Photomorphogenesis

Photomorphogenesis
(control of growth & development by light)

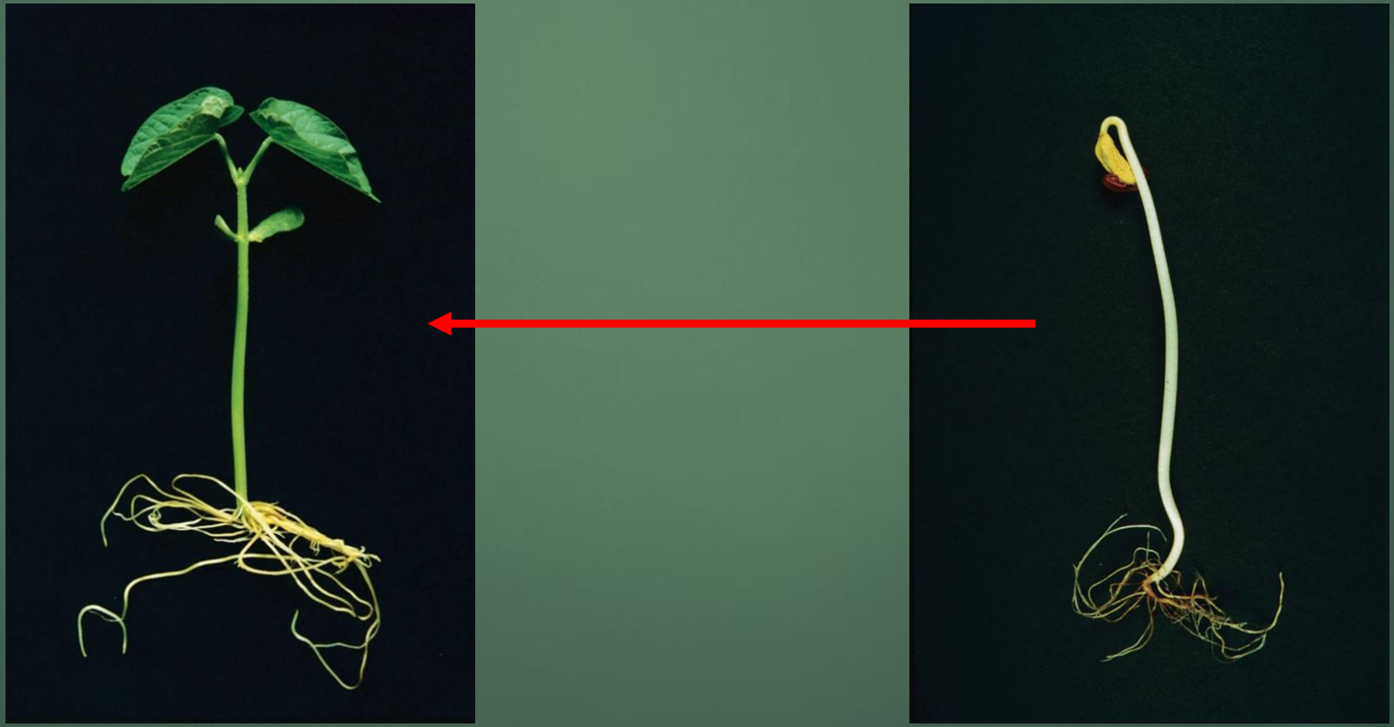
- Environmental signals (light, temperature and gravity) are important signals for plant development

- Light affects many aspects of plant development, for example:

1. required for proper leaf development
2. inhibits stem elongation in the emerging seedling
3. promotes flowering (photoperiodism)
4. promotes (or inhibits) seed germination

Light and plant development

Photomorphogenesis – a change in plant development induced by specific kinds of light and not dependent on photosynthesis.



Photomorphogenesis involves special photoreceptors that initiate developmental changes.

Photoreceptors transduce information in the environment into appropriate developmental patterns.

Information examples

- position in a layered plant canopy
- seed depth in soil
- presence of competitors
- approach of sunrise
- day length

Flowering is an important phase of life cycle because the transition from vegetative growth to reproductive phase involves several changes in the physiology of a plant. Flowering is a decisive stage. It require a definite period of vegetative growth. The period may vary from plant to plant example, a fruiting tree requires several years while an annual herb flowers in a few months only. The physiological mechanism responsible for flowering has been found to be controlled by 1) periodicity of light(Photoperiodism) 2) temperature (Vernalisation)

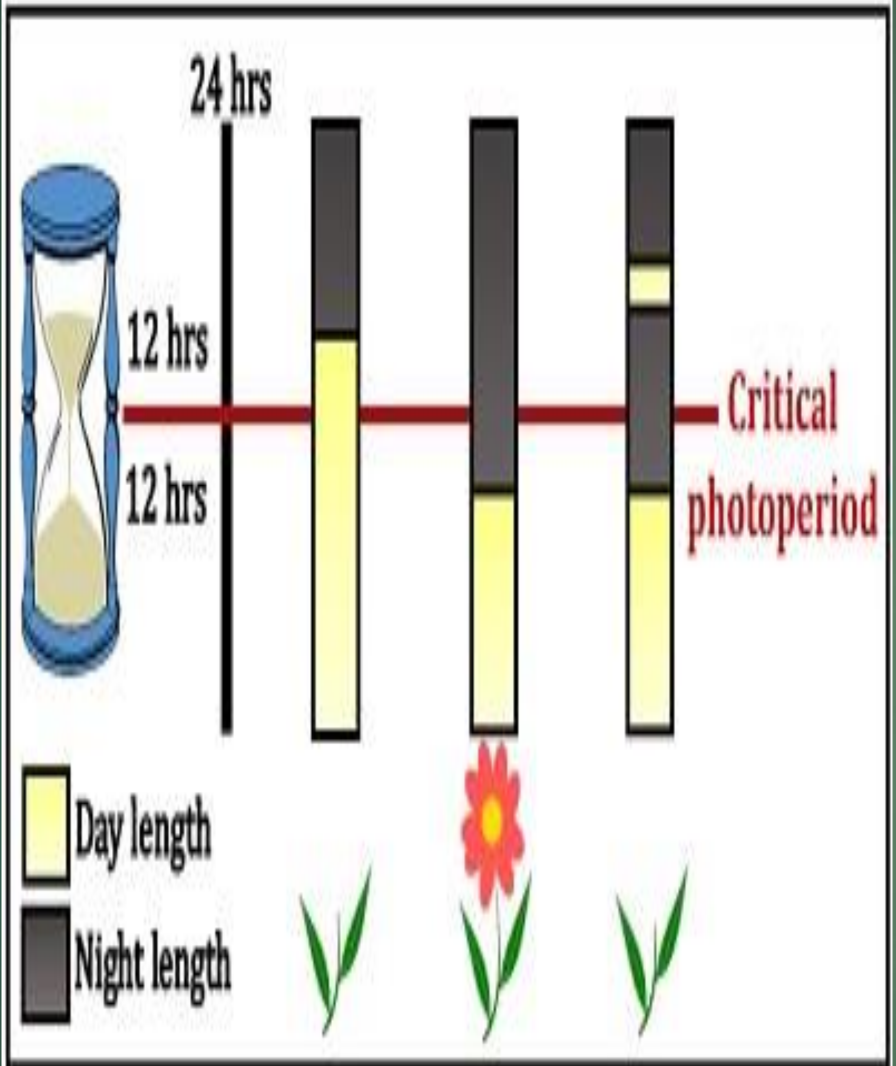
The plant in order to flower require a certain day length that is the relative length of day and night which is called as photoperiod. the response of plants show the photoperiod expressed in the form of flowering is called as photoperiodism.

The phenomenon of photoperiodism was first discovered by Garner and Allard (1920) who observed that Biloxi variety Soybean and Maryland Mammoth variety of tobacco could be made to flower only when the daily exposure to the light was reduced below a certain critical duration and after many complex experiments concluded that the relative length of the day is first importance in the growth and development of plants.

Photoperiodism can define as one of the plant's mechanisms where it can sense the alternations in the day and night length through the photoreceptor proteins and decides when to induce flowering. That's why different plant species develop flowers on different seasons, which is only due to the difference in the length of photoperiod.The photoreceptors like phytochromes and cryptochromes can perceive the light stimulus and can produce signals to induce flowering in a plant with respect to the critical length of photoperiod. Critical photoperiod can define as the minimum duration of light required to induce flowering.

Depending upon the duration of photoperiod, they classified plants into main three categories:

1. Short day plant(long night plant)- SDP
2. Long day plant(short night plant)- LDP
3. Day neutral plants- DNP



FLOWERING IN SHORT DAY PLANTS

Short day plant(Long-night plant)

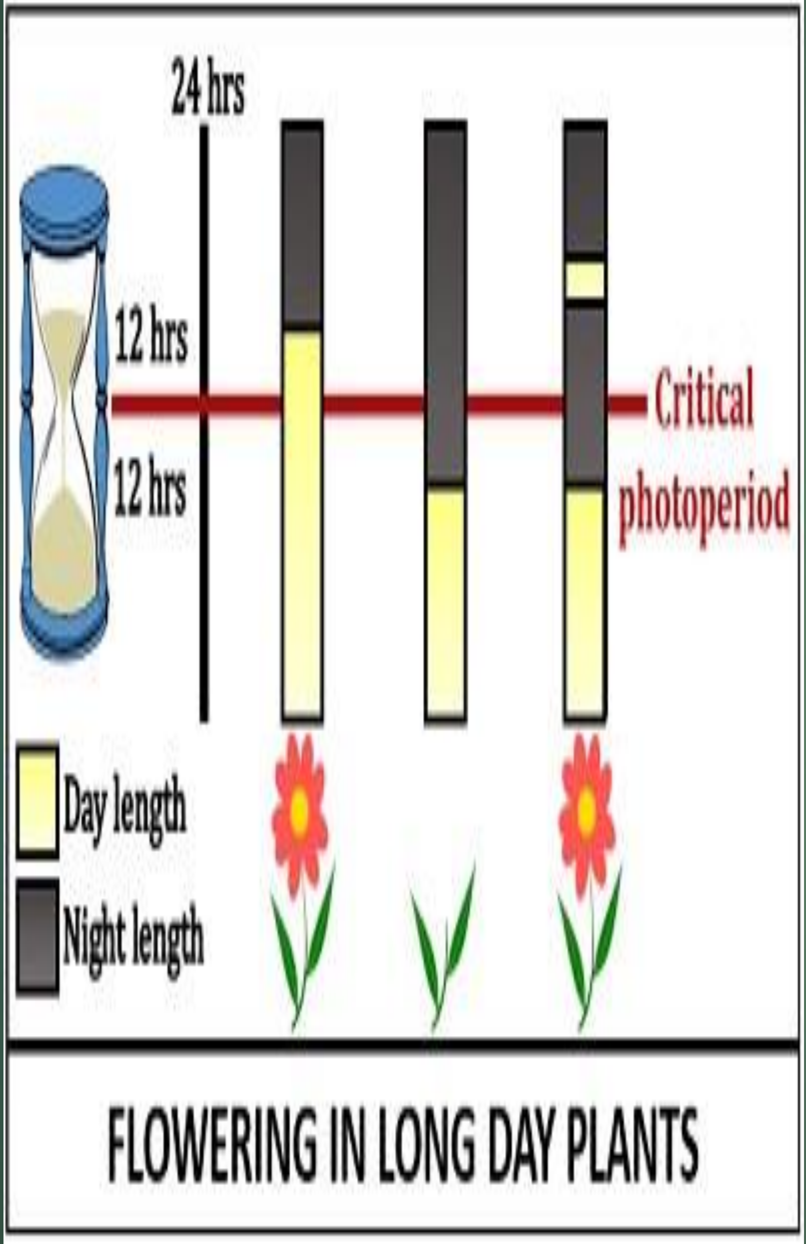
These plants required are relatively short daylight period(usually 8 to 10 hours) and a continuous dark period of about 14 to 16 hours for subsequent flowering.

example- Maryland Mammoth variety of tobacco, Biloxi variety of Soybean.

1. In short day plants the dark period is critical and must be continuous. if this dark period is interrupted with a brief exposure red light(660- 665 micrometre wavelength), the short day plant will not flower.
2. Maximum inhibition of flowering with red light occurs at the middle of critical dark period.

Contd...

3. The inhibitory effect of red light can be overcome by a subsequent exposure with far-red light(730- 735 micrometre wavelength).
4. Interruption of the light period with red light does not inhibitory effect on flowering in short day plant.
5. Prolongation of the continuous dark period initiates early flowering in short day plants.

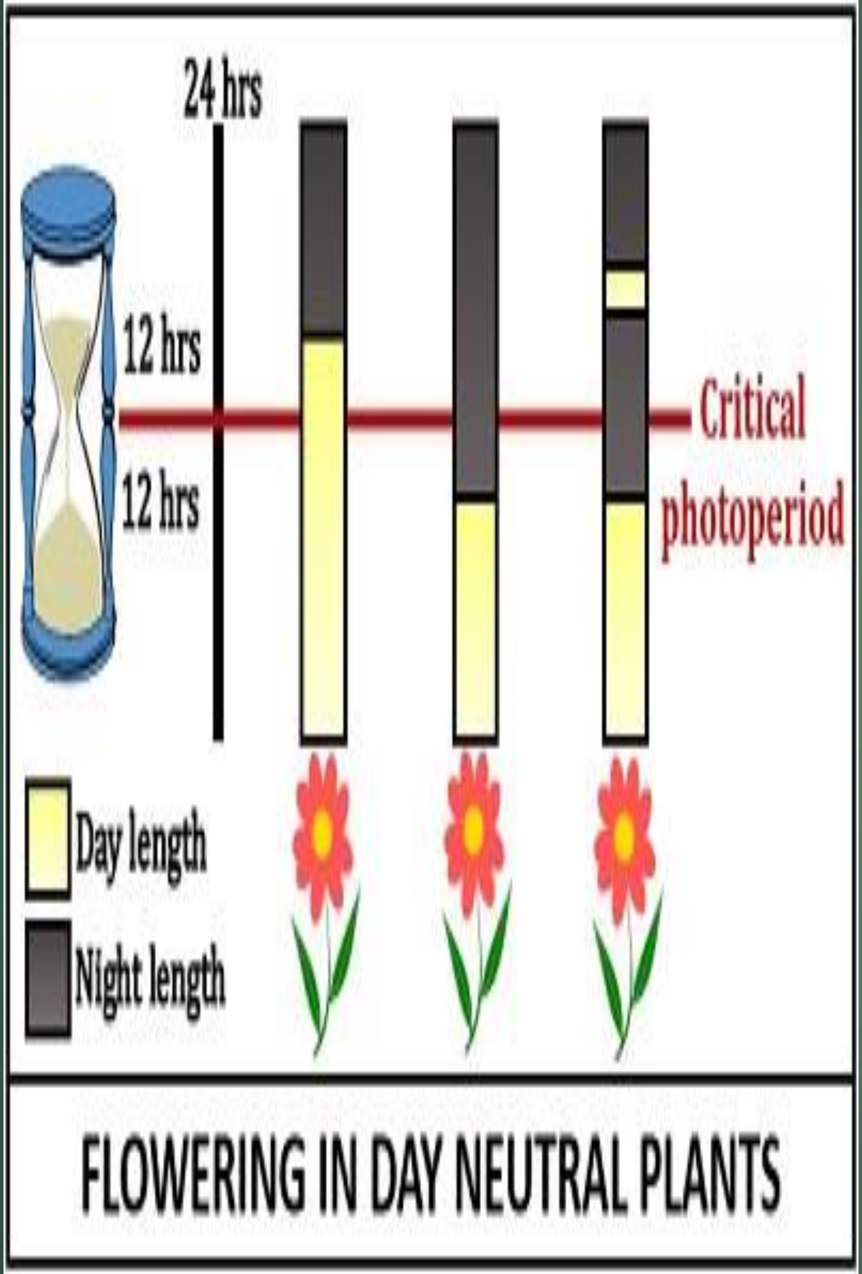


Long day plants(Short night plants)

These plants are required a longer light period(usually 14 to 16 hours) in 24 hours cycle to subsequent flowering.

Examples- spinach, sugar beet

1. In long day plants the light period critical.
2. A brief exposure in the dark period or the prolongation of the light period stimulates flowering in long day plants.



Day neutral plants

These plants flower in all photoperiod ranging from 5 hours to 24 hours continuous exposer.

Example- cotton, tomato, sunflower

Long short day plants

These are short day plants but mast exposed to long days during early periods of growth for subsequent flowering.

Example- *Bryophyllum, Cestrum nocturnum*

Short long day plants

These are long day plants but must be exposed to short days during early periods of growth for subsequent flowering.

Example *Sickle, Triticum*

Intermediate day plants

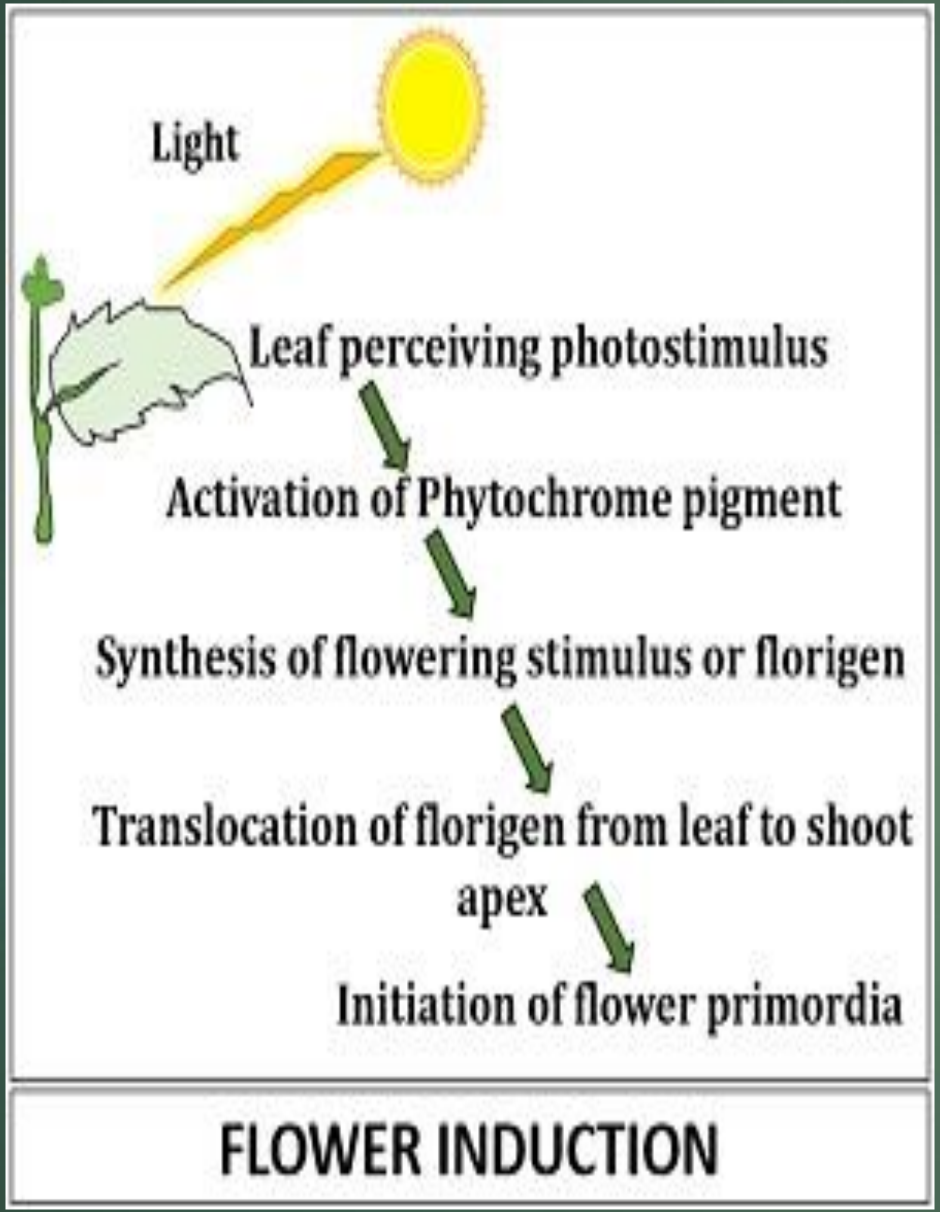
Plants flower when days are neither too long or too short.

Example- *Saccharum spontaneum, Coleus hybrida*

Amphiphotoperiodic plant

Plants quantitatively by intermediate day lengths.

Example- *Madia elegans, Setaria verticillata*



Photoperiodic induction

An appropriate photoperiod in 24 hours' cycle constitutes one inductive cycle. Plants may require one or more inductive cycles for flowering. The phenomenon of conversion of leaf primordia into flower primordia under the influence of suitable inductive cycles is called photoperiodic induction. Example: Xanthium (SDP) – 1 inductive cycle and Plantago (LDP) – 25 inductive cycles.

Site of Photoinductive perception

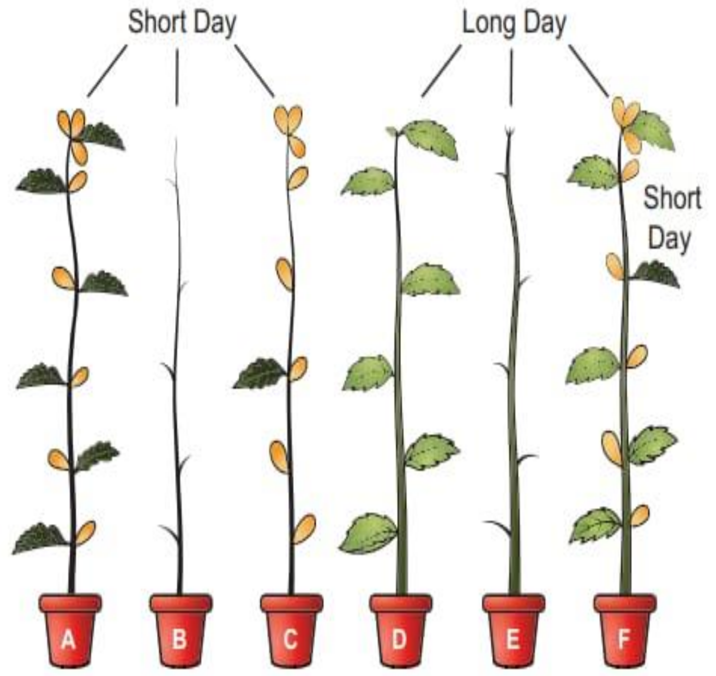


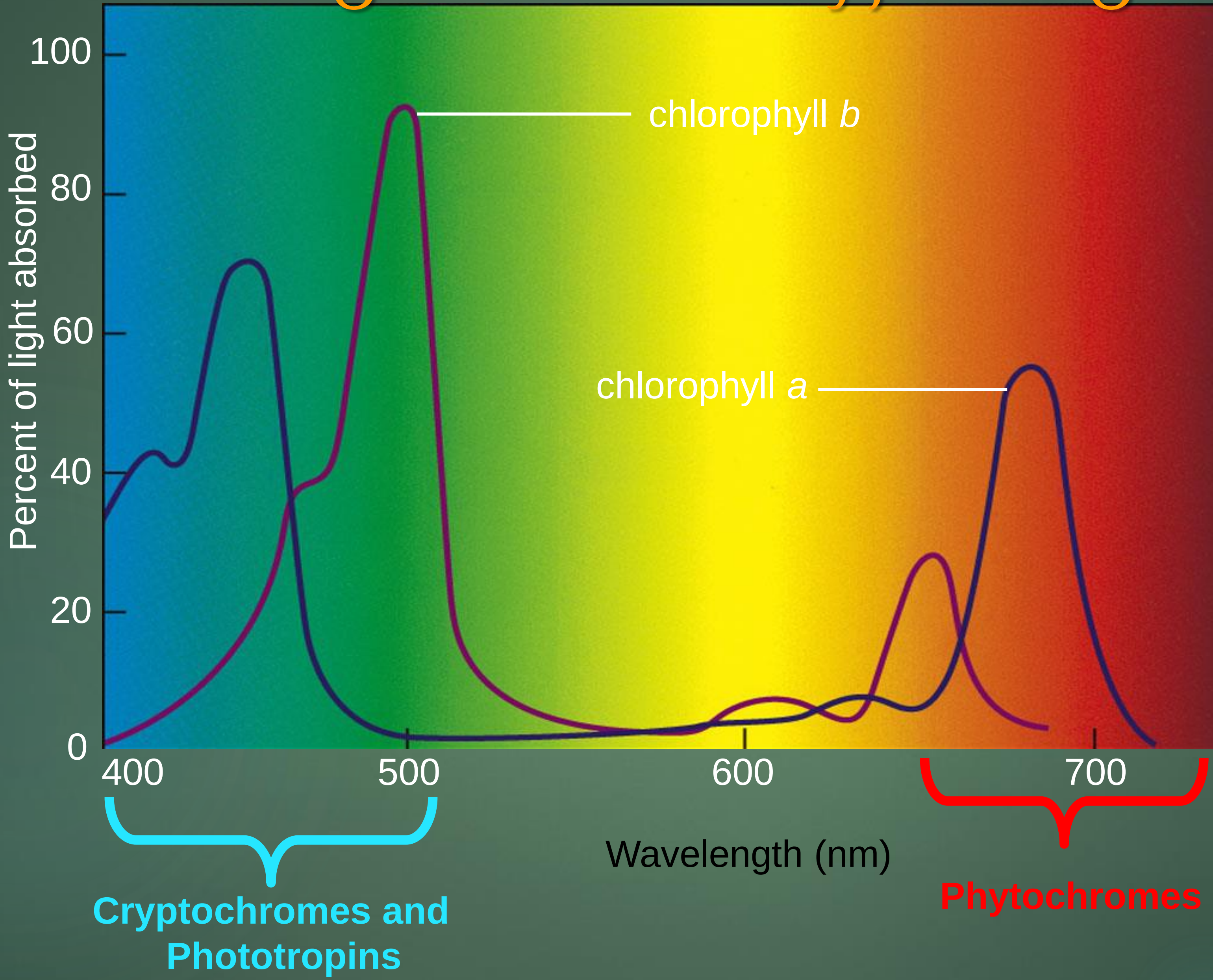
Figure 15.25: Experiment on Cocklebur plant showing photoperiodic stimulus

Photoperiodic stimulus is perceived by the leaves. Floral hormone is synthesised in leaves and translocated to the apical tip to promote flowering. This can be explained by a simple experiment on Cocklebur (*Xanthium pensylvanicum*), a short day plant. Usually *Xanthium* will flower under short day conditions. If the plant is defoliated and kept under short day conditions it will not flower. Flowering will occur even when all the leaves are removed except one leaf. If a cocklebur plant is defoliated and kept under long day conditions, it will not flower. If one of its leaves is exposed to short day condition and rest are in long day condition, flowering will occur.The nature of flower producing stimulus has been elusive so far. It is believed by many physiologists that it is a hormone called florigen. The term florigen was coined by Chailakyan (1936) but it is not possible to isolate.

Light and Plant Development

- 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

Light wavelengths detected by plant light receptors



Phytochromes

- Phytochrome protein occurs as a dimer of two 124 kDa polypeptides, each with a covalently-attached pigment molecule.
- The pigment is called chromophore. It is a linear tetrapyrrole.
- When the chromophore absorbs light, there is a slight change in its structure. This causes a change in the conformational of the protein to the form that initiates a response.
- Molecular genetics has revealed the existence ofseveral genes for this protein in a given plant.
- The different phytochromes are involved in different biological responses to red light.
- Plants make 5 phytochromes: Phy A, Phy B, Phy C , Phy D , Phy E.

History of Phytochrome discovery

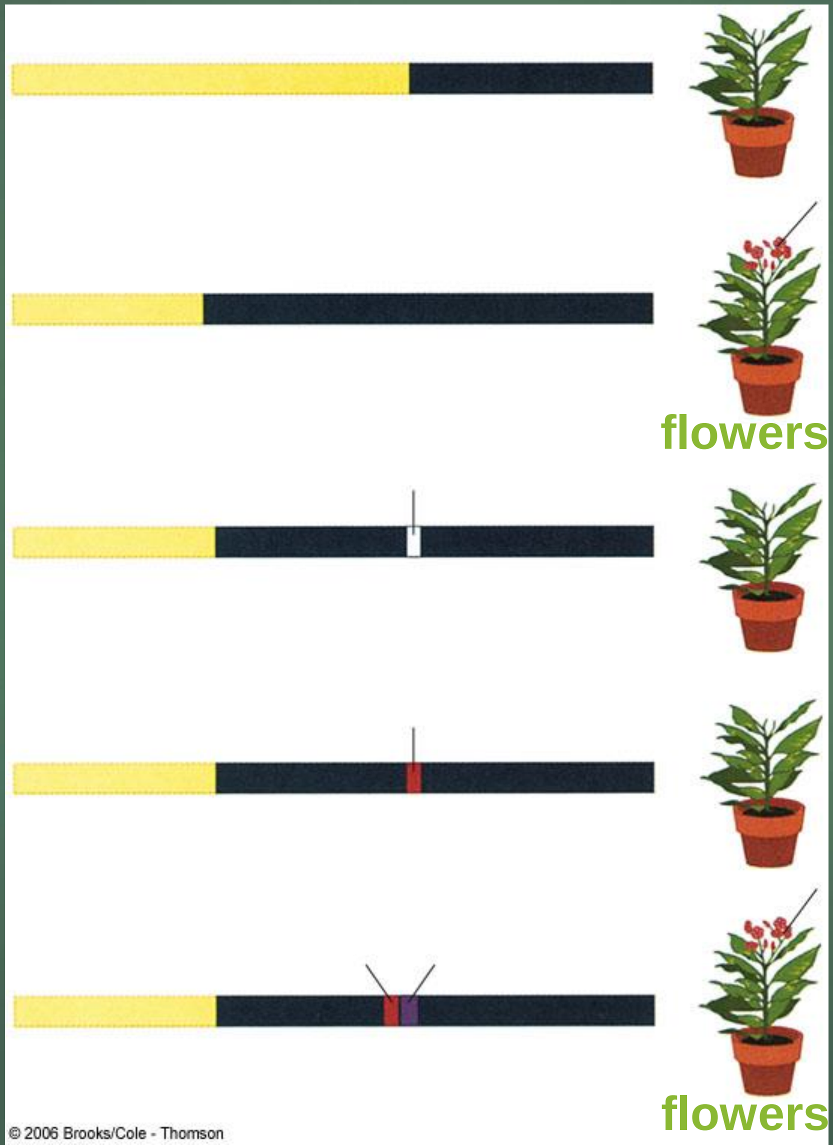
long day, short night

short day, long night

short day, interrupted night

short day, red interruption

short day, red followed by far-red



Short-day plants flower only when nights are sufficiently long. When long nights are interrupted by a short dose of white light, flowering is again delayed. The active wavelength for this light-response was found to be red light. Moreover, the effect of the red light treatment could be suppressed by treatment with far red light.

Suggests the existence of a receptor protein that is activated by red light and inhibited by far red light.

Experimental evidences

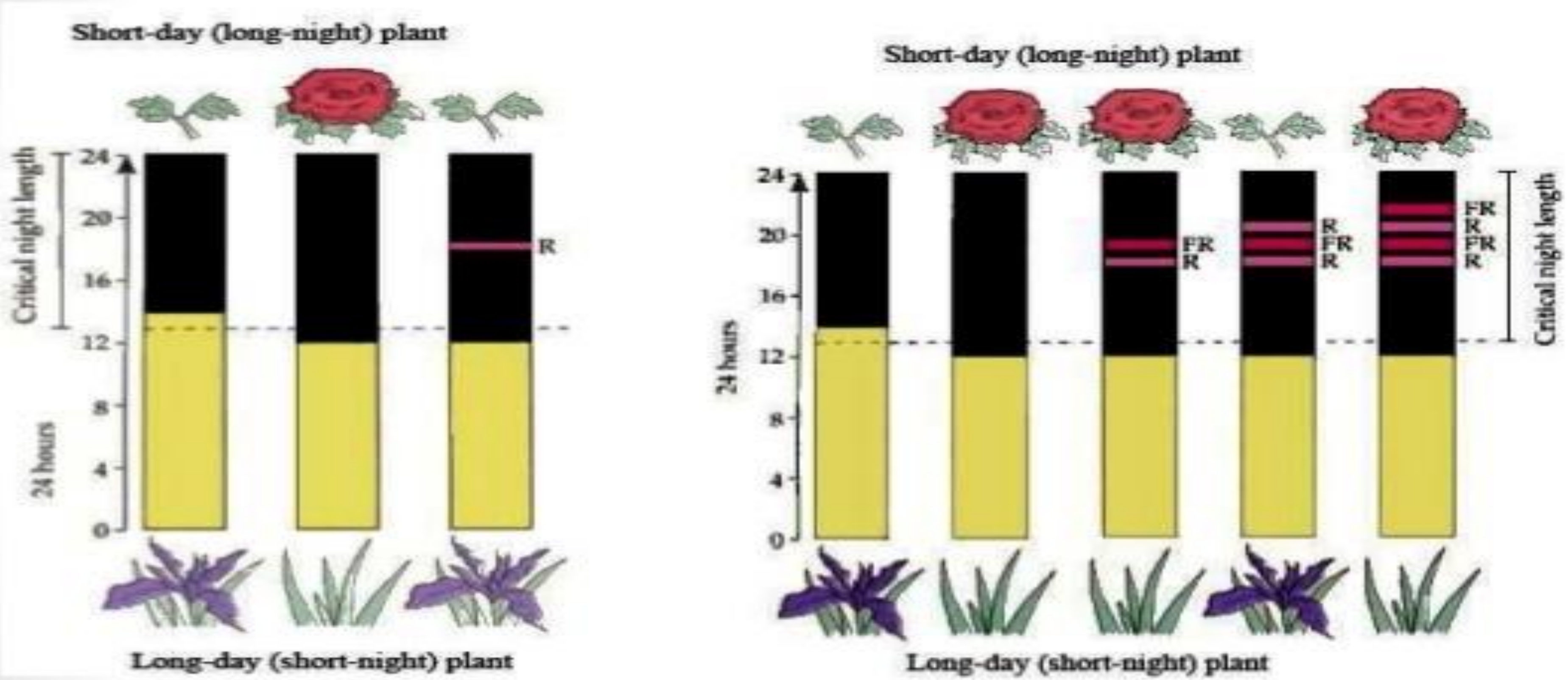
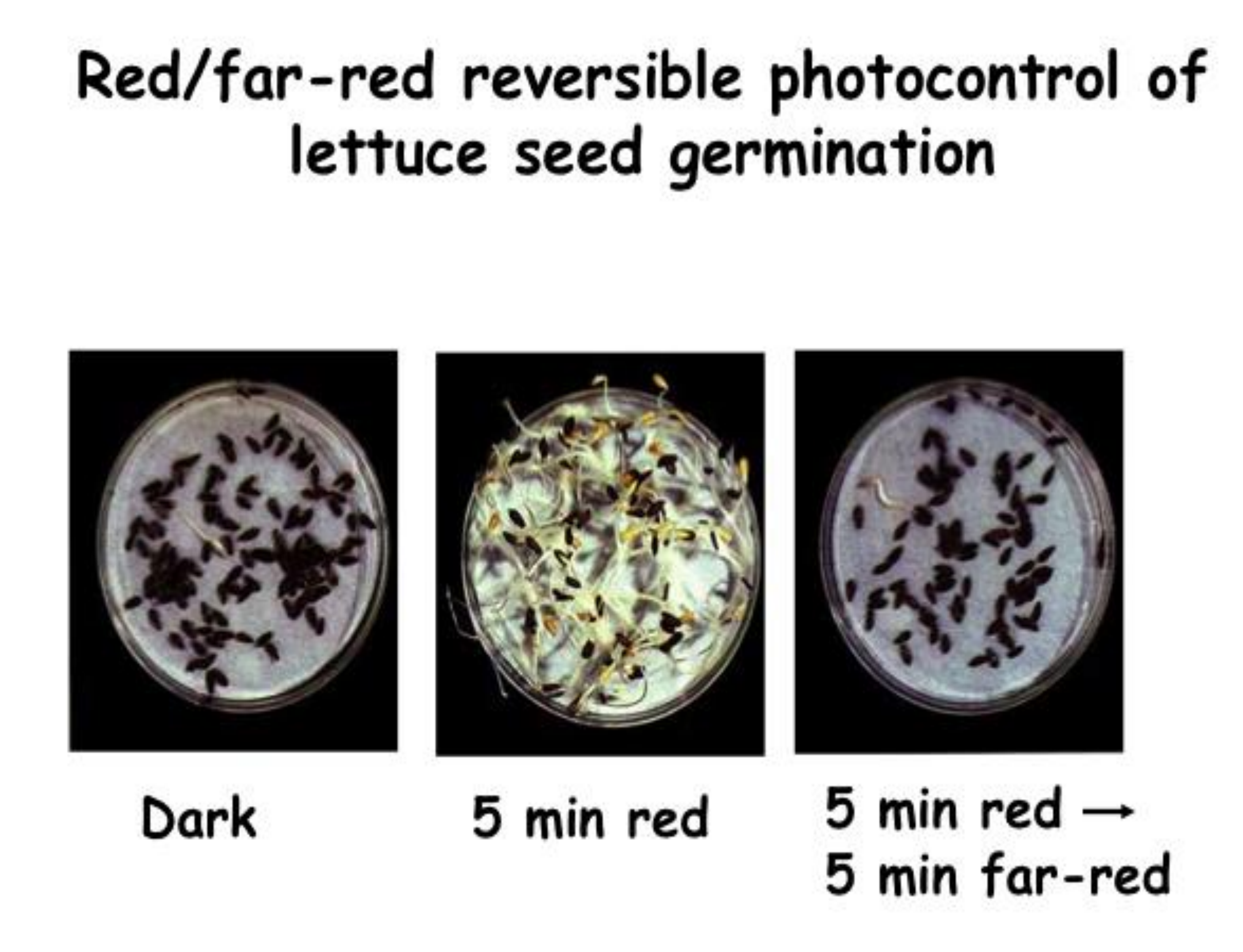


Fig- Effects of flashes of red and far red light on flowering in LDP and SDP (figure 39.18, page 768, Campbell's *Biology, 5th Edition)*

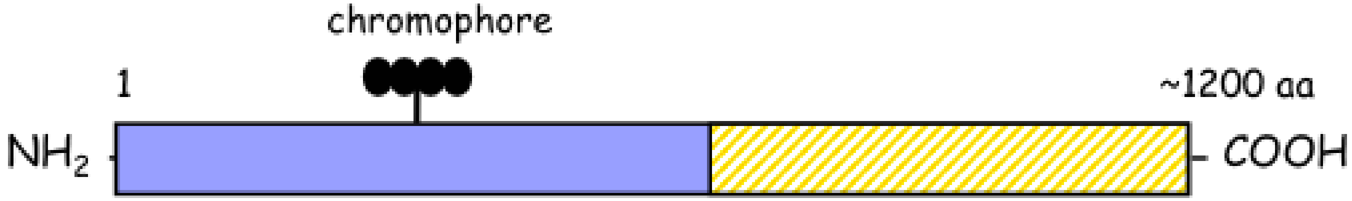
History of Phytochrome discovery



Phytochrome was also shown to control the germination of seeds. Red light (activates the receptor) promotes seed germination and far red light suppresses the red light effect.

Phytochrome structure

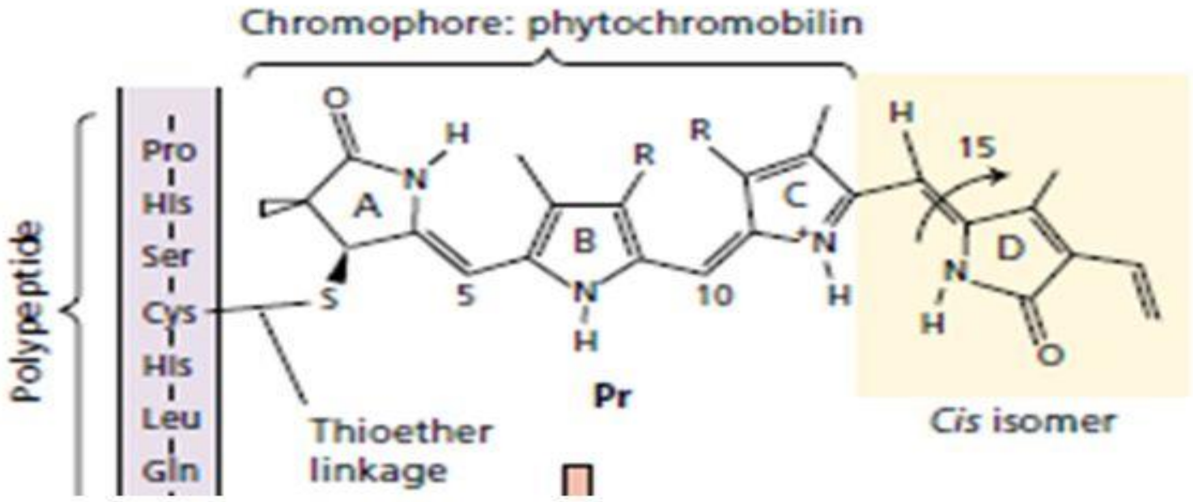
A protein linked to a chromophore.



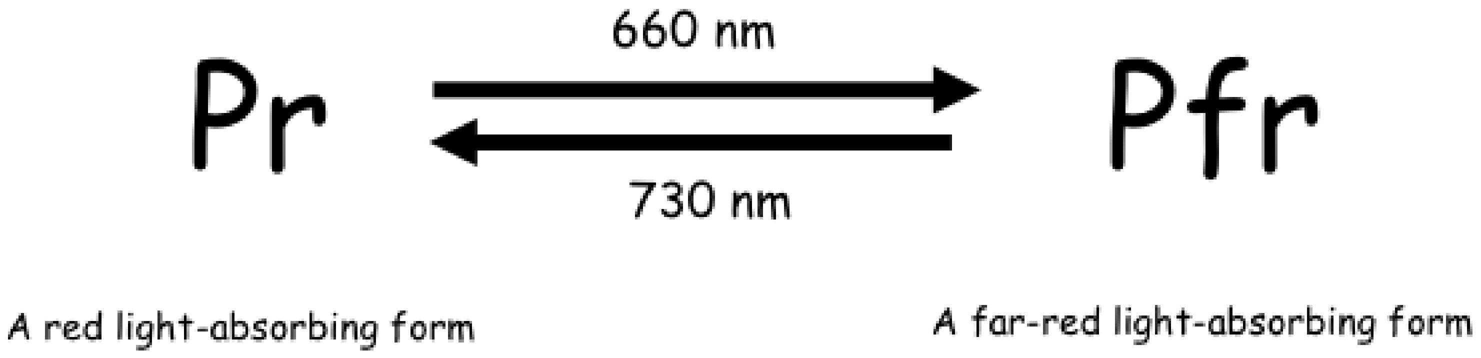
The chromophore (a tetrapyrrole compound) allows phytochrome to change in response to red or far-red light.

STRUCTURE OF PHYTOCHROME

- Phytochrome → a dimer → @ holoprotein (chromophore + apoprotein)
- Chromophore: a light-absorbing pigment molecule
- In higher plants, the chromophore is called phytochromobilin
- Apoprotein**:** a polypeptide chain
- Chromophore attached to apoprotein, through a thioether linkage to a cysteine residue



The predicted properties of the receptor

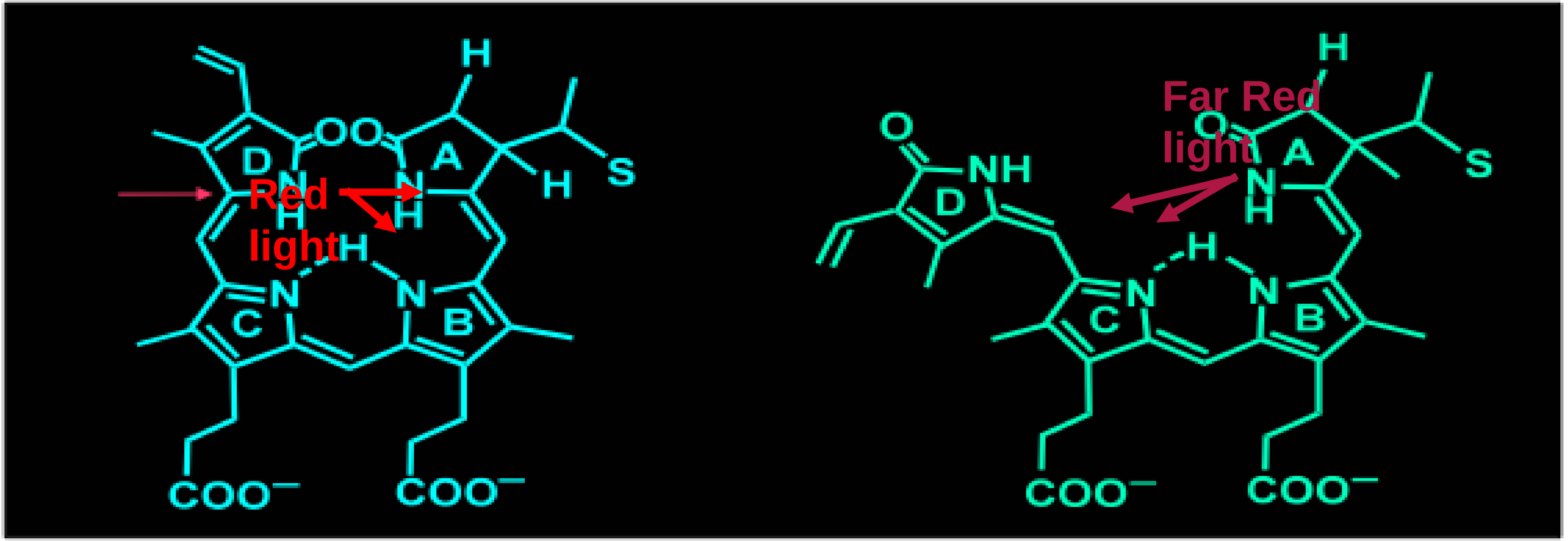


The photoreceptor should show light-induced absorbance changes

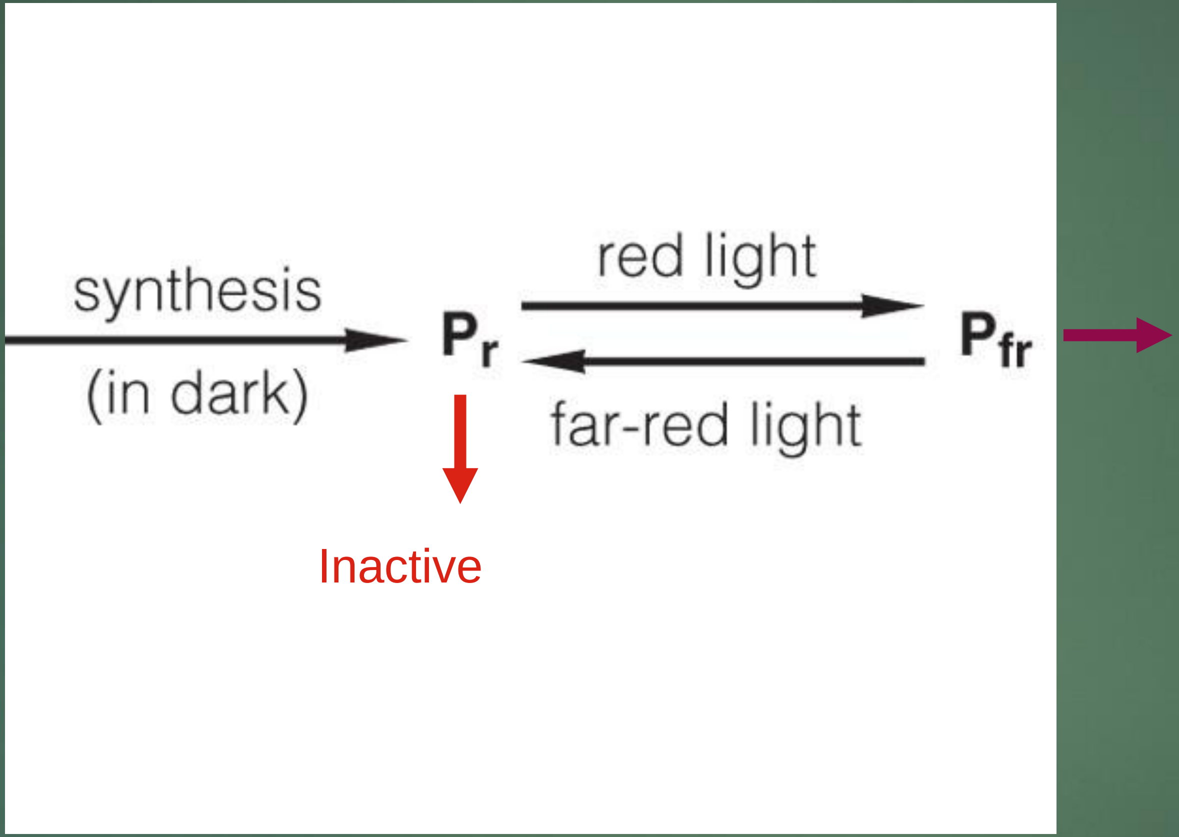
Irradiation with red light should increase absorbance in the far-red and decrease absorbance in the red.
Irradiation with far-red light should increase absorbance in the red and decrease absorbance in the far-red.

Light absorption leads to isomerization of the chromophore

This in turn causes a change in the conformation of the protein leading to a change in its activity.



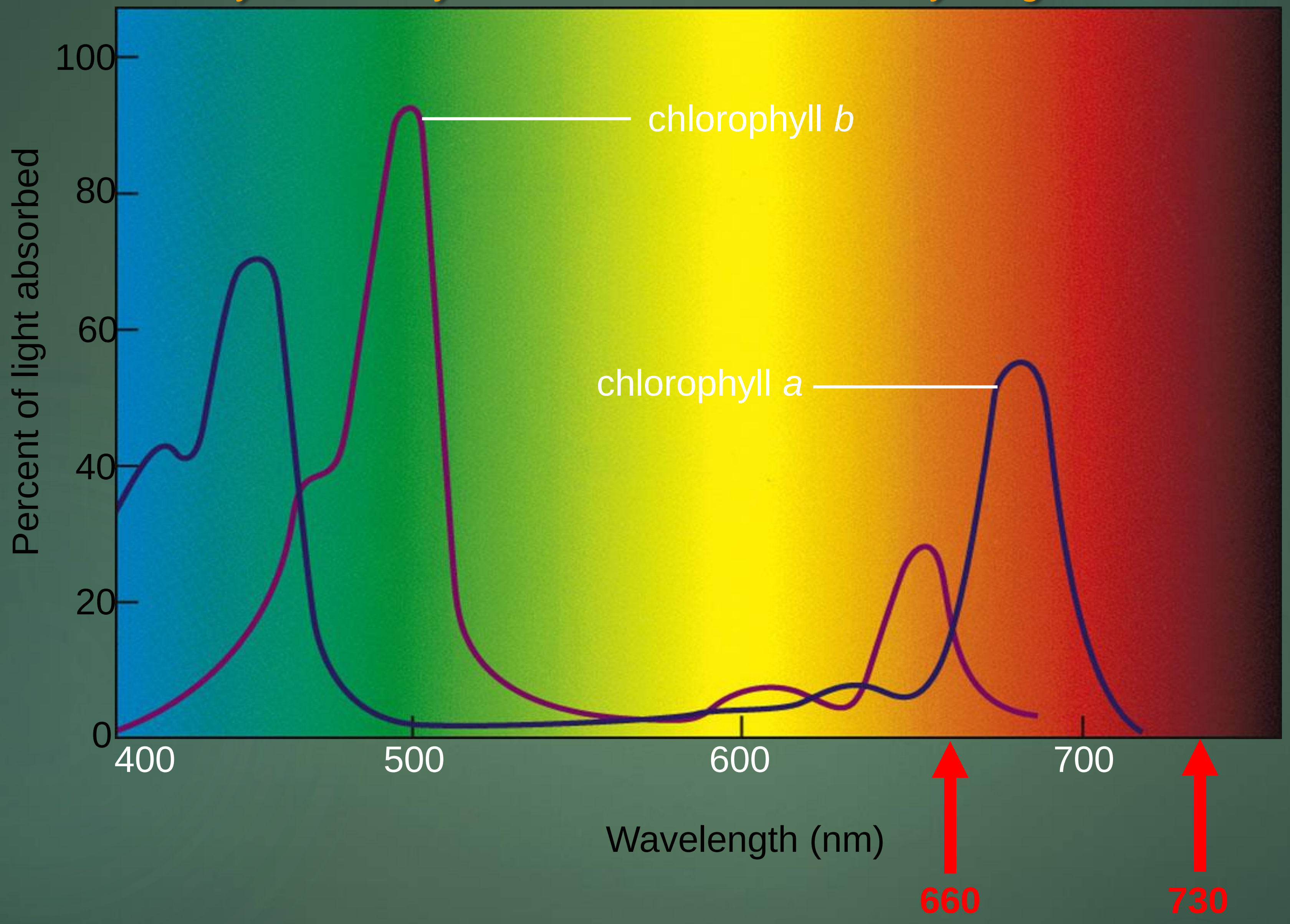
Pr chromophore ⇄ Pfr chromophore



Active version of Phytochrome:

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

Absorption spectra of Chlorophyll a and b



The ratio of Red (660 nm) to Far Red (730 nm) light will be low underneath green leaves that absorb light between 640 and 700 nm.

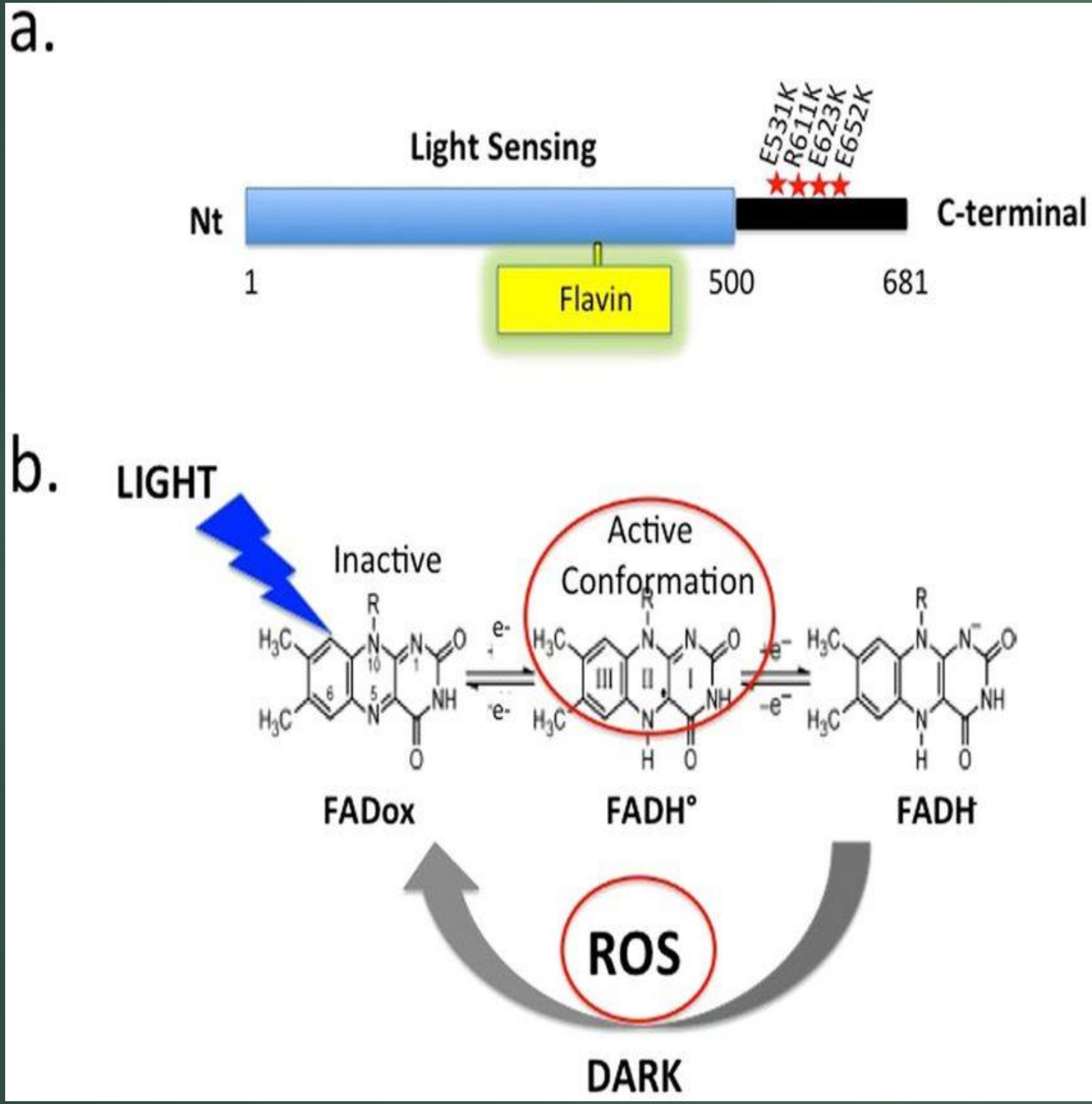
Cryptochromes

Blue Light and Plant Development

- To maximize photosynthesis

Cryptochromes :

1) promote de-etiolation
2) control circadian entrainment
3) control flowering

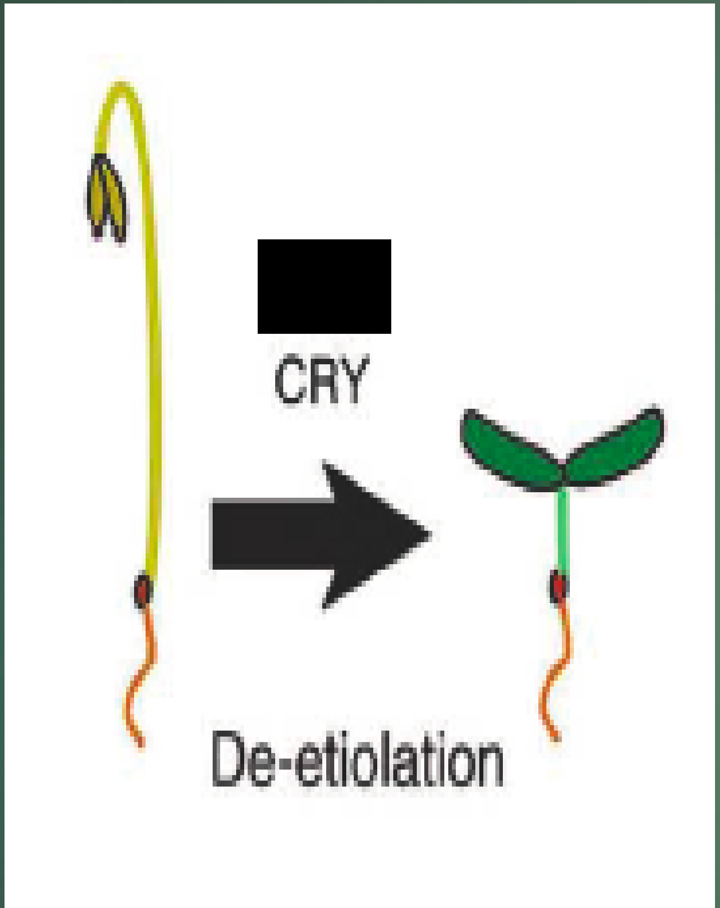


Cryptochrome is a class of flavoprotein that absorb blue or UV-A of the spectrum.

Most plant cryptochromes have a chromophore-binding domain(PHR) similar to DNA photolyase and a carboxyl terminal extension that contains DAS (DQXVP-acidic-STAES) domain conserved from moss, to fern, to angiosperms.

In *Arabidopsis*, has at least two cryptochrome genes, *CRY1* and *CRY2*.

Cryptochromes promote de-etiolation



Similar to Phytochromes, Cryptochromes promote the de-etiolation of seedlings and control the timing of flowering. However, in this case the response depends on blue light (not red).

The combined effects of red and blue light in promoting de-etiolation is stronger than treatments with only red or only blue light.

Cryptochromes and Phytochromes enhance each others effects in promoting seedling de-etiolation.

When plants are exposed to both red and blue light, their growth responses become optimal for light harvesting. Light harvesting is done from the red and blue parts of the light spectrum.

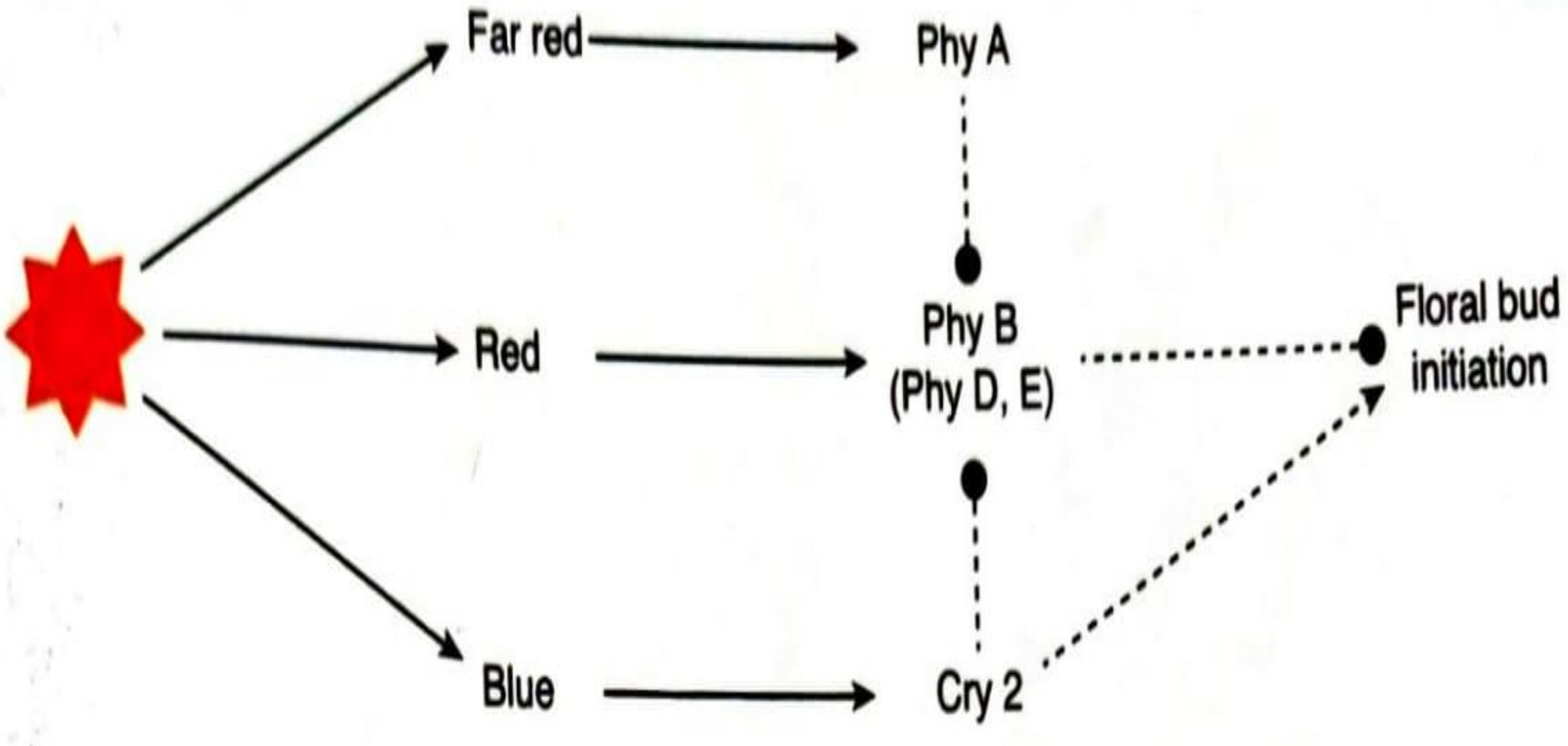
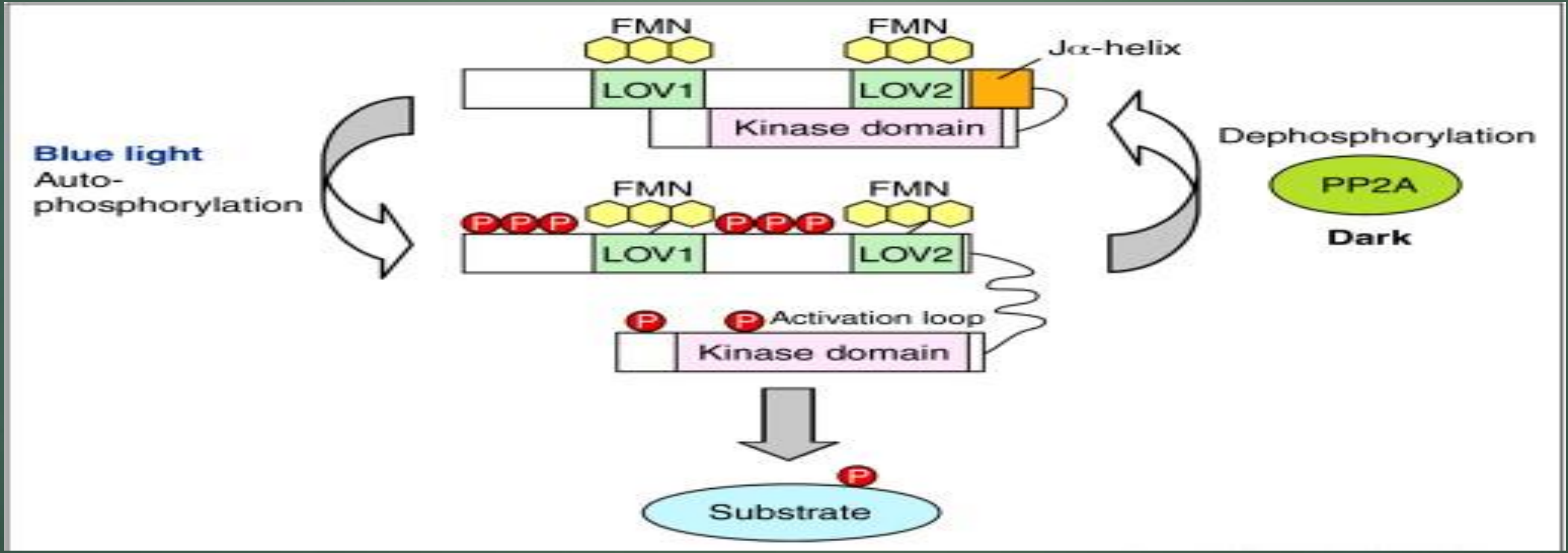


Fig. 2.13.15: Mode of phytochrome and cryptochrome action in floral bud initiation.

Phototropins

- Phototropin is a blue light photoreceptor protein(flavoproteins) in plants.
- It has two photoreceptive domains LOV1 and LOV 2, in the N-terminal half and the C-terminal half forms Ser/Thr kinase.



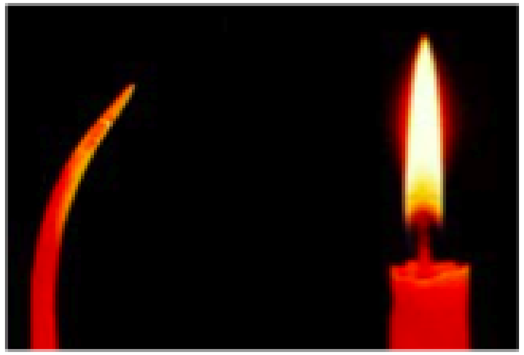
Blue Light and Plant Development

- To maximize photosynthesis

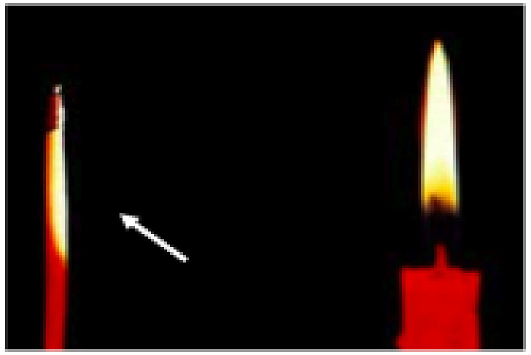
Phototropins promote:

1) Phototropism
2) Chloroplast movement
3) Stomatal opening

Darwin's experiments on phototropism



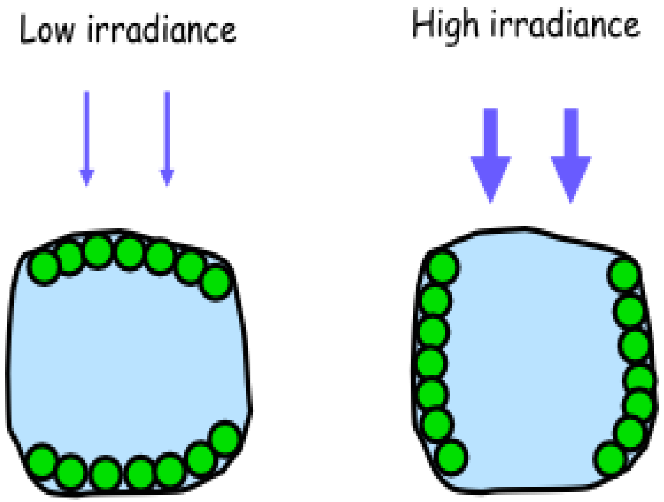
Grass coleoptiles curve towards the light of a candle



An opaque cap over the tip of the coleoptile prevents bending

When the tip alone is illuminated bending still occurs

Blue light regulates chloroplast movement in leaf mesophyll cells



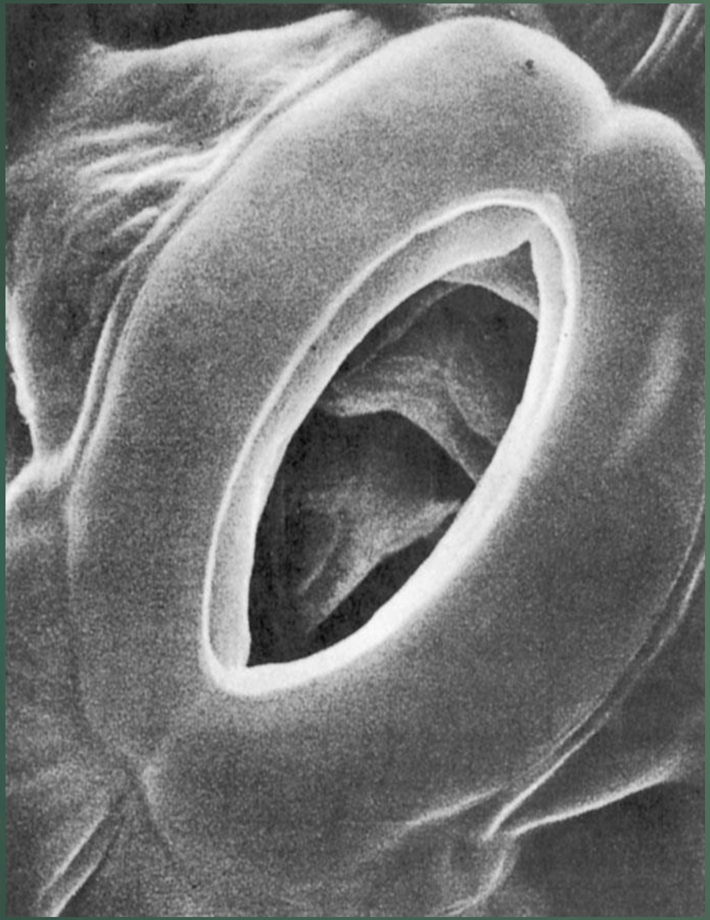
Chloroplasts move towards the source of light (too maximalize light harvest)

(more energy reaches the leaf)

(too much light)

Chloroplasts move away from the source of light (to minimize damage by the excess light energy).

Phototropins and stomatal opening



Light affects the opening of stomata. In dim or no light, the stomata are closed; as the light intensity increases, the stomata open up to some maximum value.

The blue part of the light spectrum is responsible for this response.

Blue light is perceived by phototropins that then promote the increase in solute concentration of guard cells starting with the conversion of starch into malic acid.