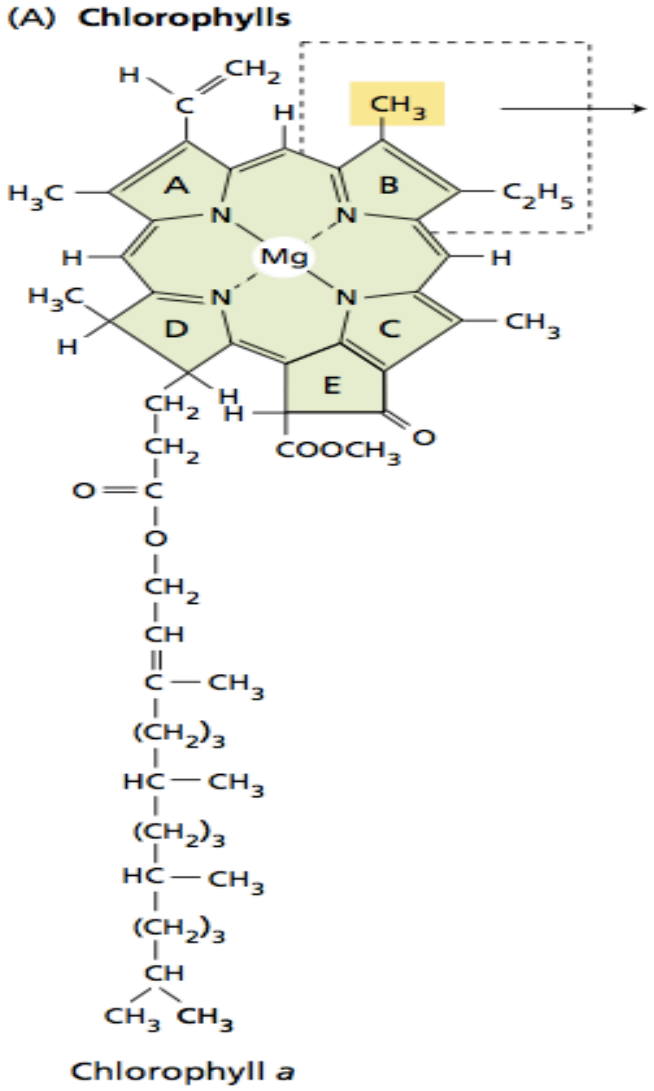
Concept

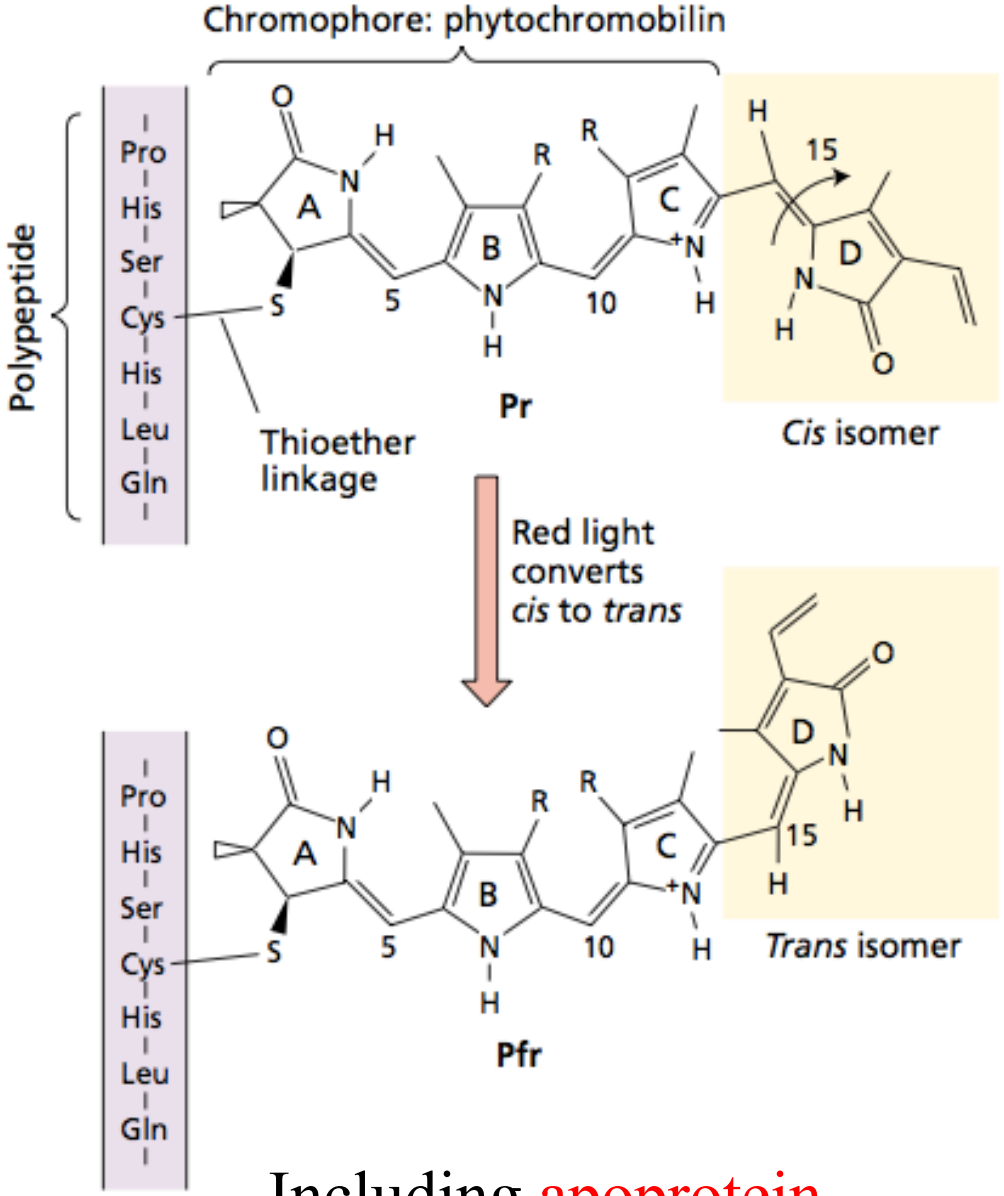
Red light promotes lettuce seed germination
Far-red light treatment reverses light effect





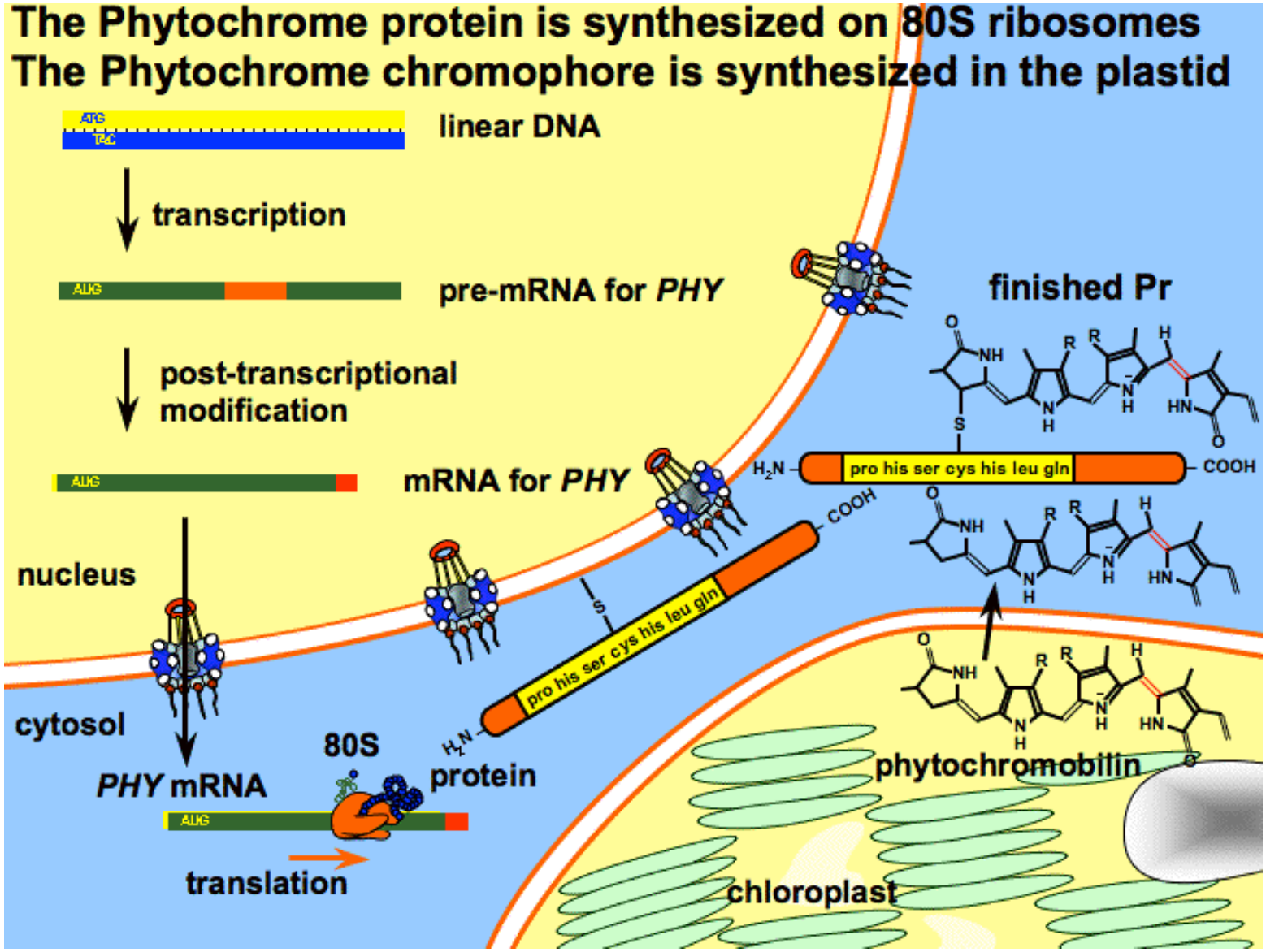
Structure of phytochrome



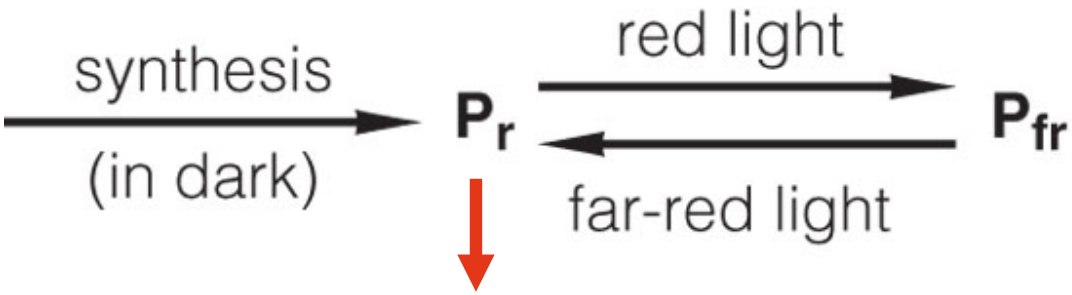


Including apoprotein and chromophore

Phytochrome biosynthesis



Phytochrome biosynthesis and function



Inactive version of Phytochrome

Active version of Phytochrome:

Promotes seed germination, shade avoidance, and controls circadian entrainment, flowering, etc…

Ecological function of Phytochrome: seasonal sensor

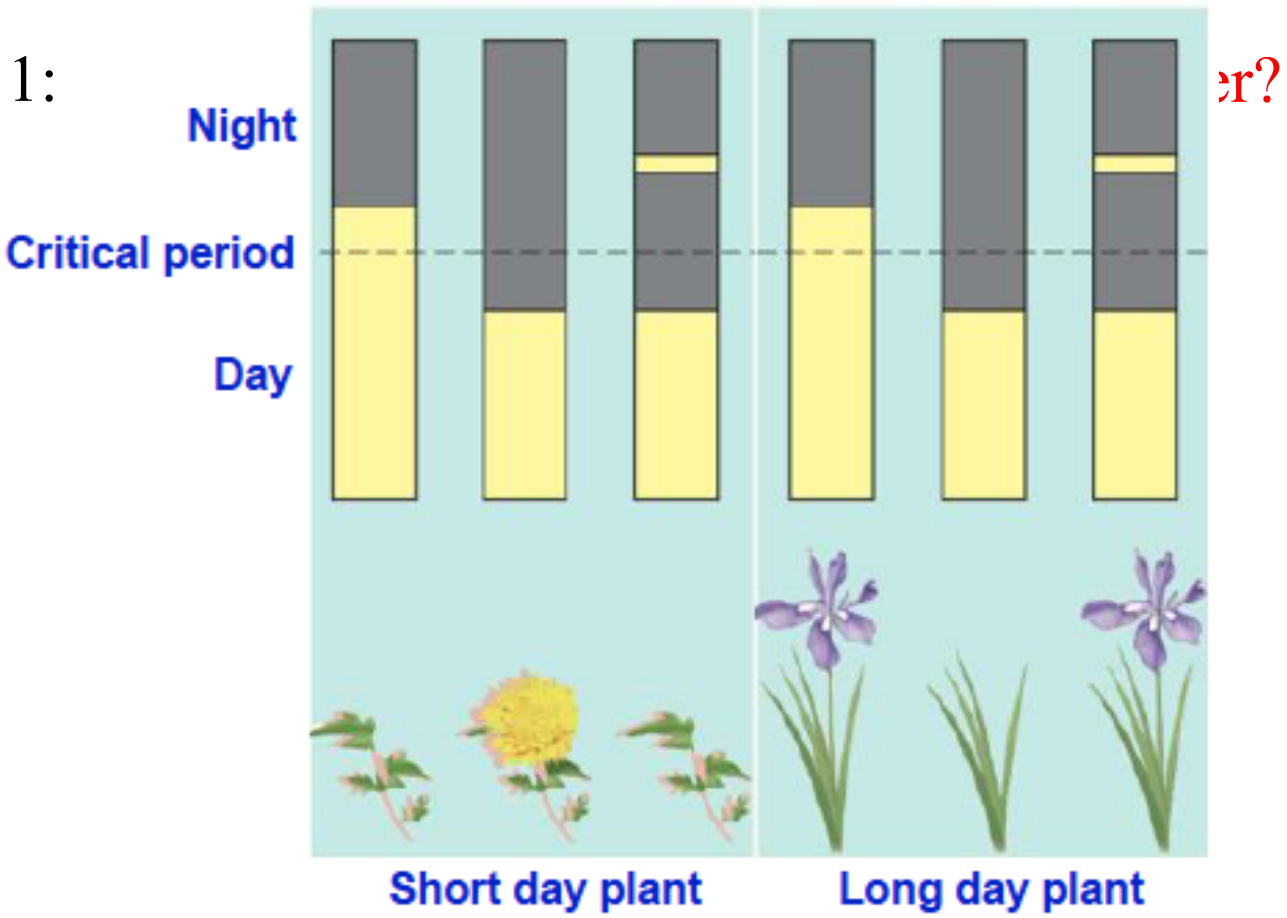
Long day plants:
Flowering summer
(VN)

Short day plants:
Flowering in winter
(VN)

Photoperiodism

Ecological function of Phytochrome: seasonal sensor

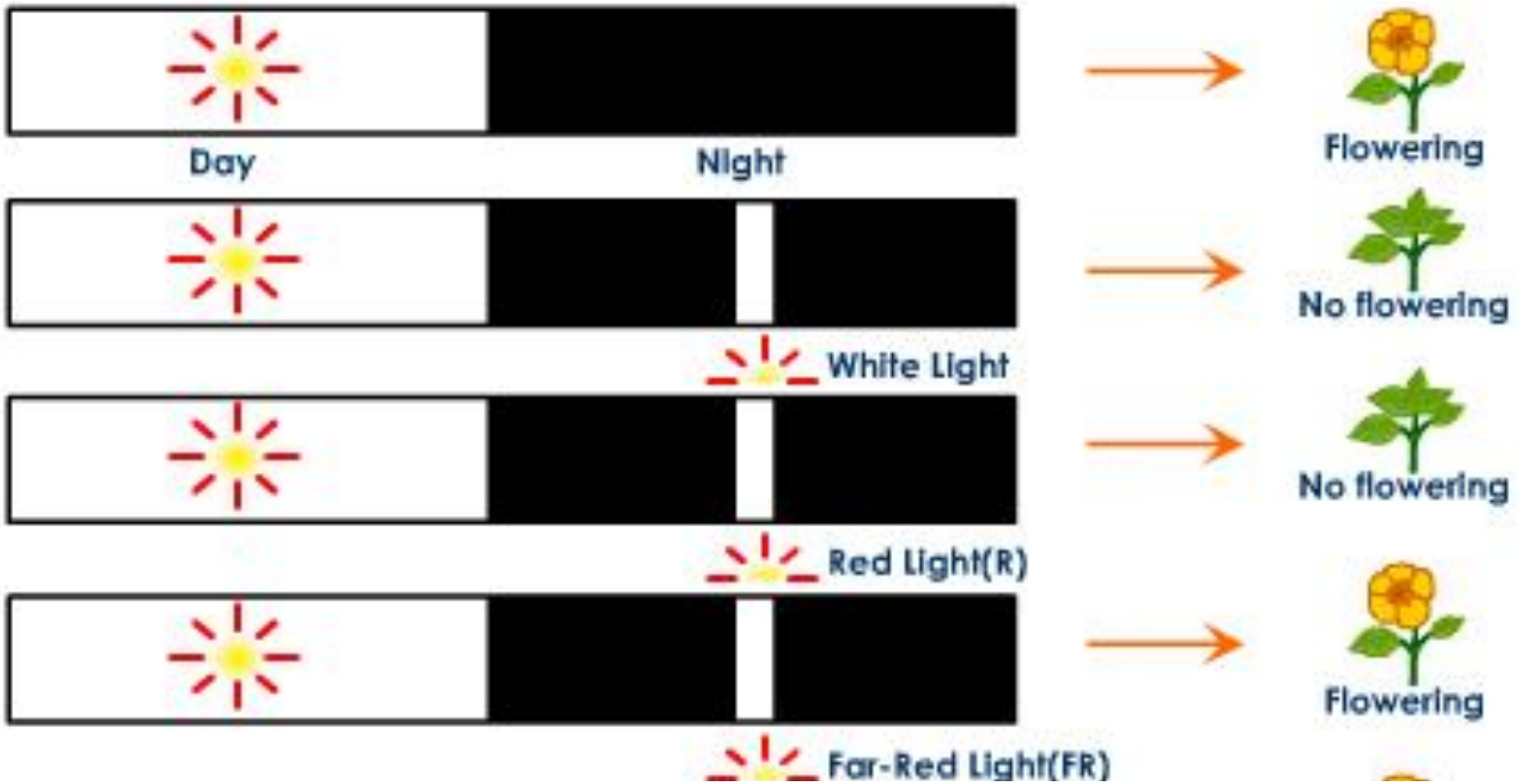
Experiment 1:



The length of night is the factor determining plant flowering

Ecological function of Phytochrome: seasonal sensor

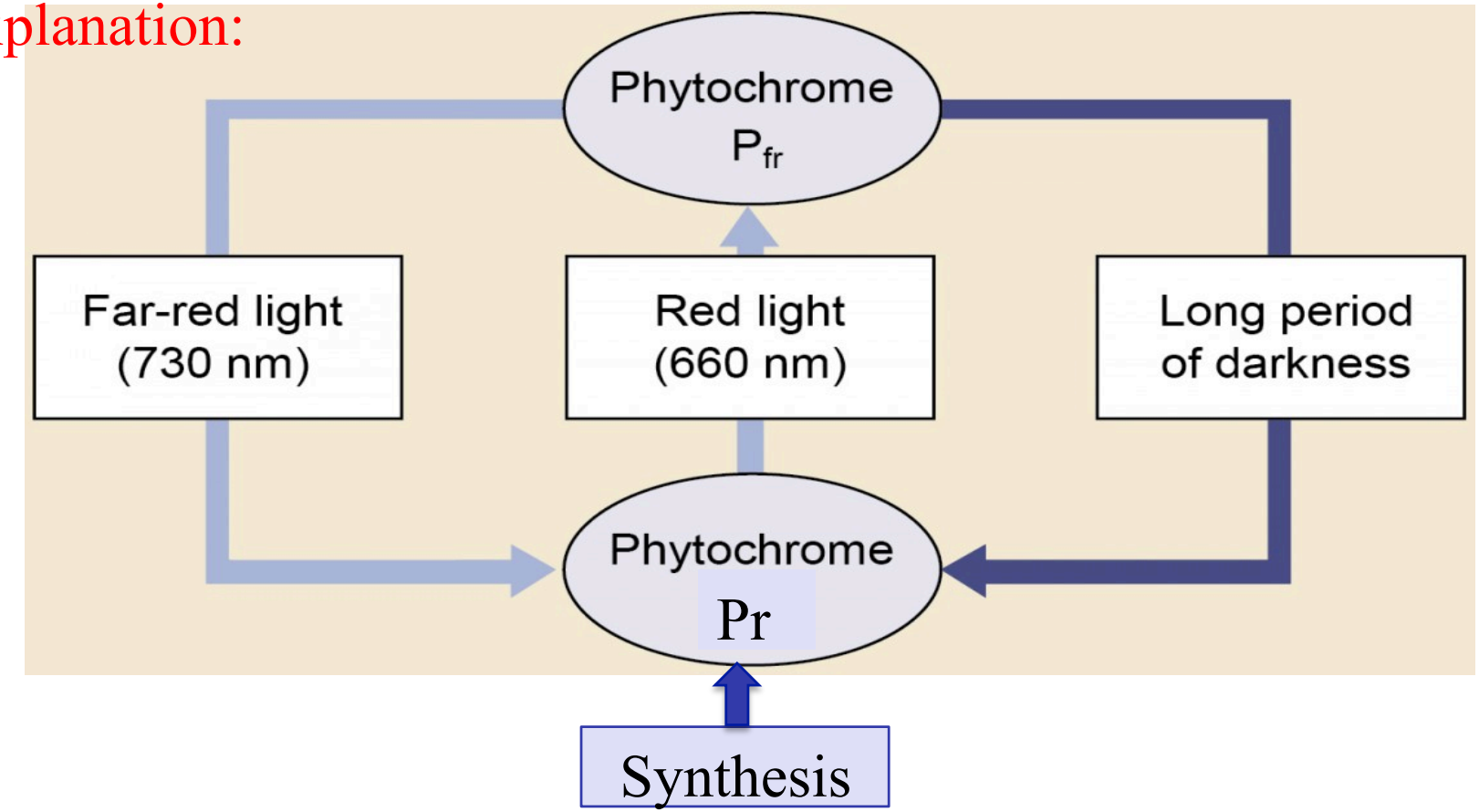
Experiment 2 for short-day plants:



Red light is "guilty"

Ecological function of Phytochrome: seasonal sensor

Explanation:



Flowering depends on the **Ratio Pr/Pfr**

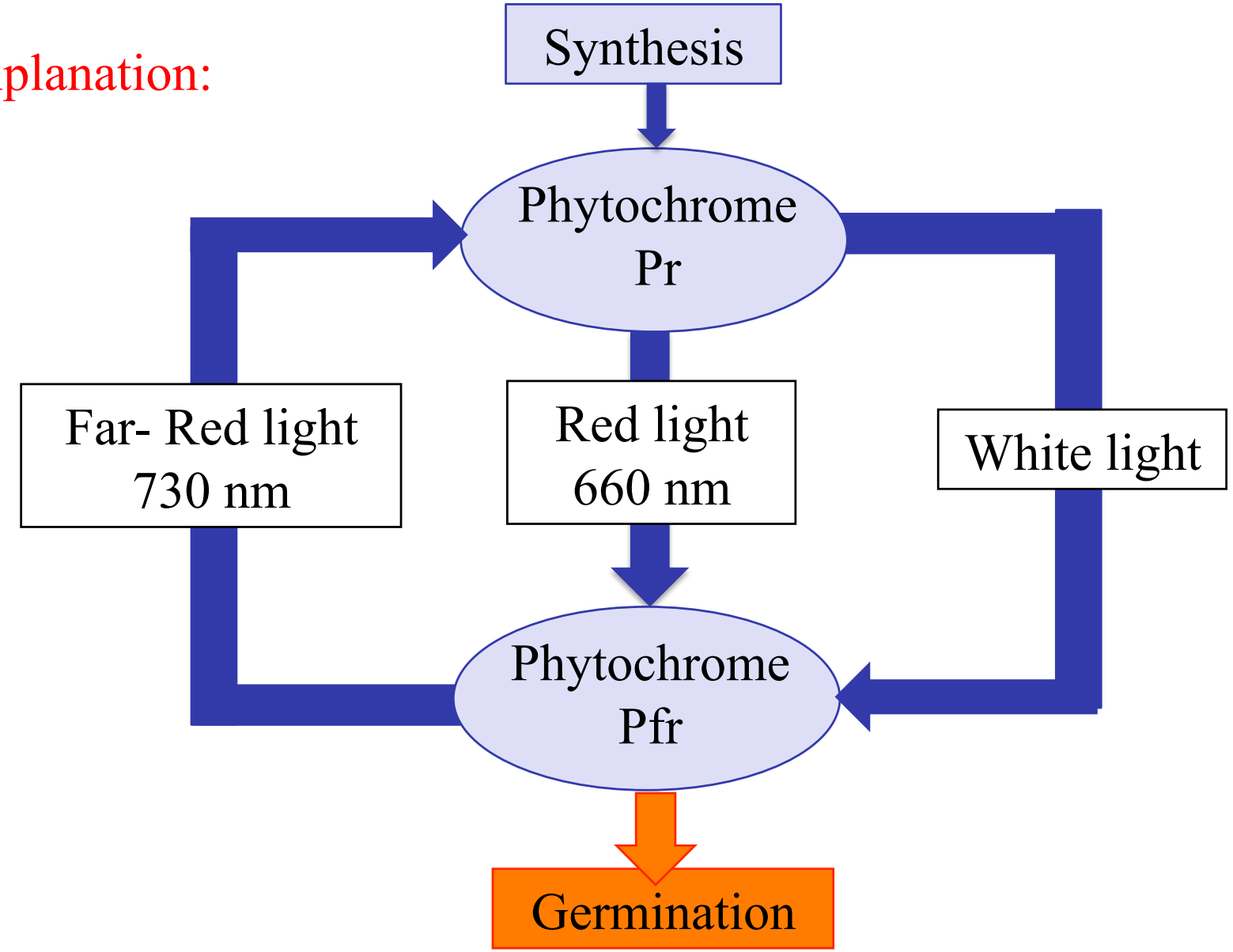
Ecological function of Phytochrome: light sensor

Experiment: effect on germination

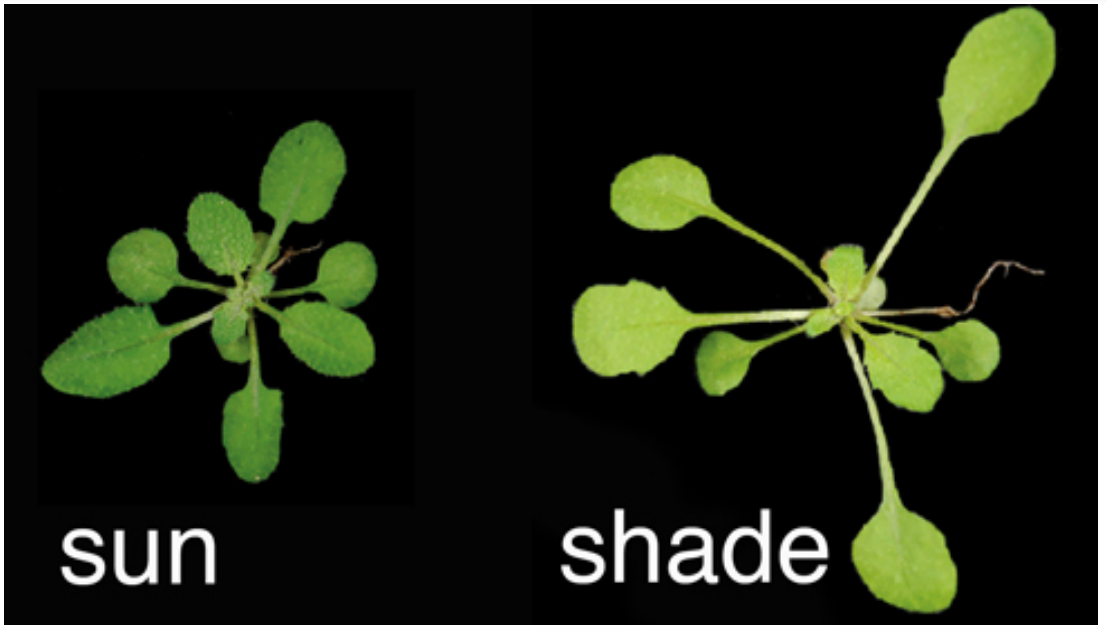
Red light is responsible for germination

Ecological function of Phytochrome: light sensor

Explanation:



Ecological function of Phytochrome: colour sensor

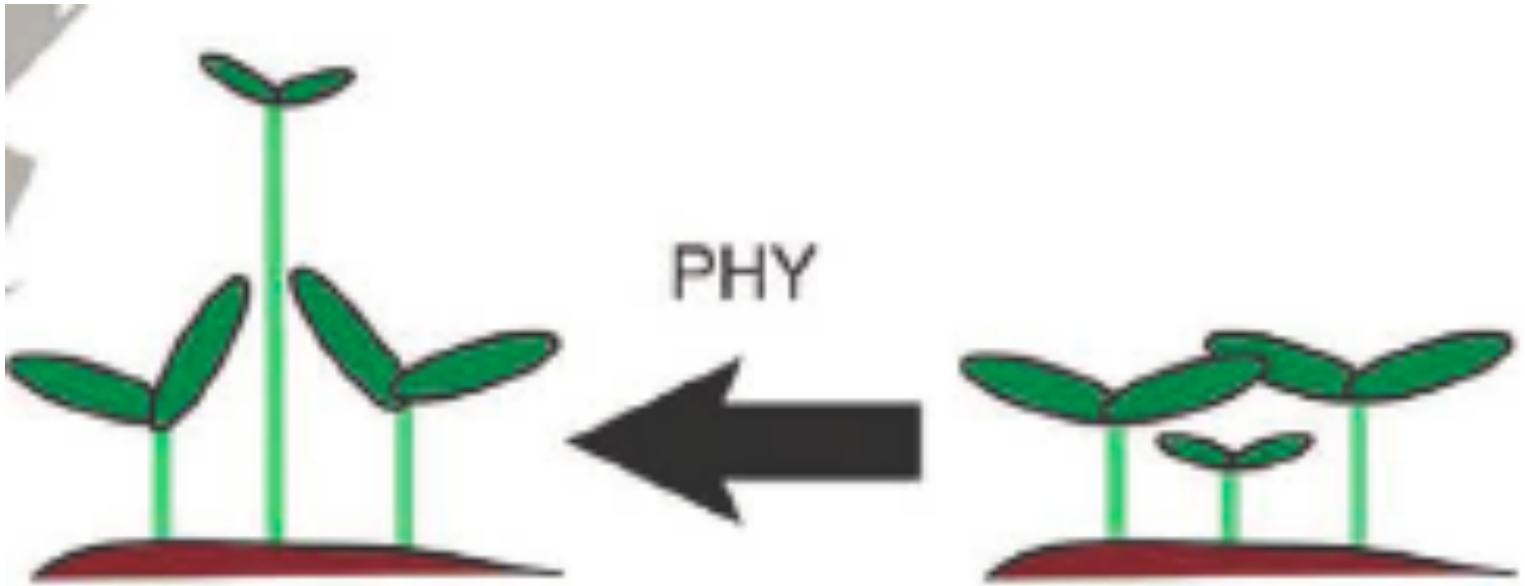


In shade: less branching
more elongating

↓

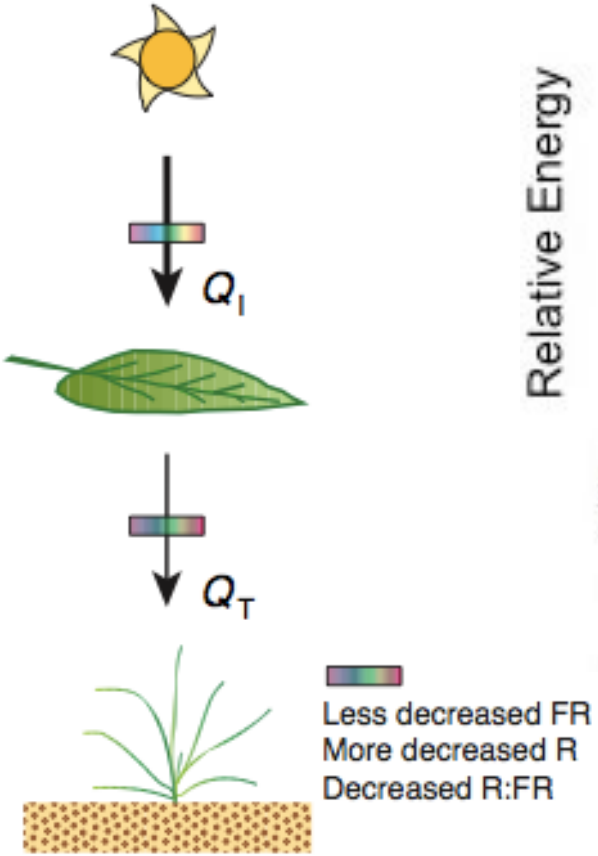
Shade avoidance response

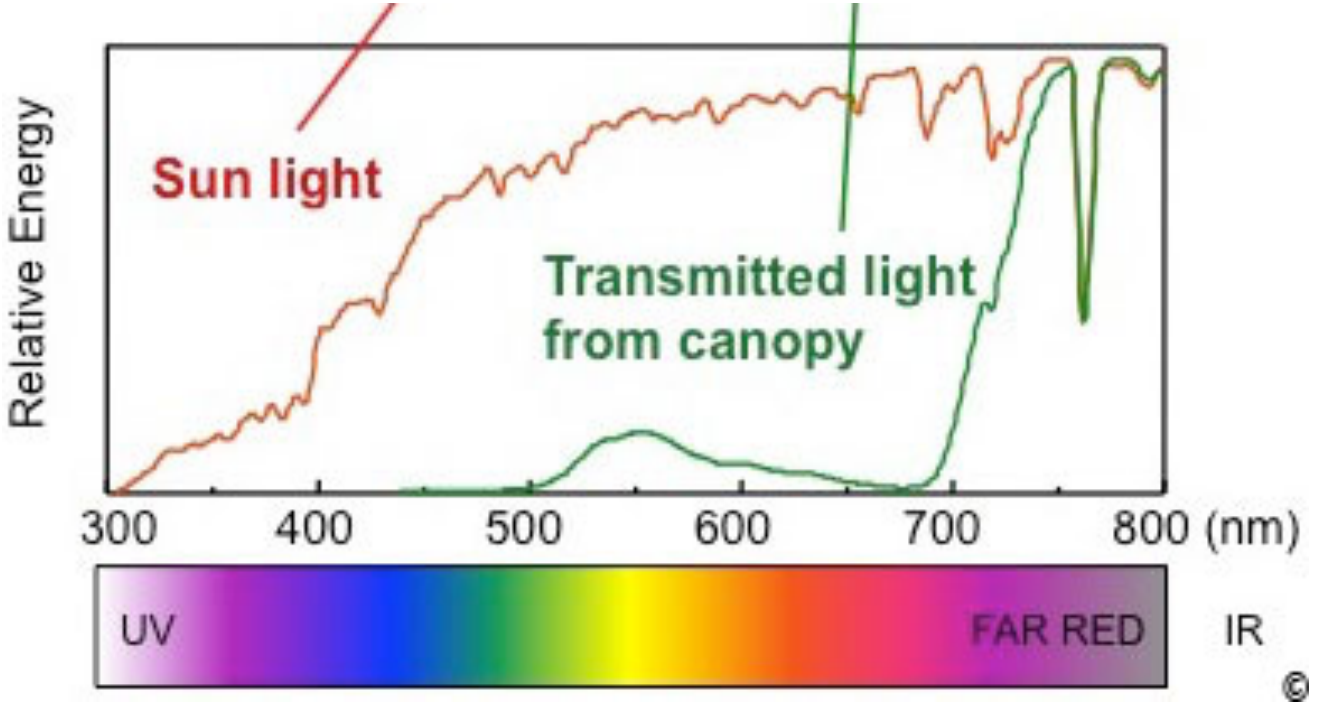
Shade avoidance?



Shade Avoidance

Ecological function of Phytochrome: colour sensor

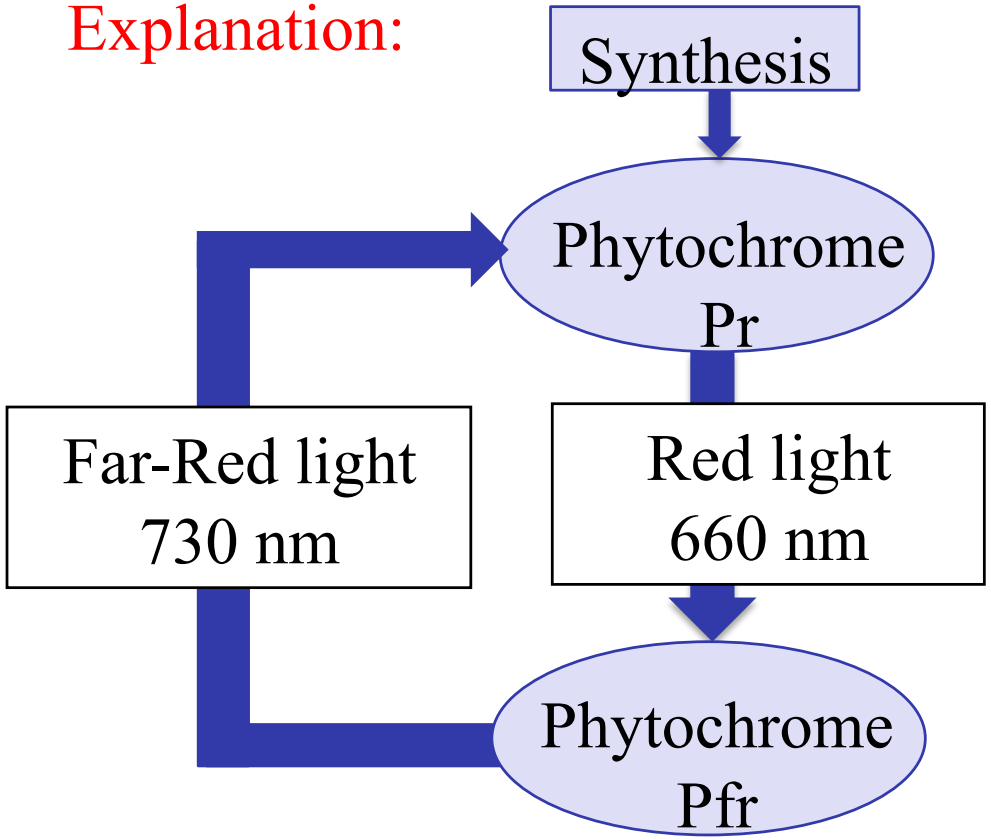




Under the foliage:
R/FR decrease

Ecological function of Phytochrome: colour sensor

Explanation:



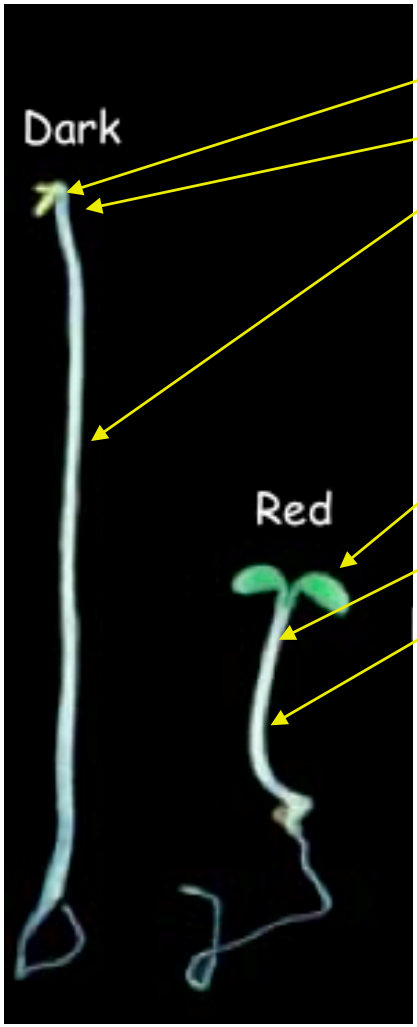
Under the foliage:
FR/R decrease

Under the foliage:
Pr/Pfr increase

Stimulation of stem elongation
Limitation of branching
Inhibition of leaf expansion

Phytochrome reactions serve to focus growth toward maximizing photosynthesis

Phytochrome promotes de-etiolation



Seedlings grown in the dark display an **etiolated** growth pattern:

1) yellow unexpanded cotyledons
2) apical hook
3) Long hypocotyl

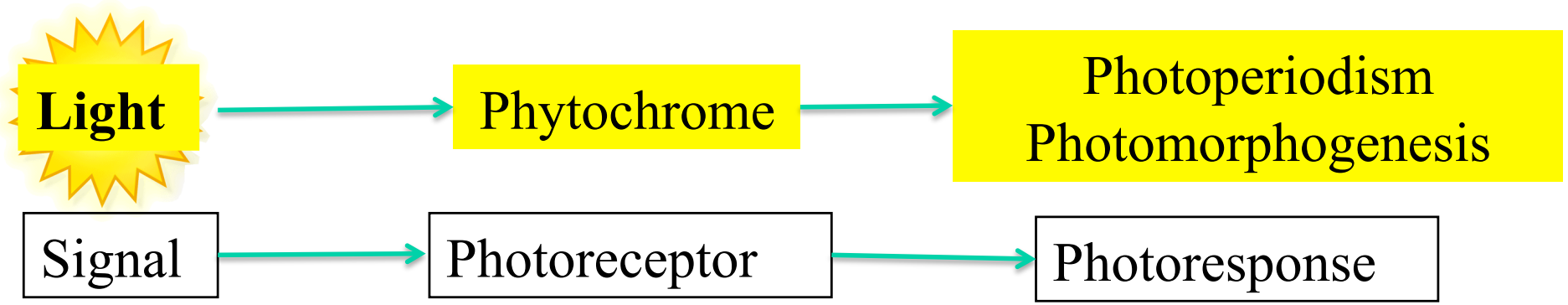
Seedlings grown in red light (or white light) display a **de-etiolated** growth pattern (opposite to etiolated):

- Green expanded cotyledons
- No apical hook
- Short hypocotyl

→ Red light promotes **chloroplast development** and **leaf expansion**. Leaves (cotyledons) are also growing in **upright position**, allowing optimal light impact. Active phytochrome promotes seedling development that is **optimal for photosynthesis.**

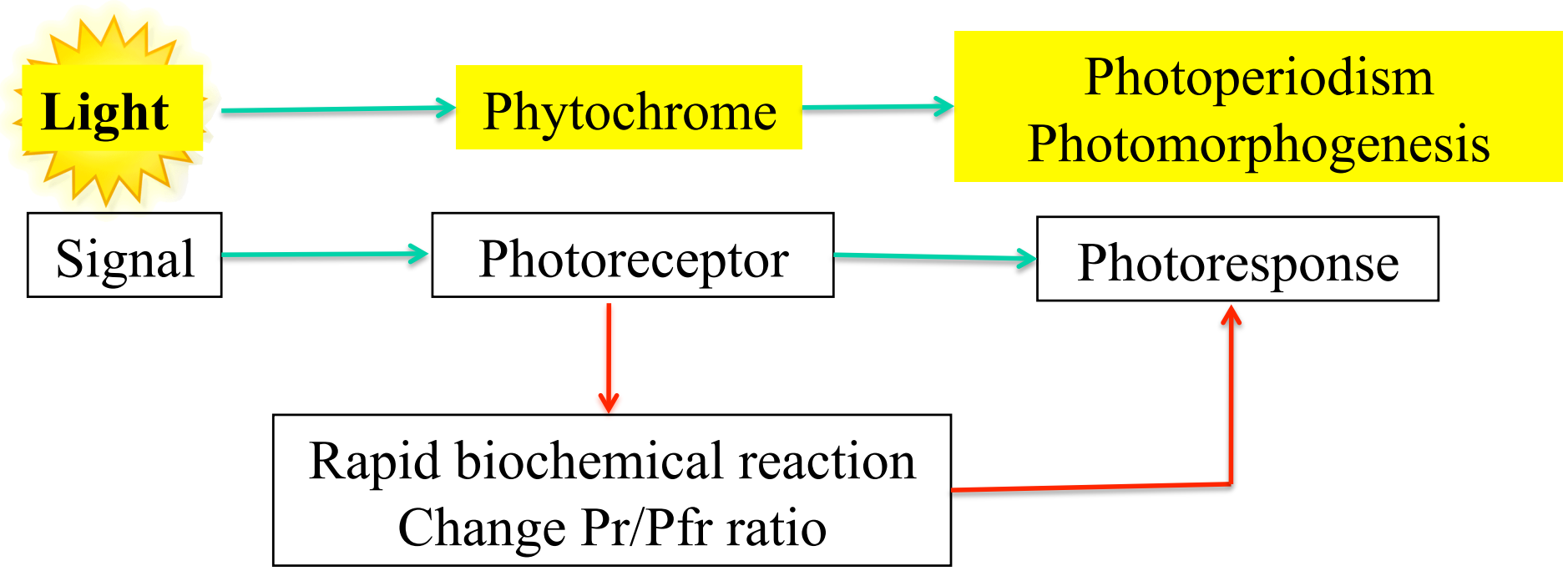
Ecological function of Phytochrome: In summary

- Seasonal sensor: photoperiodism
- Light sensor: for several physiological process. Eg. germination
- Light quality sensor: shape avoidance response



The way for plants to adapt to environment!

Characteristics of Phytochrome respone: conclusion



The response is always ontime!

Blue light detection

Blue light responses

1. Phototropism
2. Inhibition of stem and hypocotyl elongation
3. Stimulation of Chlorophyl and carotenoid system
4. Stomatal opening
5. Chloroplast movement
6. Anthocyanin synthesis

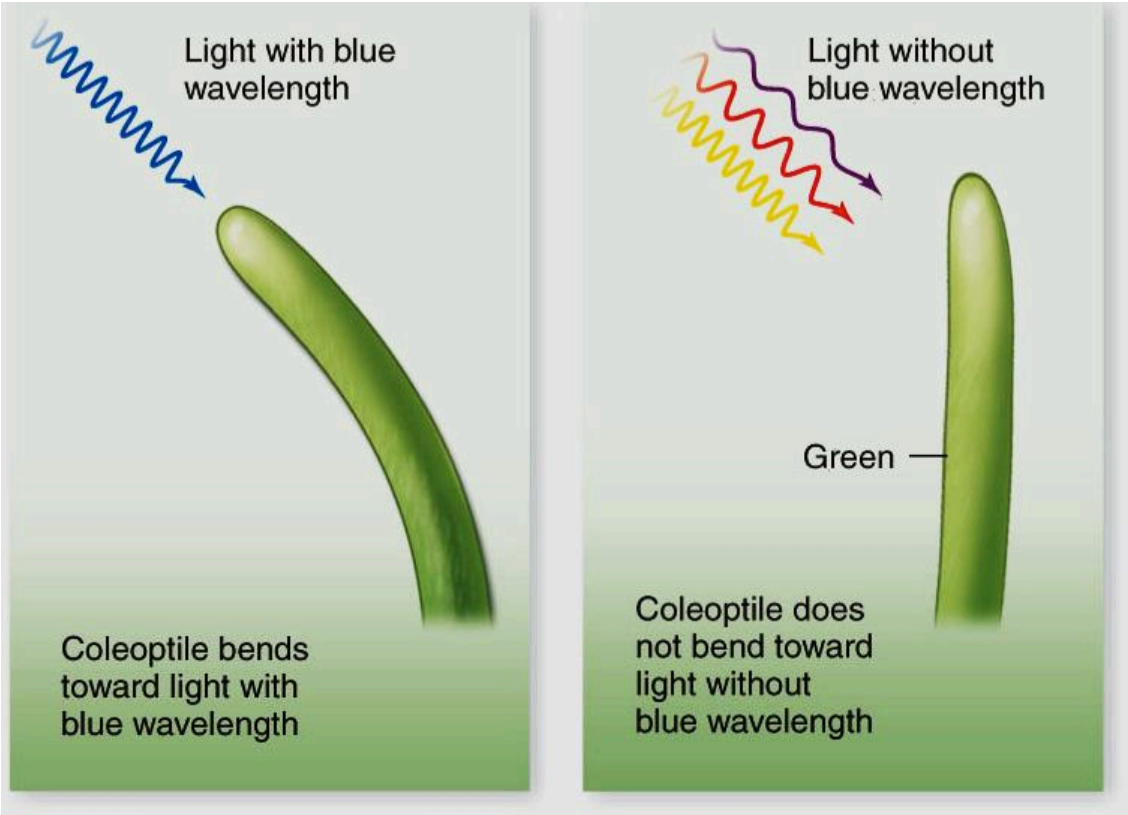
Phototropism- growth in response to directional light

The growth of a plant part toward or away from light (from Greek *tropos,* meaning “turn”)

Positive phototopism

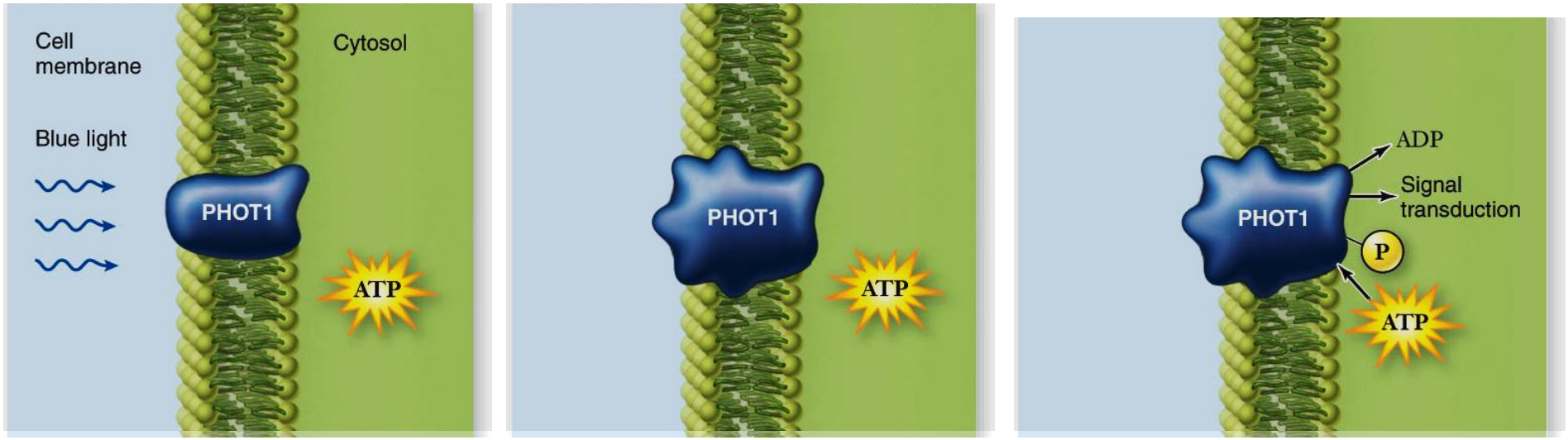
Phototropism – Light Detection

Plants not only detect the presence of light,
- also direction, intensity, and wavelength (color)



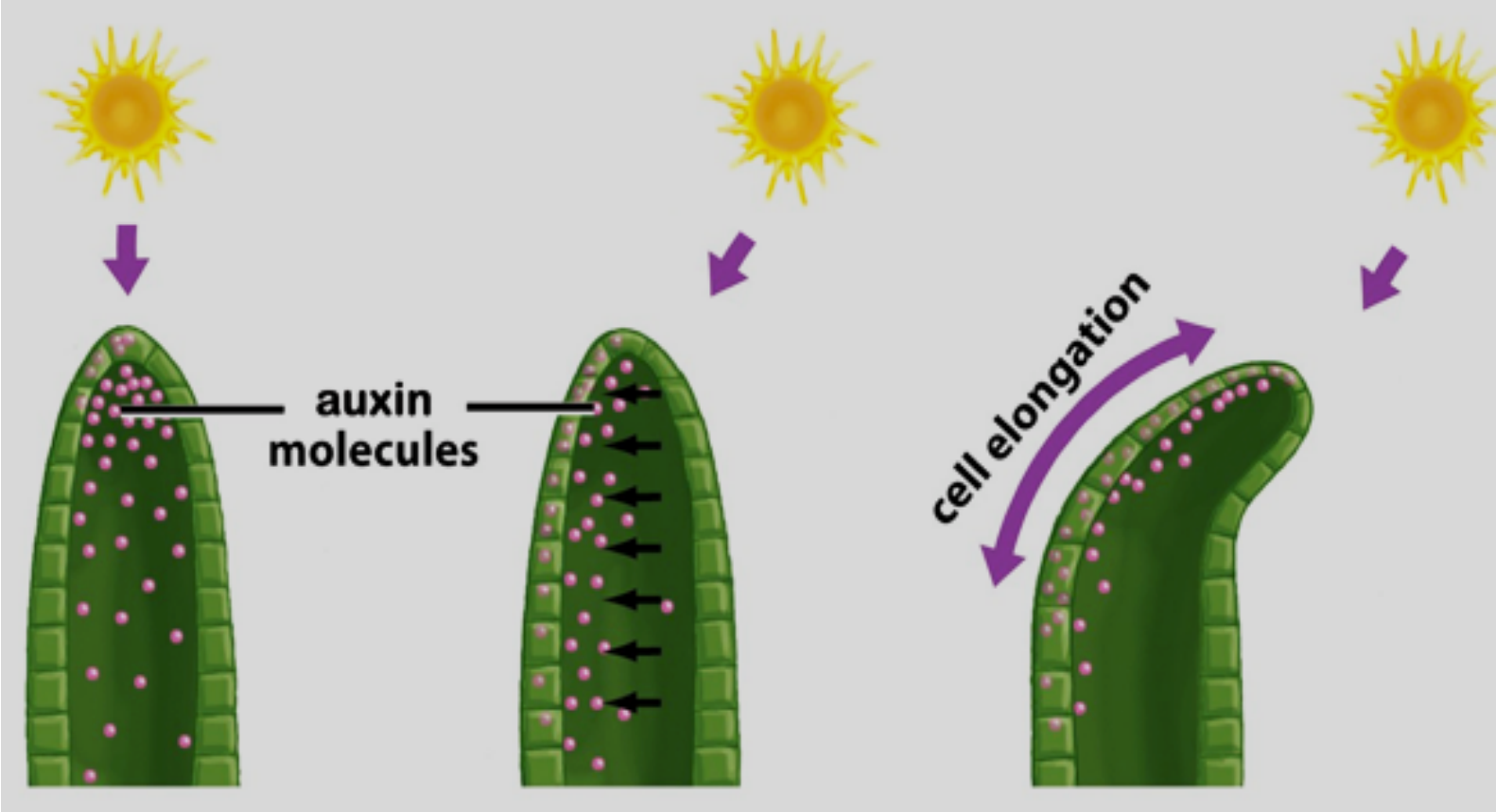
Blue light: Directional growth responses

Phototropism – Light Detection



- Blue light receptor: Embedded in cell membrane
- When blue light detected, changes conformation, signal transduction → differential elongation

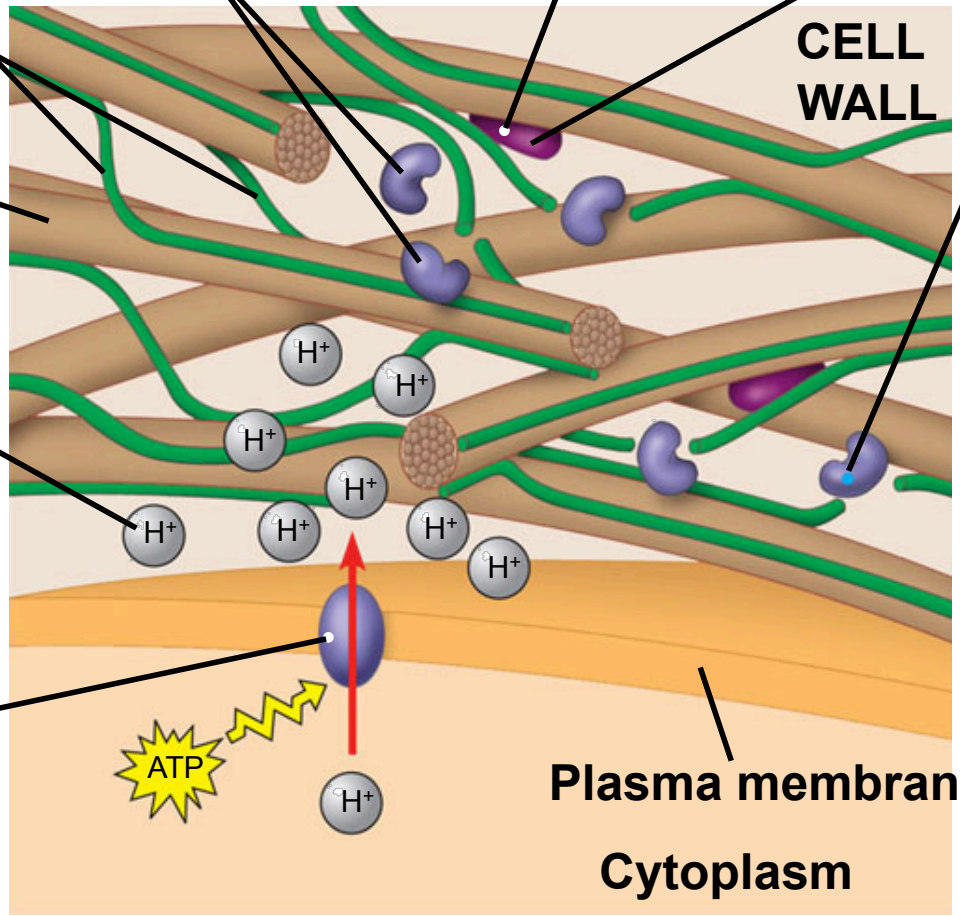
Light cause asymmetric distribution of auxin



- Auxin exits basal end of one cell and enters apical end of adjacent cell

Cell elongation in response to auxin

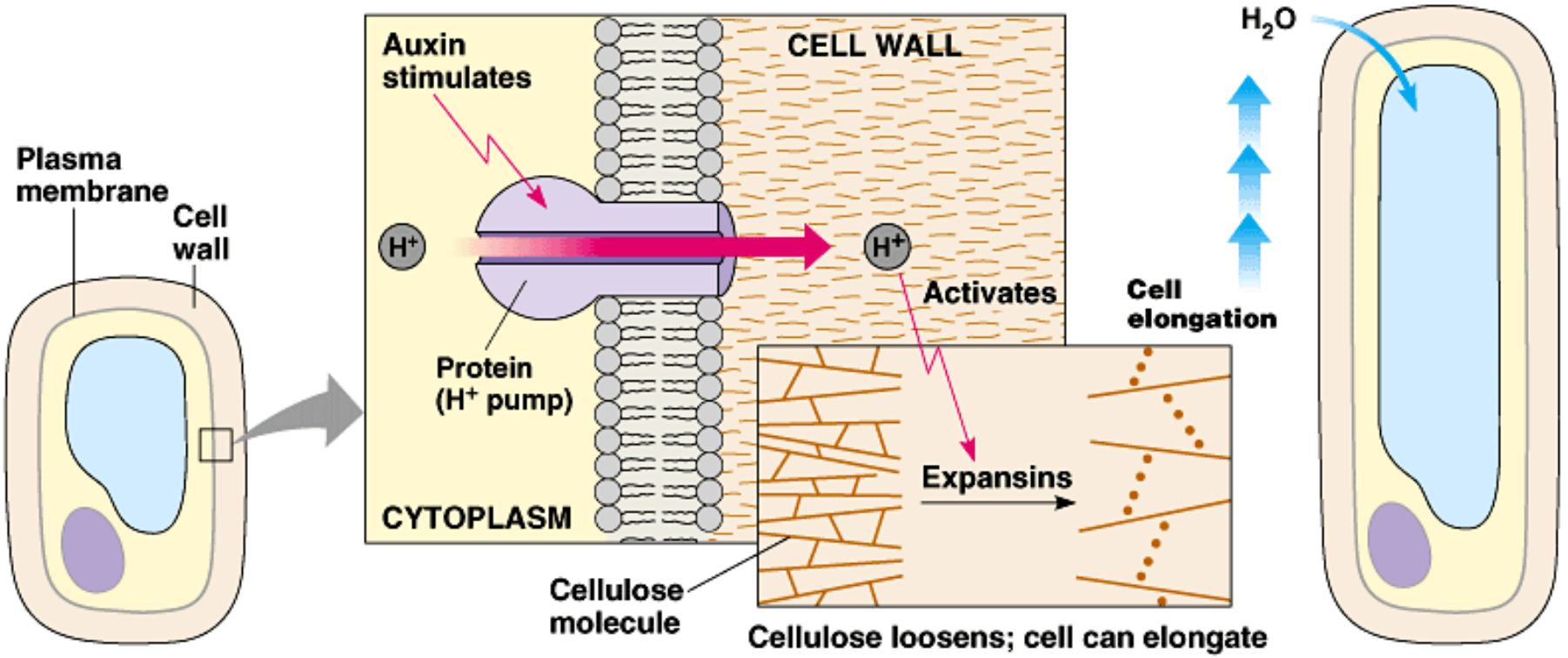
Expansins (active at low pH) cleave cellulose microfibrils from polysaccharides. Exposed polysaccharides now accessible to enzymes.



Cell wall becomes acidic. Auxin increases activity of proton pumps.

Enzymatic cleavage of polysaccharides allows microfibrils to slide.Cell wall can extend. Turgor causes the cell to expand.

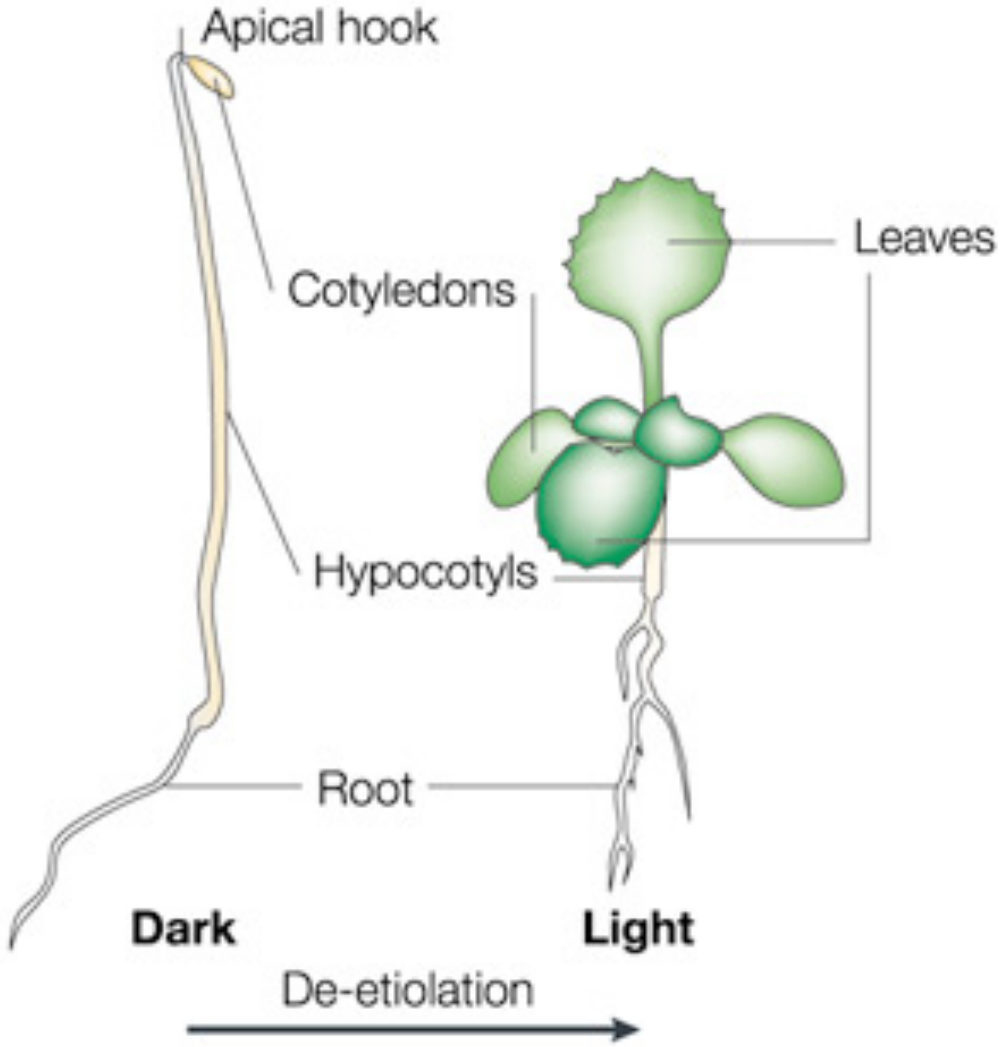
Cell elongation in response to auxin



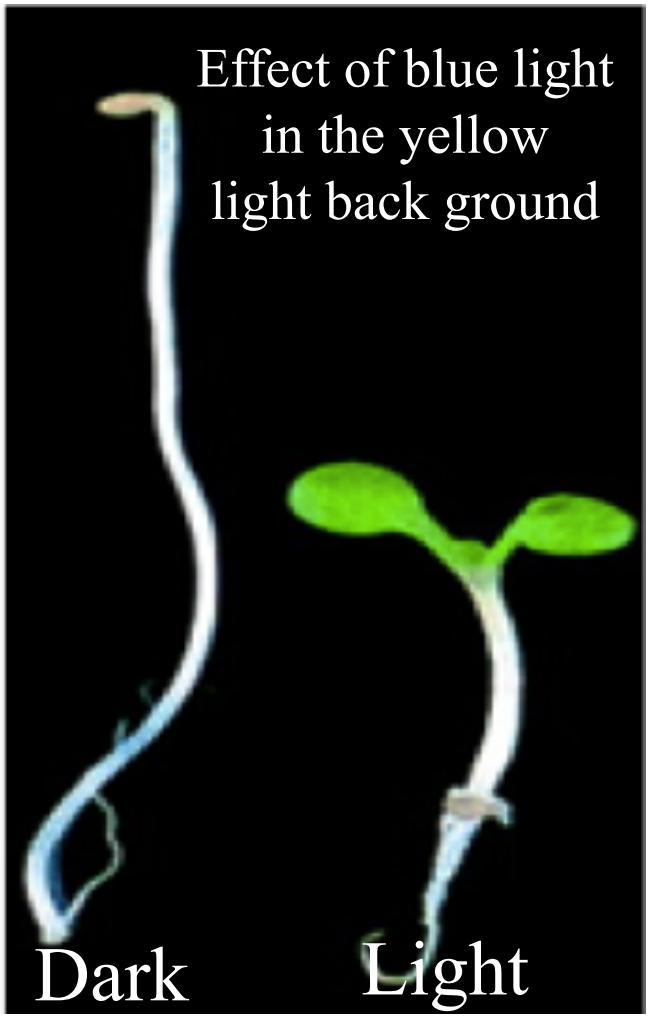
Auxin cause the cellulose loosened, thus the cell can elongate

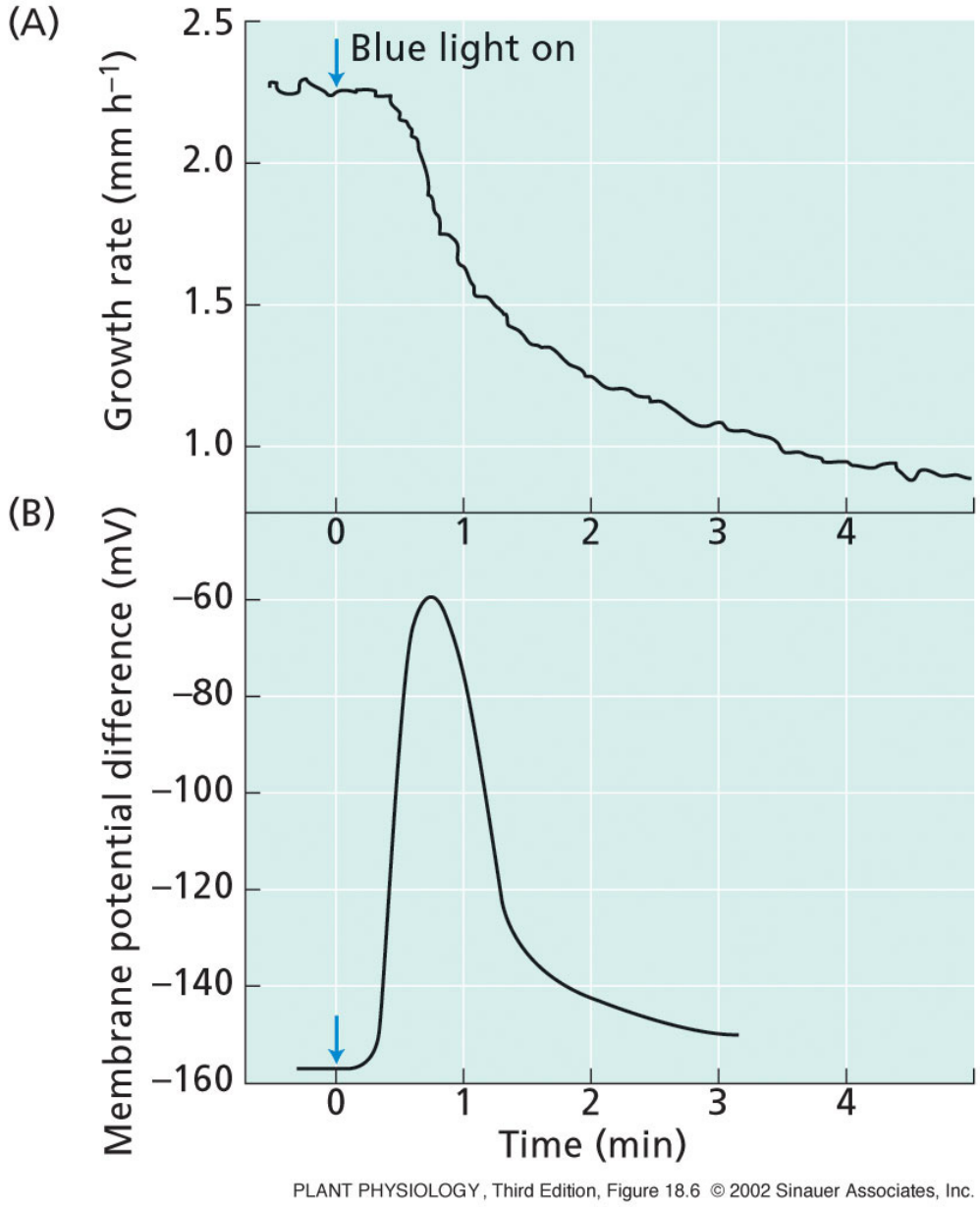
De-etiolation….

Caused by red light



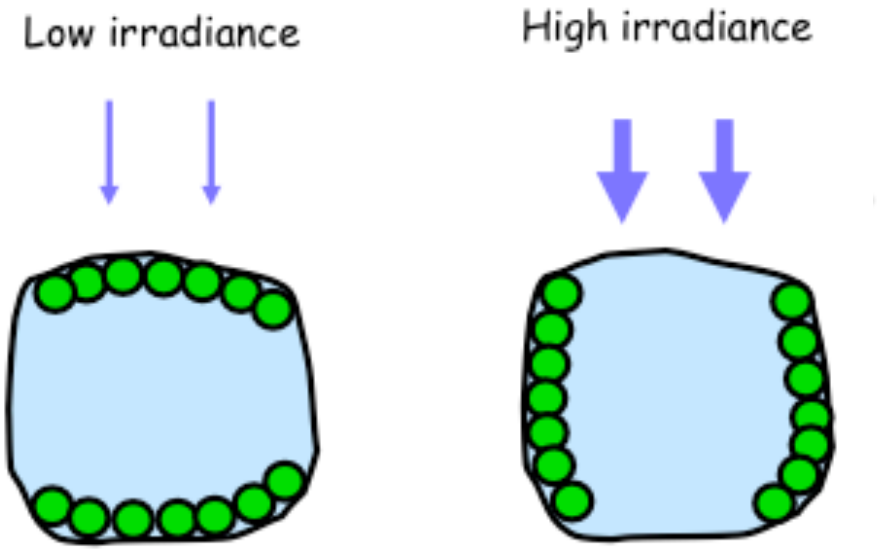
Blue light inhibit hypocotyl elongation

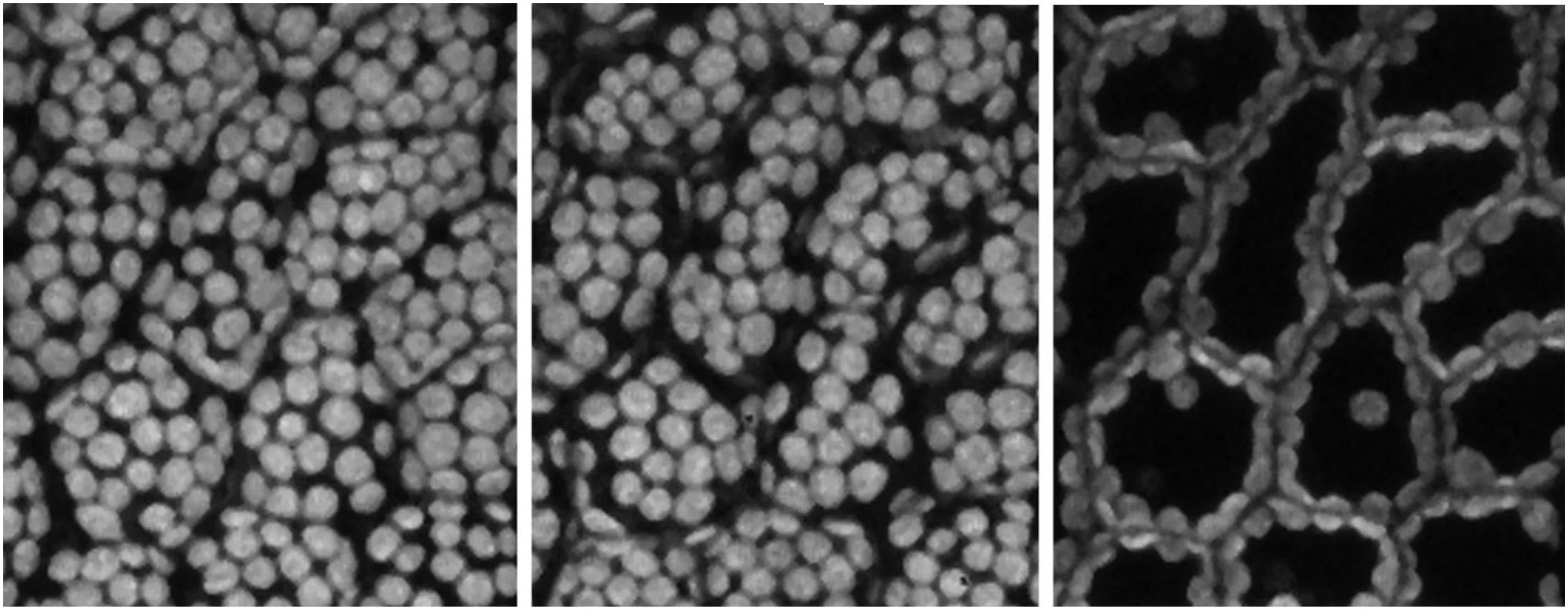




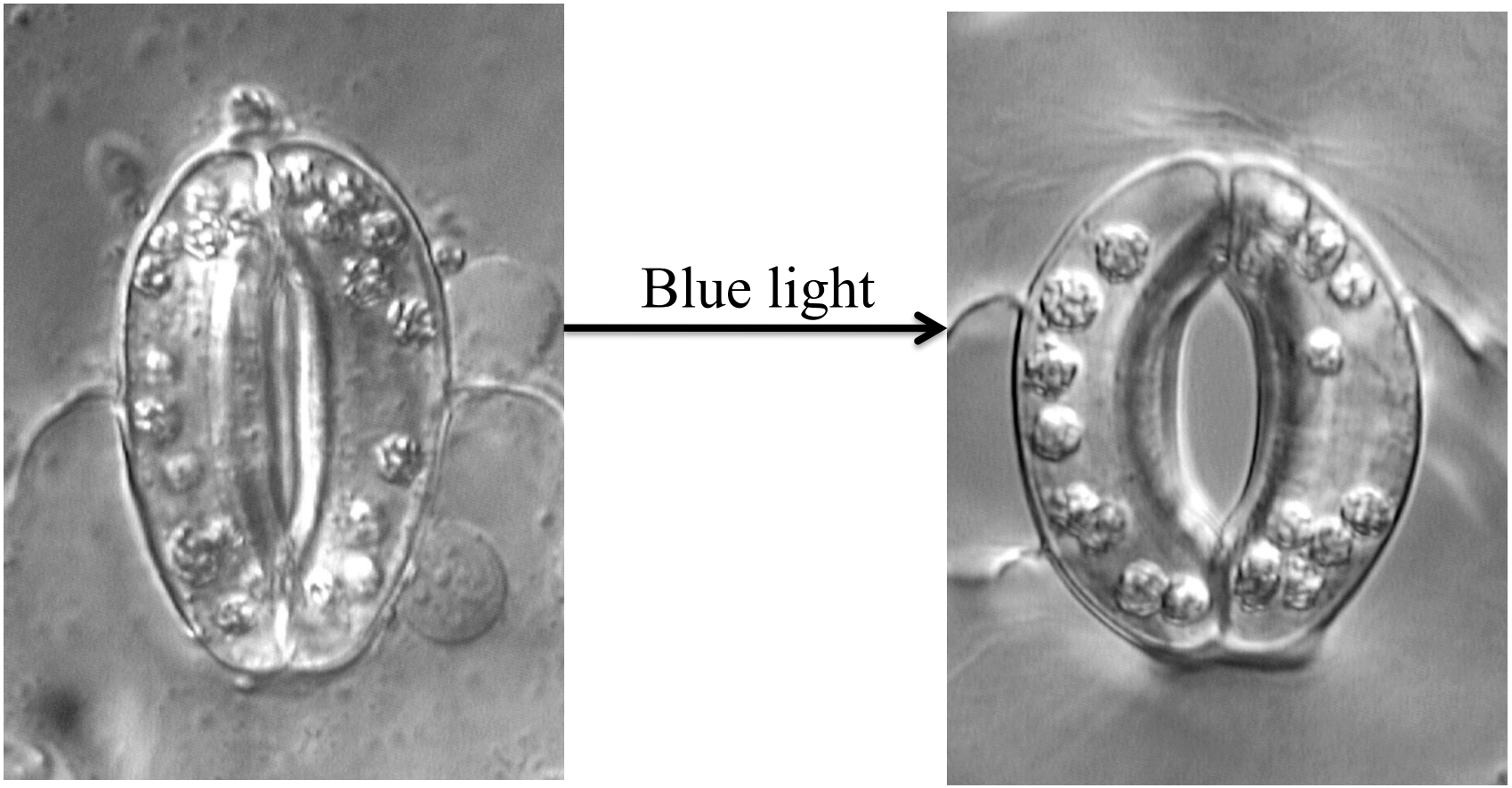
PLANT PHYSIOLOGY, Third Edition, Figure 18.6 © 2002 Sinauer Associates, Inc.

Regulation of chloroplast movement

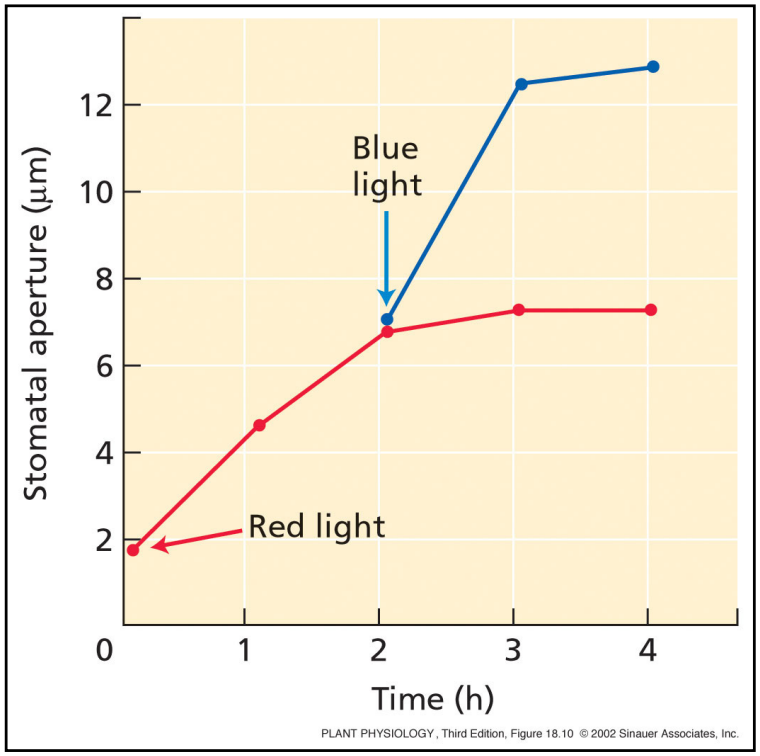


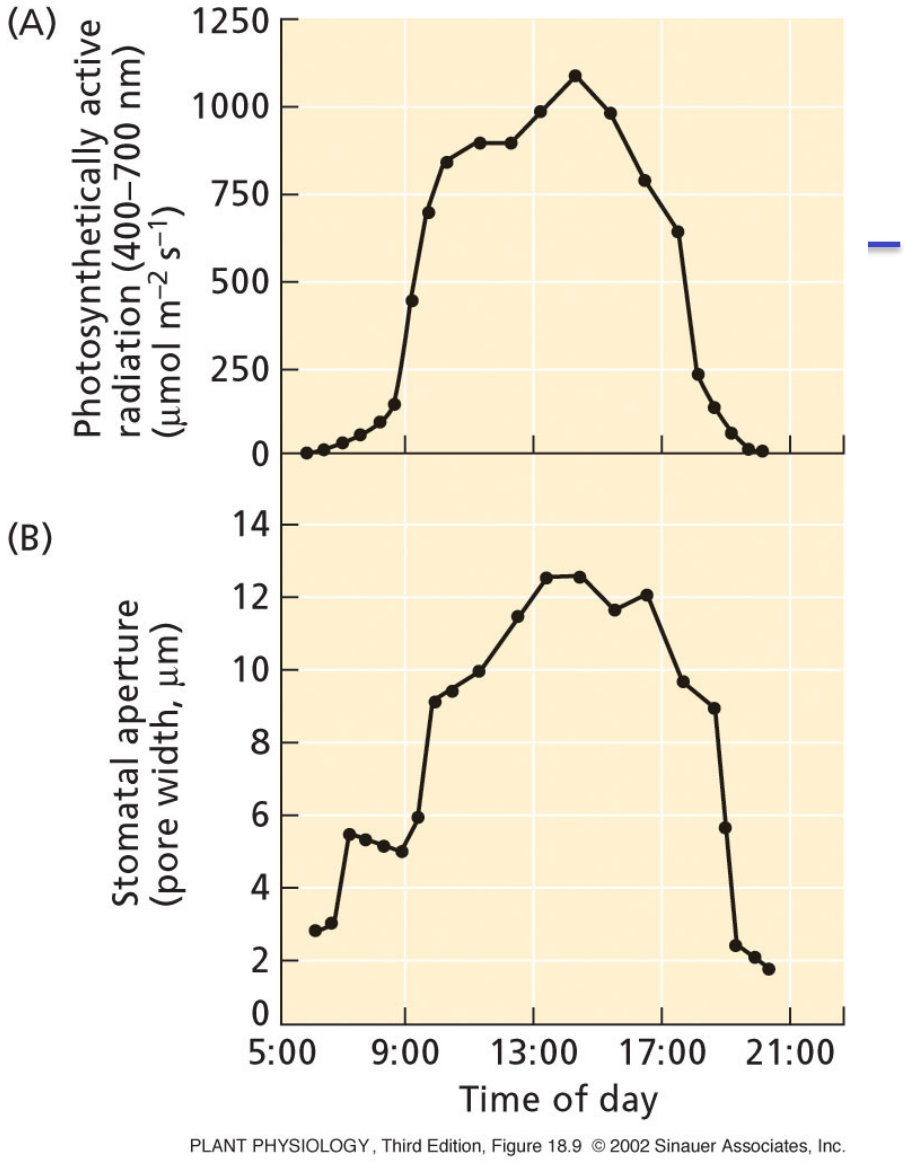


Stimulation of stomatal opening

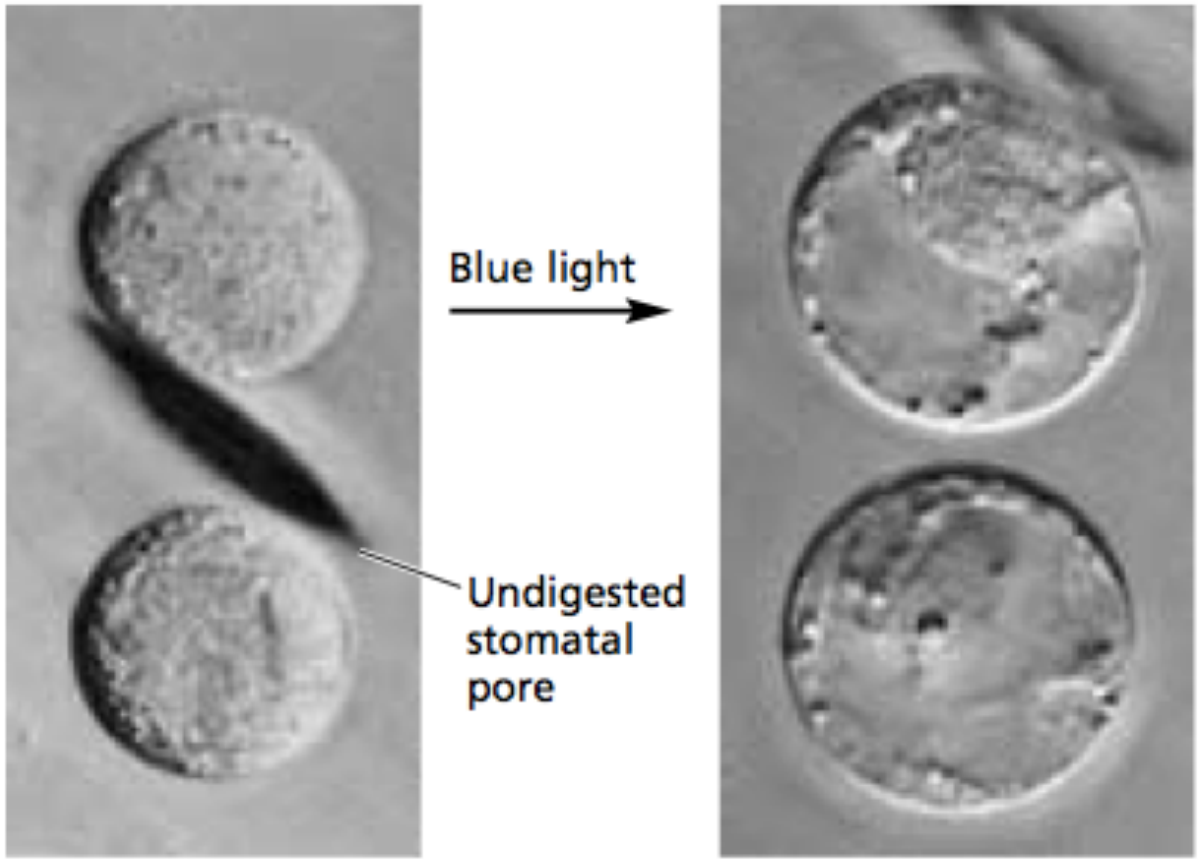


Close correlation between light and stomatal opening

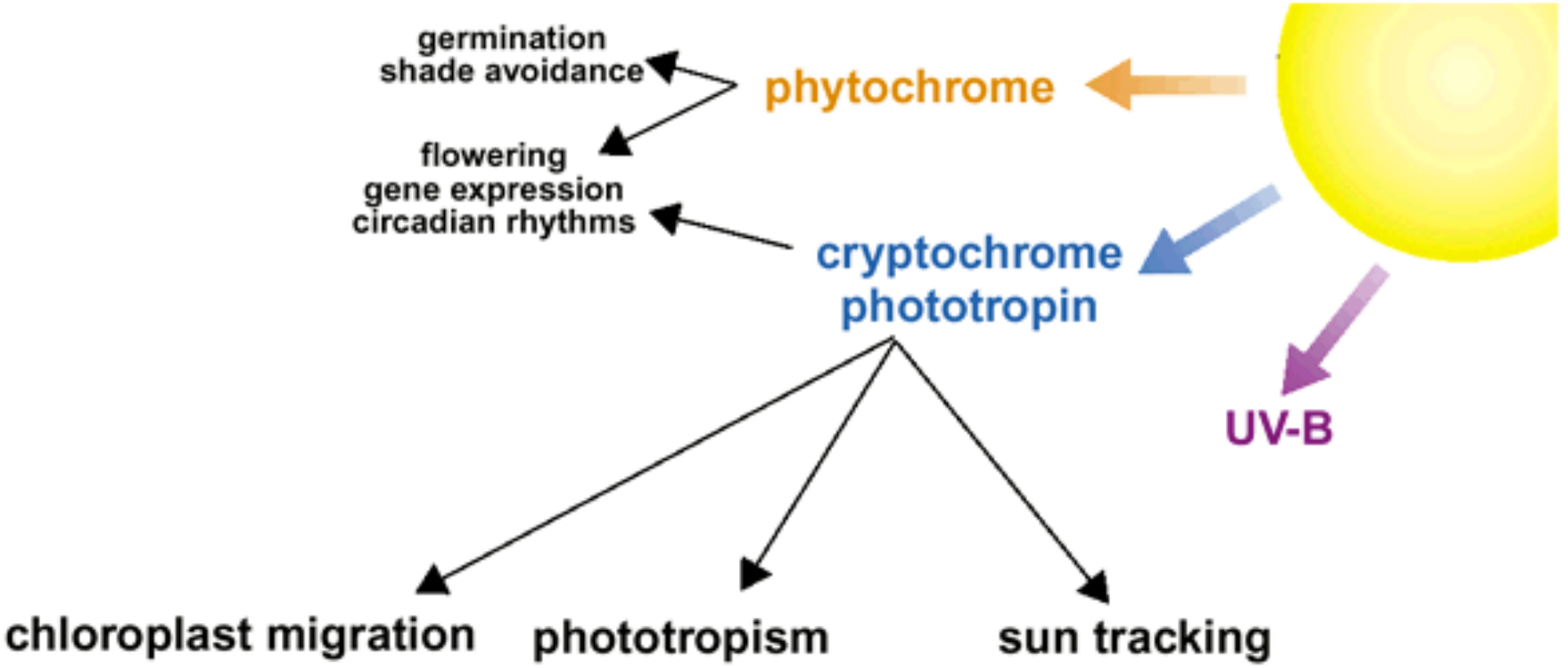




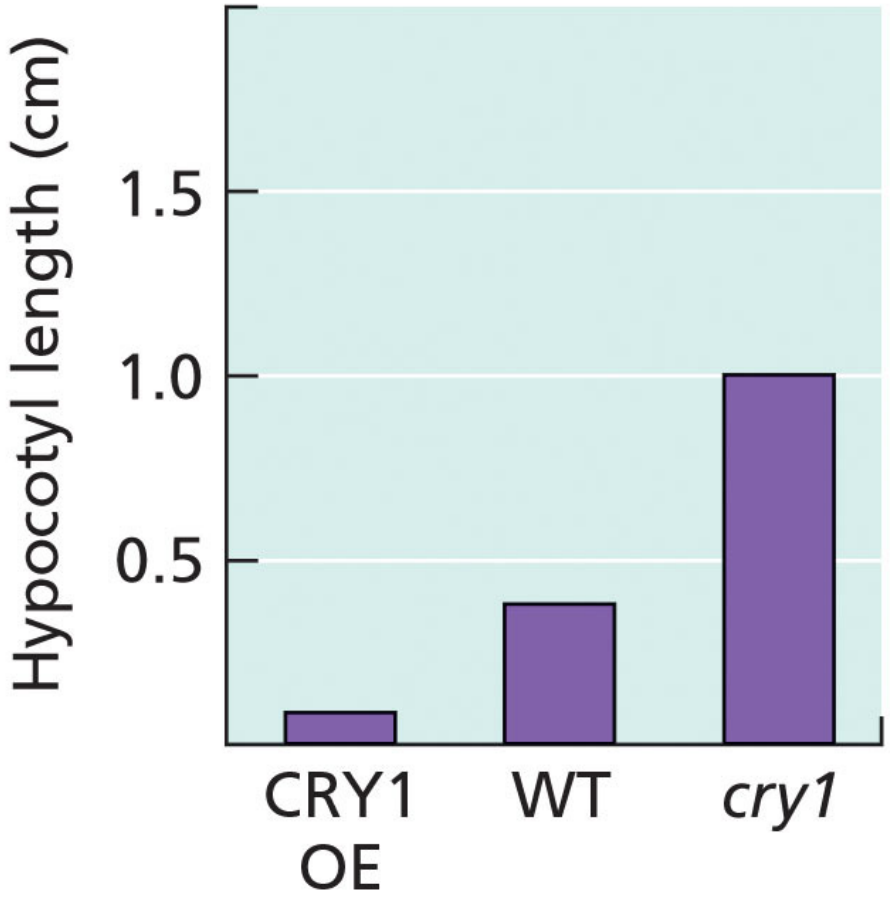
To open stomata, blue light effect on the guard-cells



Concepts: light receptors



Cryptochromes regulate plant development



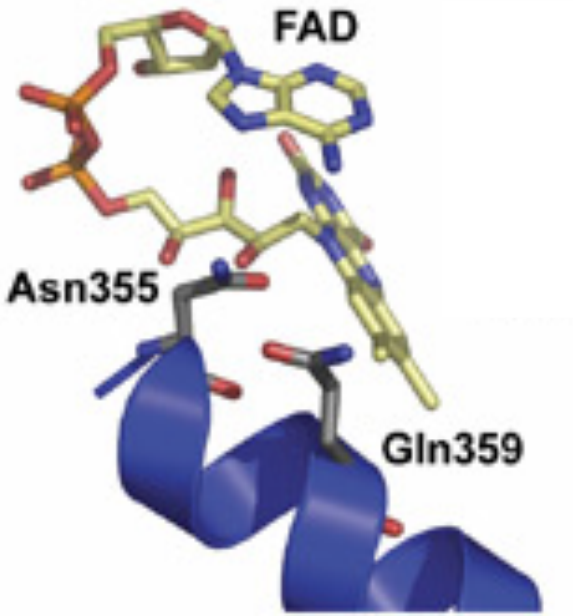
PLANT PHYSIOLOGY, Third Edition, Figure 18.17 © 2002 Sinauer Associates, Inc.

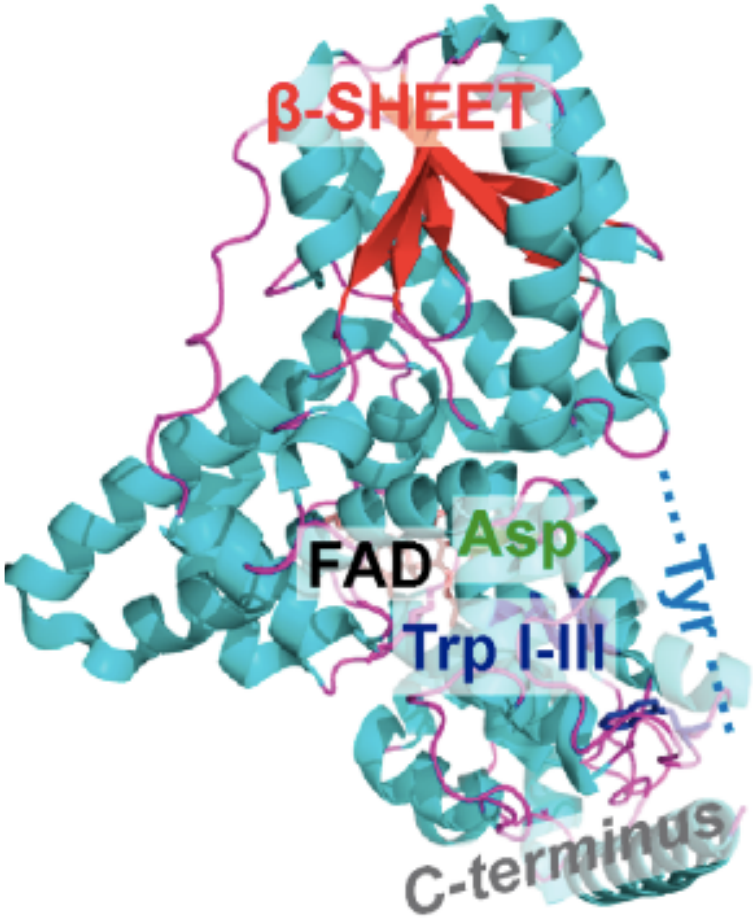
Chemical structure of Cryptochrome

N-terminal: Photolyase homology region (PHR), bind to pterin Methyltetrahydrofolate

Cofactor: FAD

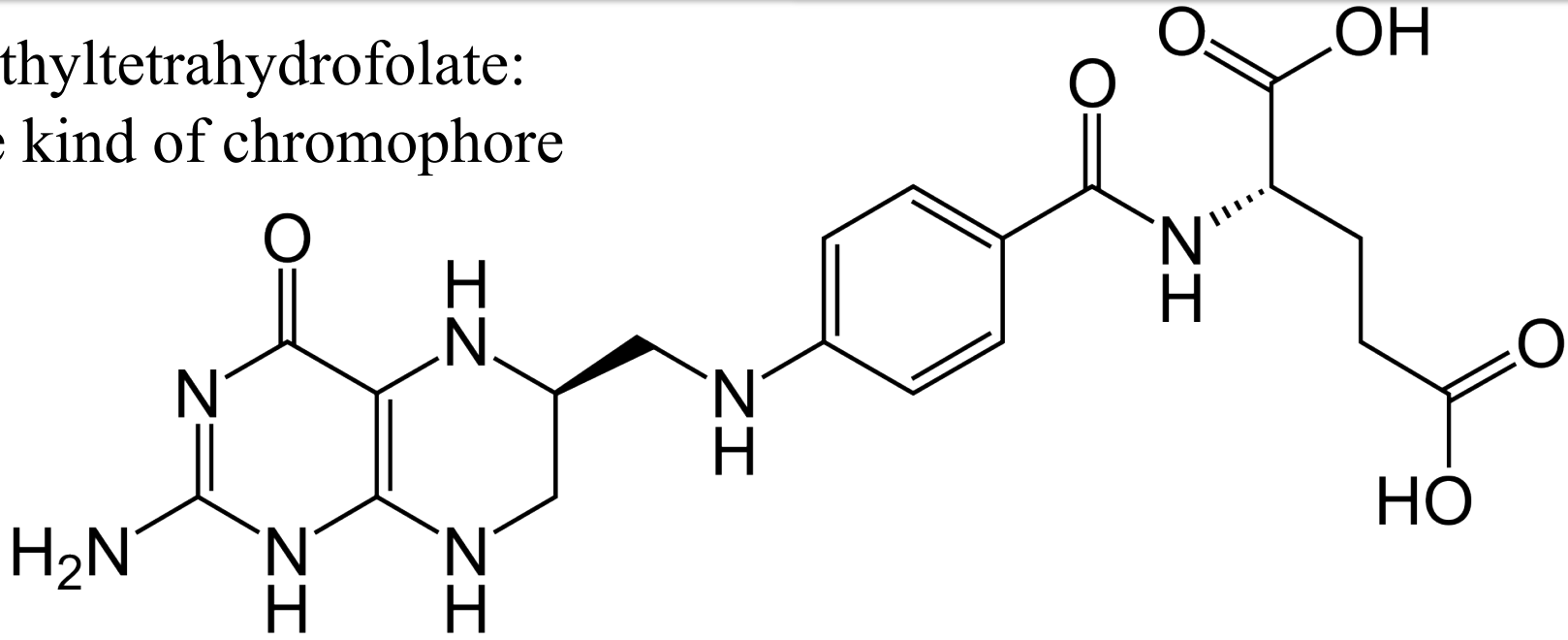
C-terminal:





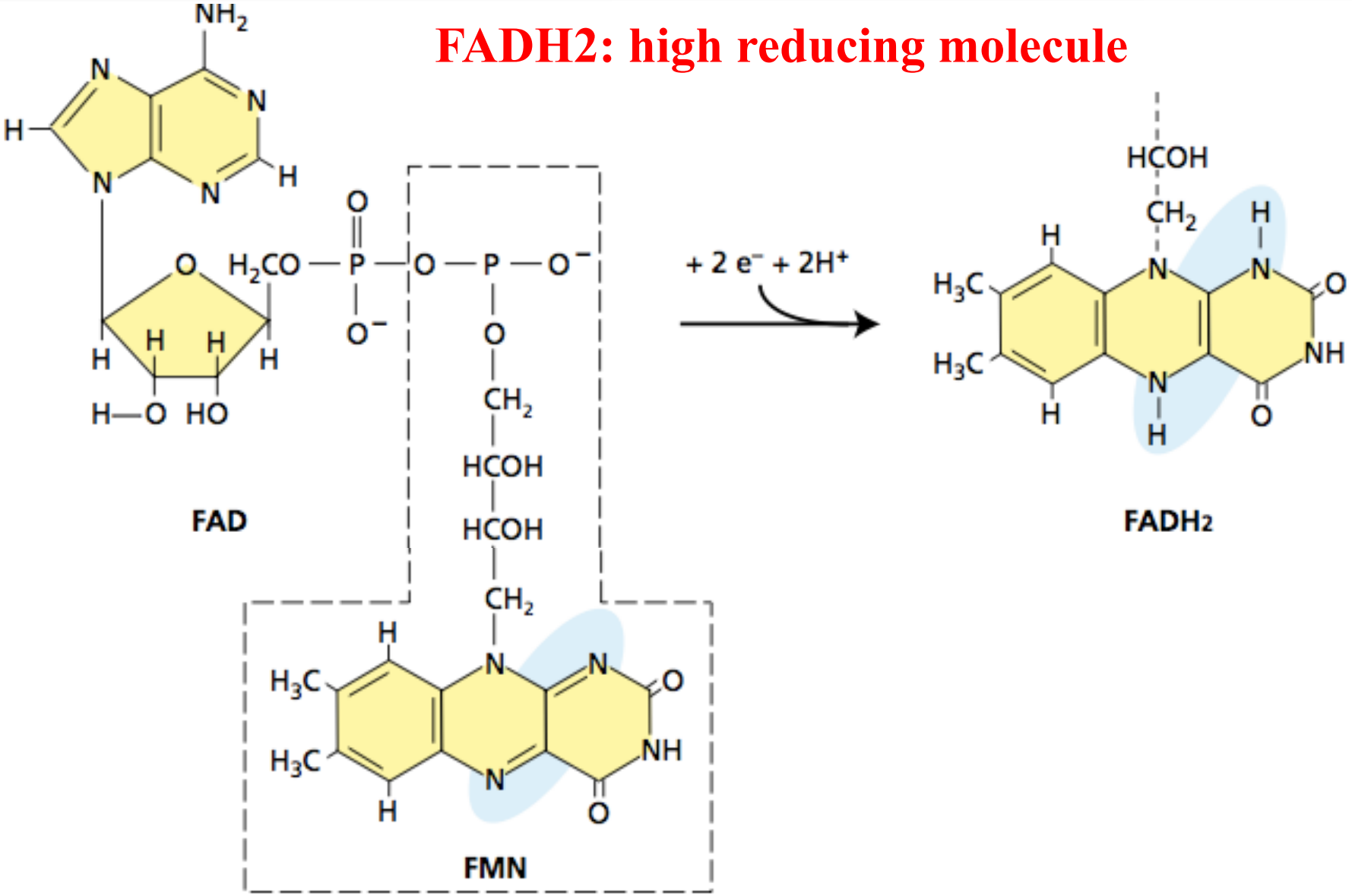
Chemical structure of Cryptochrome

Methyltetrahydrofolate:
one kind of chromophore



Electron transport, ATP synthesis

FADH2: high reducing molecule

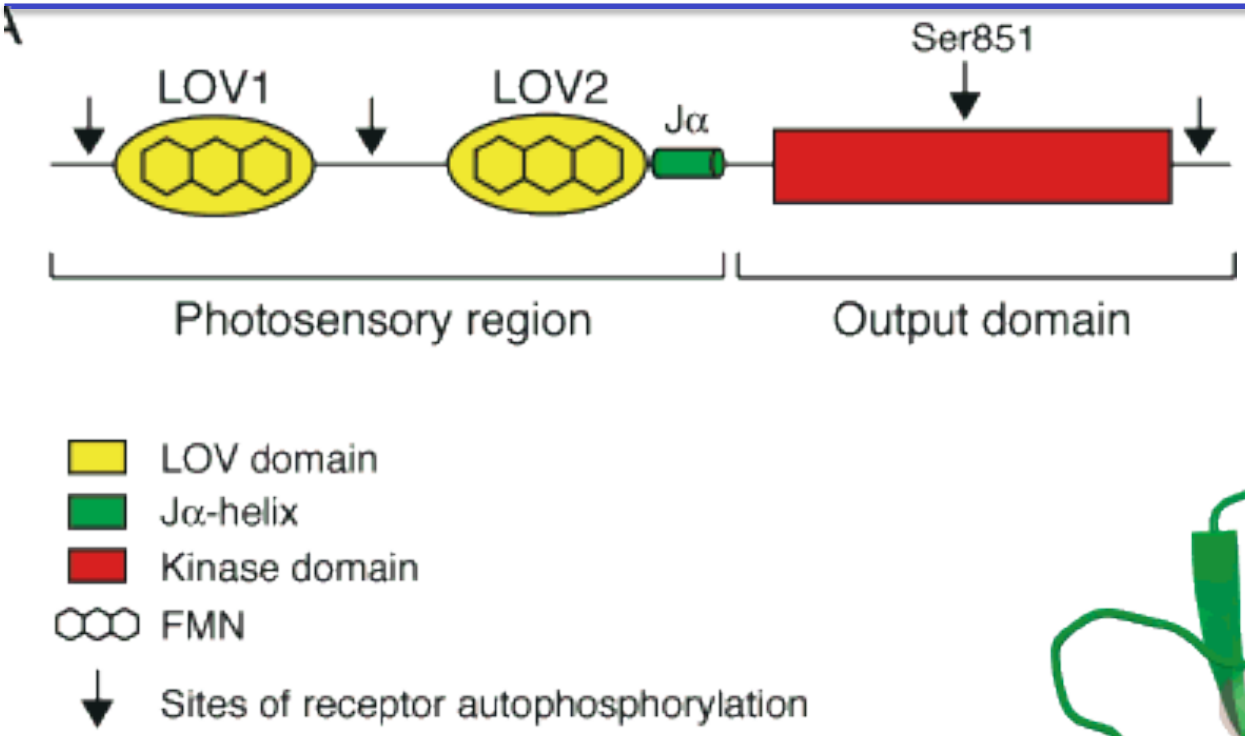


Phototropins regulate phototropism

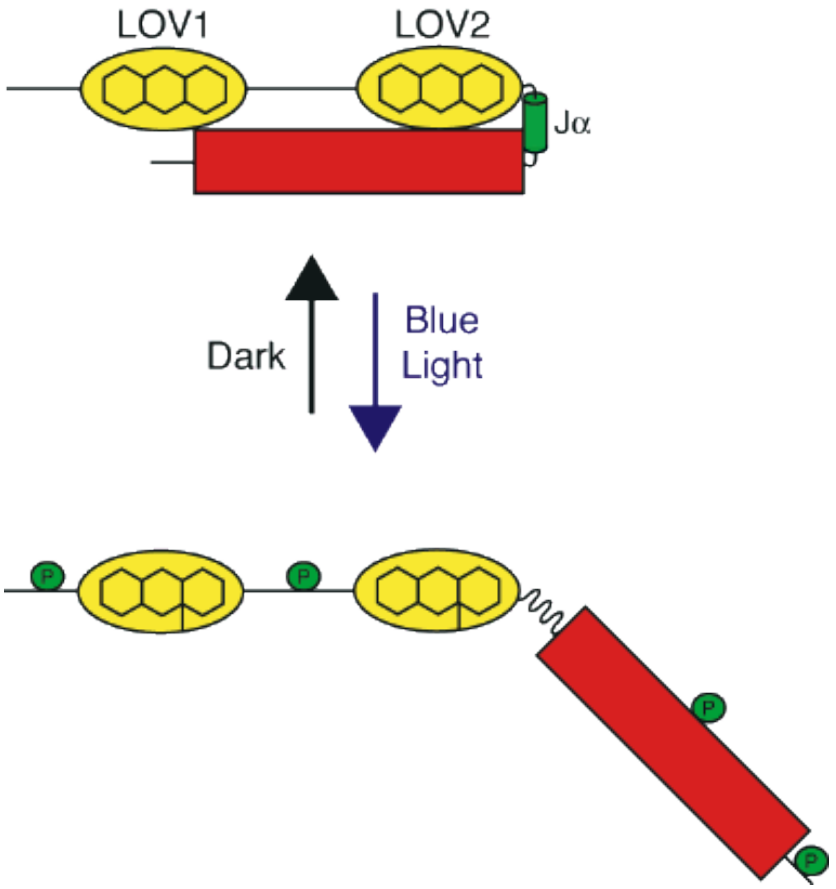
WT | ***nph1* mutant** | **complementation mutant with *nph1* gene**

Seeds were vernalized, given 30 min of red light to stimulate germination, grown for 3 days in darkness, and treated with 16 hours of unilateral blue light from the right.

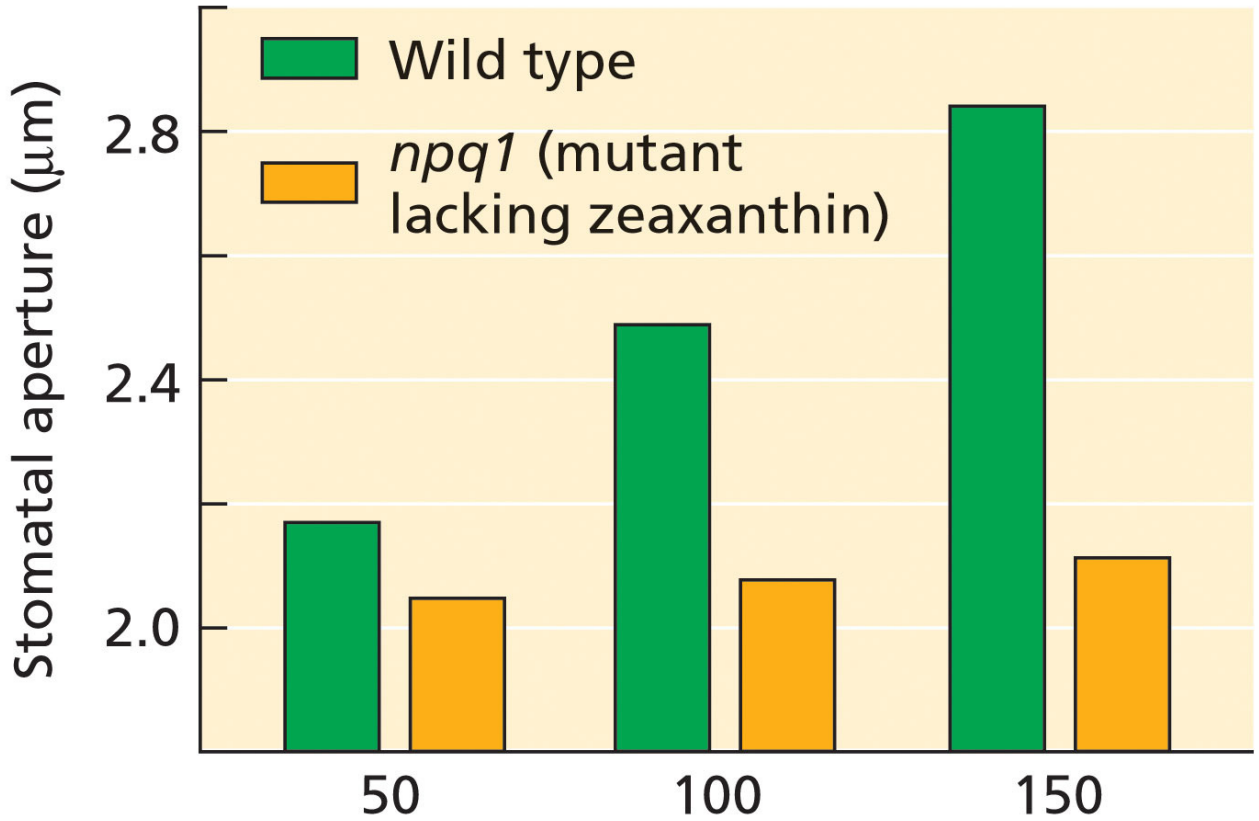
Chemical structure of Phototropins



Chemical structure of Phototropins



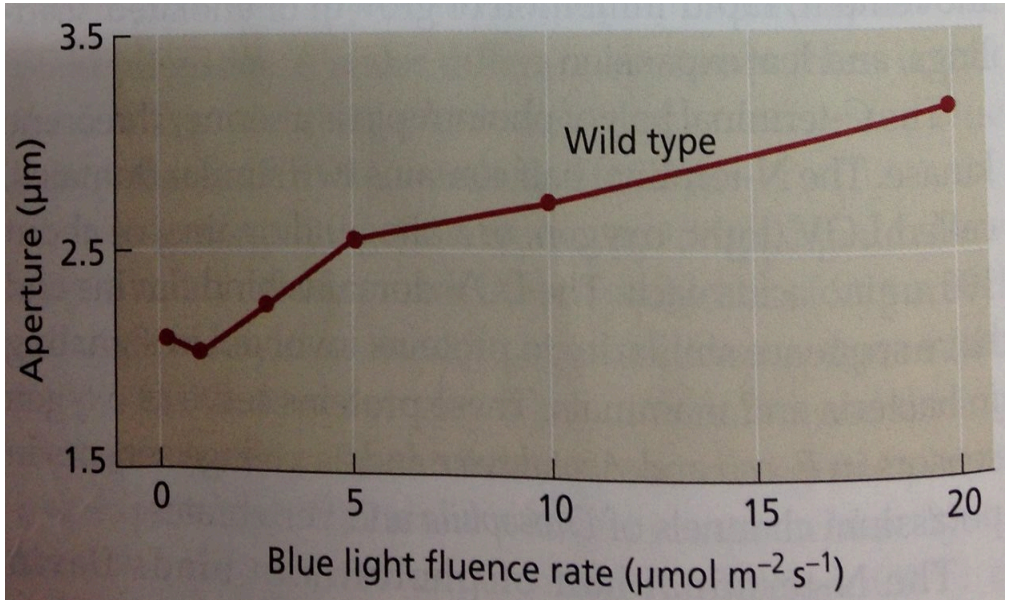
Zeaxanthin regulate stomatal opening

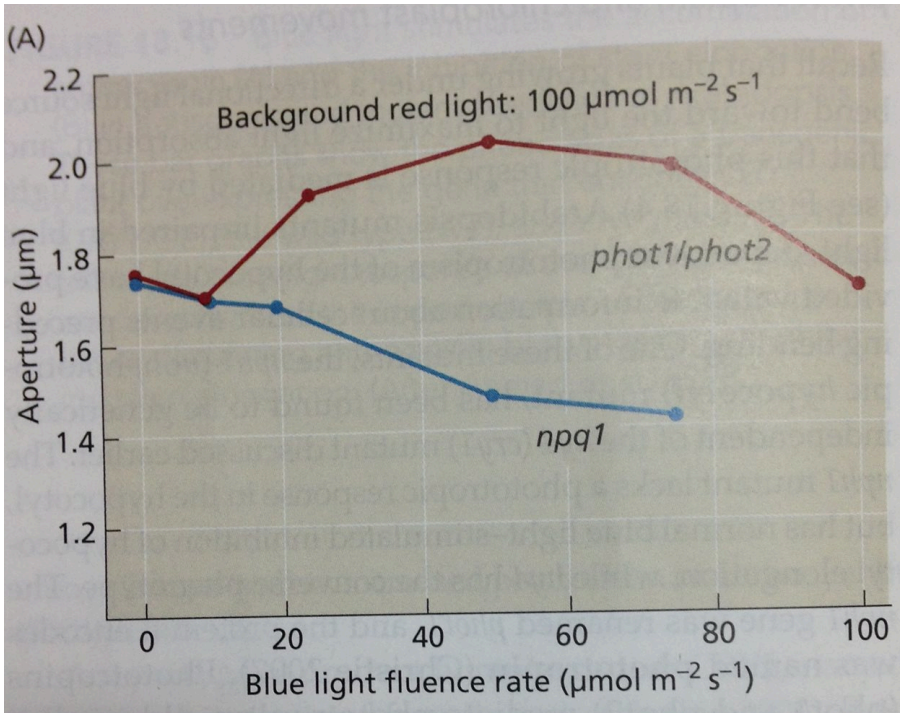


Back ground red light for 2 hours

Treatment with blue light, 1 additional hour

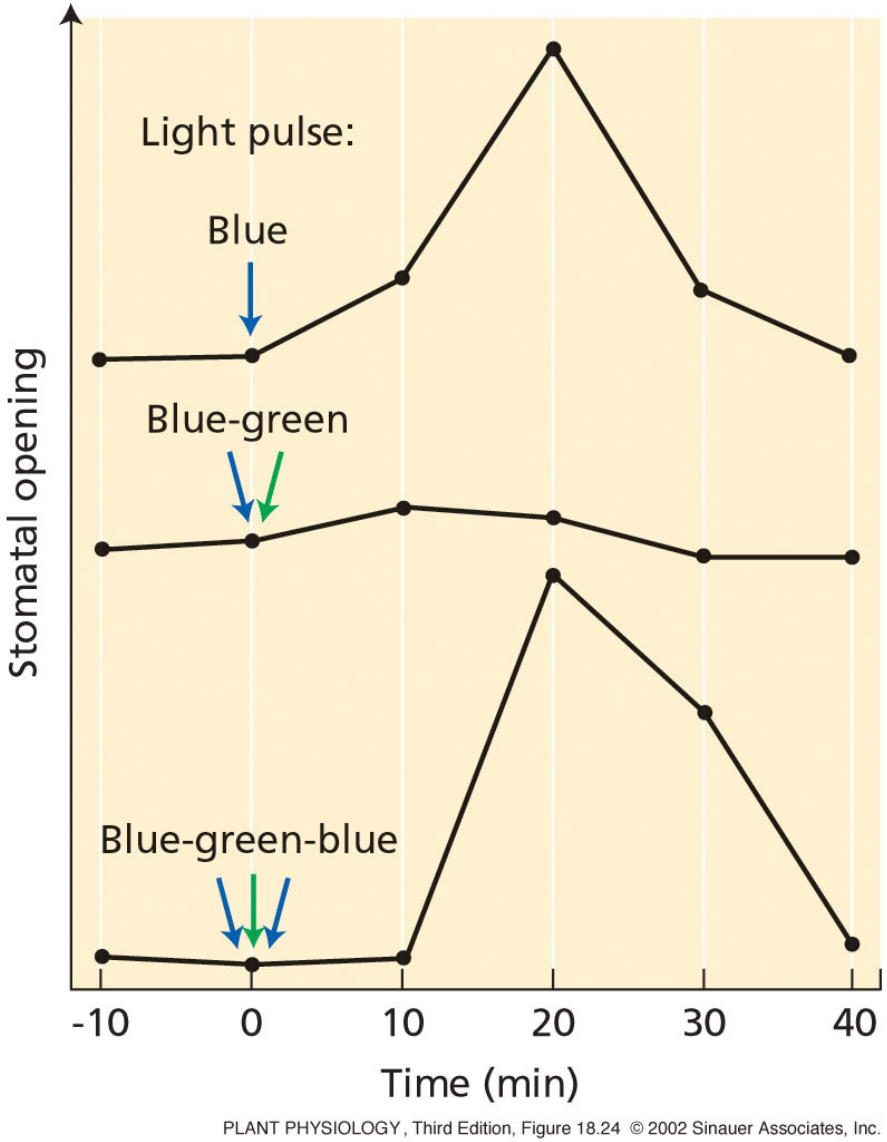
Zeaxanthin regulate stomatal opening





npq1: zeaxanthinless mutant

Zeaxanthin regulate stomatal opening



PLANT PHYSIOLOGY, Third Edition, Figure 18.24 © 2002 Sinauer Associates, Inc.

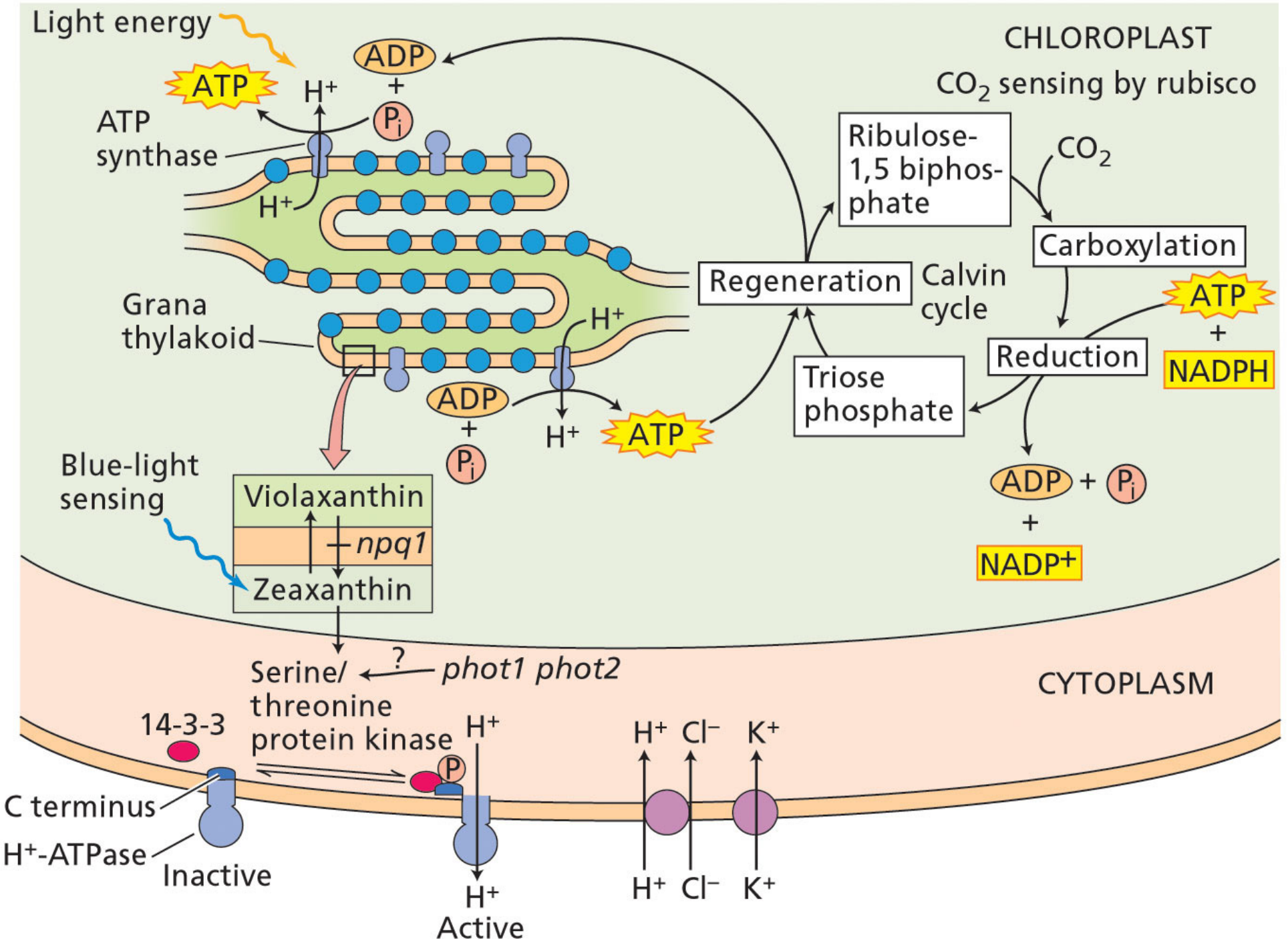
ZEAXANTHIN CAN UNDERO A CIS-TRANS ISOMERIZATION

BLUE

Trans-Zeaxanthin ⇌ **Cis-Zeaxanthin**

GREEN

(THIS MODEL IS STILL HYPOTHETICAL)



PLANT PHYSIOLOGY, Third Edition, Figure 18.21 © 2002 Sinauer Associates, Inc.

Summary-take home message!

- Plants detect parts of the light spectrum that are relevant for photosynthesis.
- Classes of major plant photoreceptors:

    1) Phytochromes: detect red light

    2) Cryptochromes: detect blue light

    3) Phototropins: detect blue light

    4) Zeaxanthin: detect blue light

Summary-take home message!

Phytochrome:
Promote seed germination
Promote de-etiolation
Control shade avoidance
Control circadian entrainment
Control flowering

Zeaxanthin:
Regulate stomatal opening

Phototropin regulate:
Phototropism
Chloroplast movement
Stomatal opening

Cryptochrome:
Promote de-etiolation
Control circadian entrainment
Control flowering