Plant Growth

Phytochrome Action

Phytochrome, Photoperiodism and Flowering

Phytochromes

- **Phytochromes** are a class of photoreceptor in plants, bacteria and fungi used to detect light. They are sensitive to light in the red and far-red region of the visible spectrum and can be classed as either Type I, which are activated by far-red light, or Type II that are activated by red light.

Action

- Phytochromes control many aspects of plant development. They regulate the germination of seeds (photoblasty), the synthesis of chlorophyll, the elongation of seedlings, the size, shape and number and movement of leaves and the timing of flowering in adult plants.

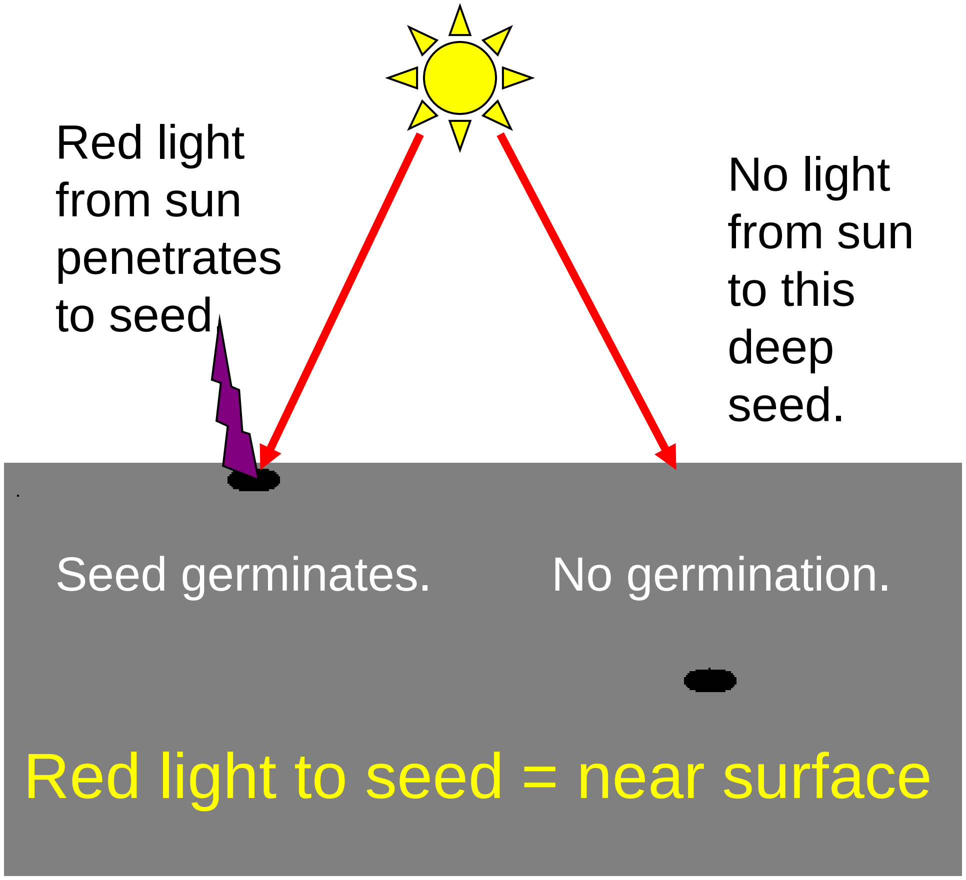
Photoblasty

- **Seeds that are stimulated to germinate by light** are described as positively photoblastic; seeds whose germination is inhibited by light are said to be negatively photoblastic. The response to light is apparently mediated by phytochrome-regulated production of the plant hormone gibberellin.

The pigment phytochrome

- Detects R and FR light
- Provides information about environment
- Answers 3 questions for plant
  - Am I in the light?
  - Do I have plants as neighbors or above me?
  - Is it time to flower?

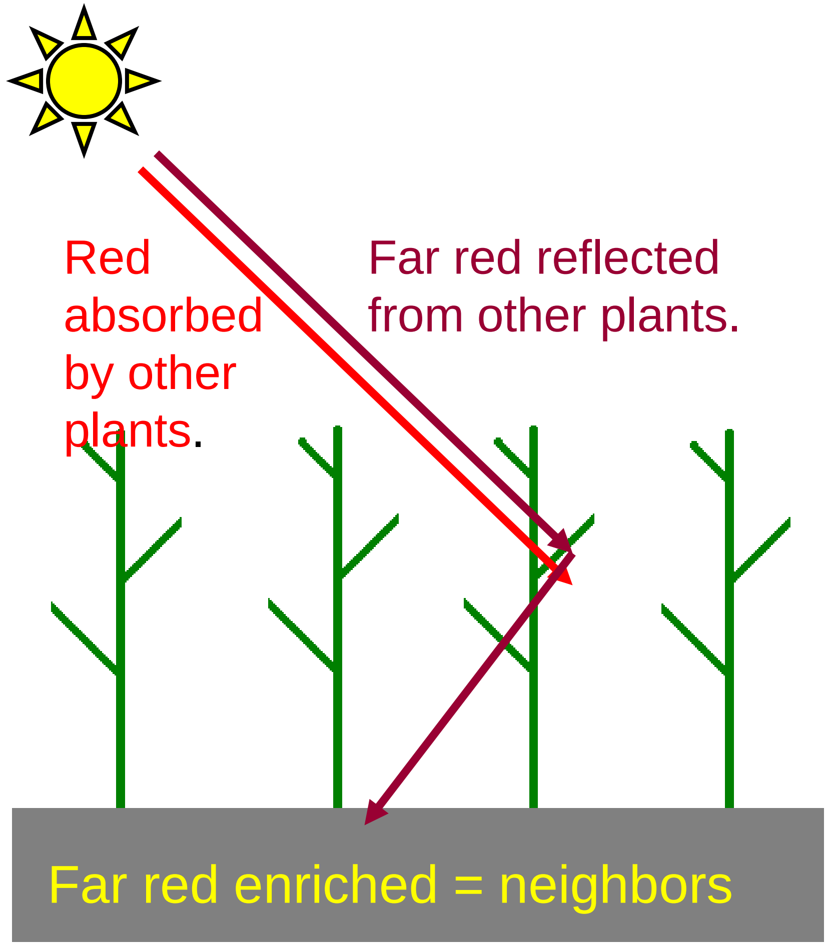
Seed location?



Why bother?

- Seeds store materials to start growth
- Must reach light before running out of stored materials
- Small seeds
  - Need to be very near surface
  - Often need light for germination
- Germinating plants straighten & open leaves at surface, too

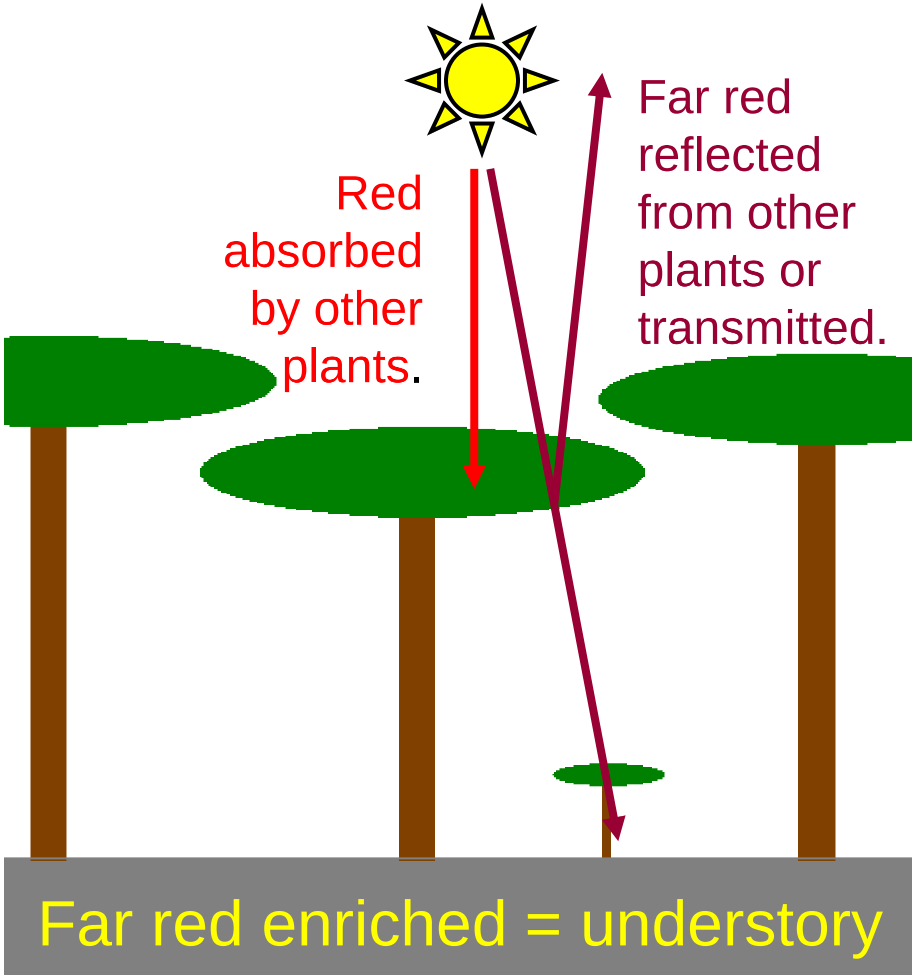
Plant neighbors?



Why does this matter?

- Neighboring plants are threats
  - Might grow taller, shade you
- Solution
  - Grow at least as tall as neighbors
  - Need to know that you have neighbors
- Isolated plants typically shorter than crowded plants
  - Other reasons, too

Under other plants?



Why important?

- Best growth strategy for understory plants is different than for plants in open
- Need to know whether
  - Shaded by other plants

  OR
  - Just cloudy

  OR
  - Late in day (low light)

Right time to flower?

- Unreliable indicators of time of year
  - Temperature
  - Moisture
  - Light levels
- Reliable: length of day/night
  - Varies with season
  - Varies with latitude
- Detected by phytochrome

Phytochrome has 2 forms

- Red-absorbing phytochrome

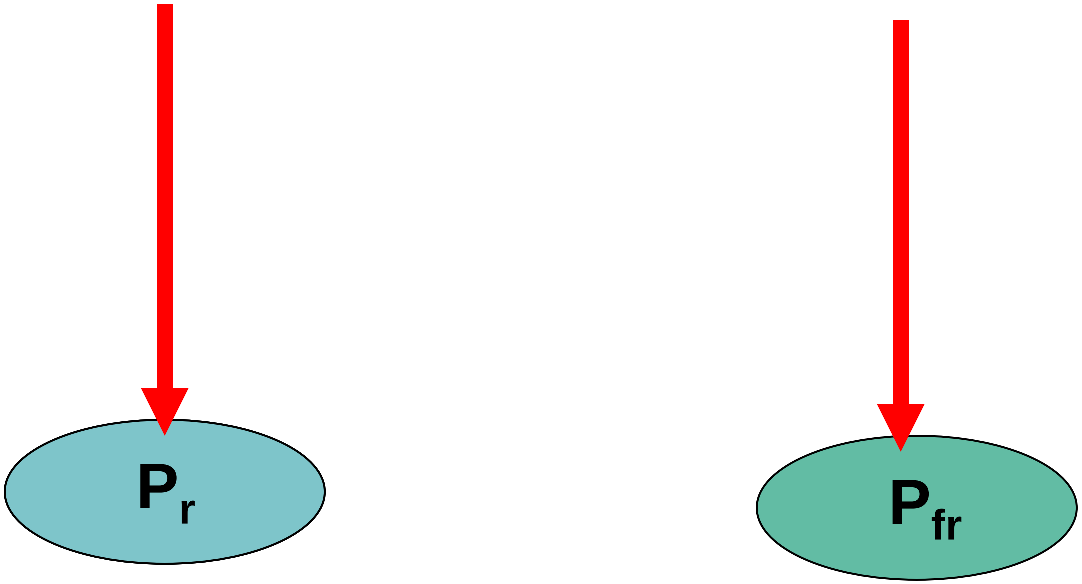
  P_r

- Far red absorbing phytochrome

  P_{fr}

- Interconverted P_r P_{fr}
- Two forms of the same compound
- Total amount same

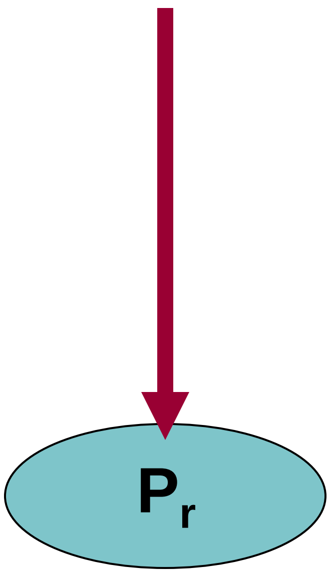
In red light

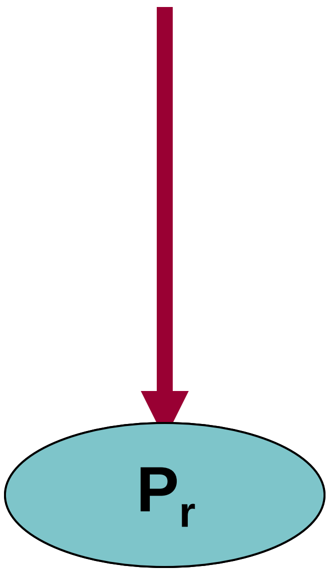


P_r absorbs red light, changes to P_{fr} form.

P_{fr} doesn't absorb red light, stays the same.

In far red light

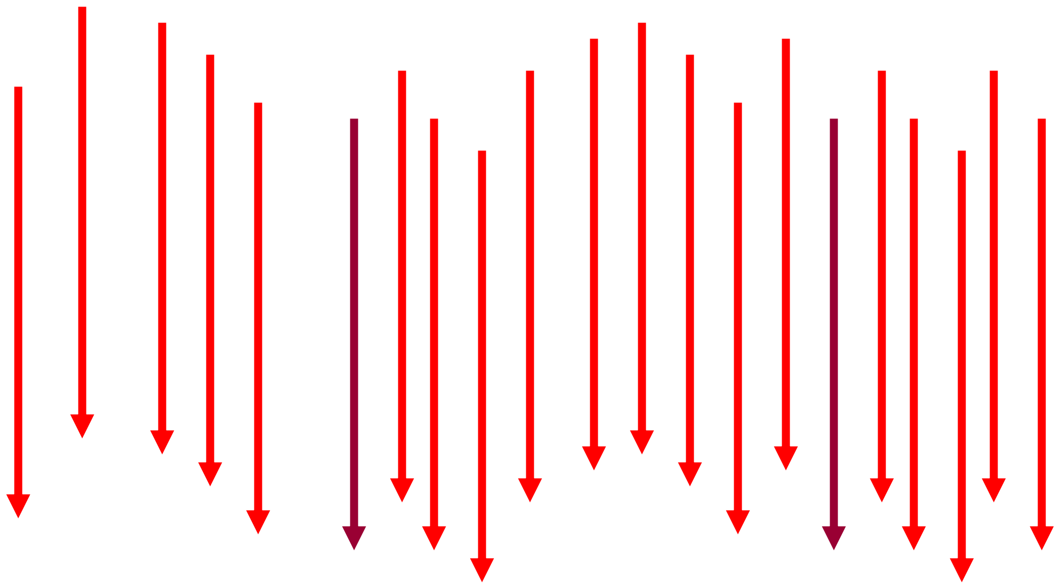




P_r doesn't absorb far red light, stays the same.

P_{fr} absorbs far red light, changes to P_r form.

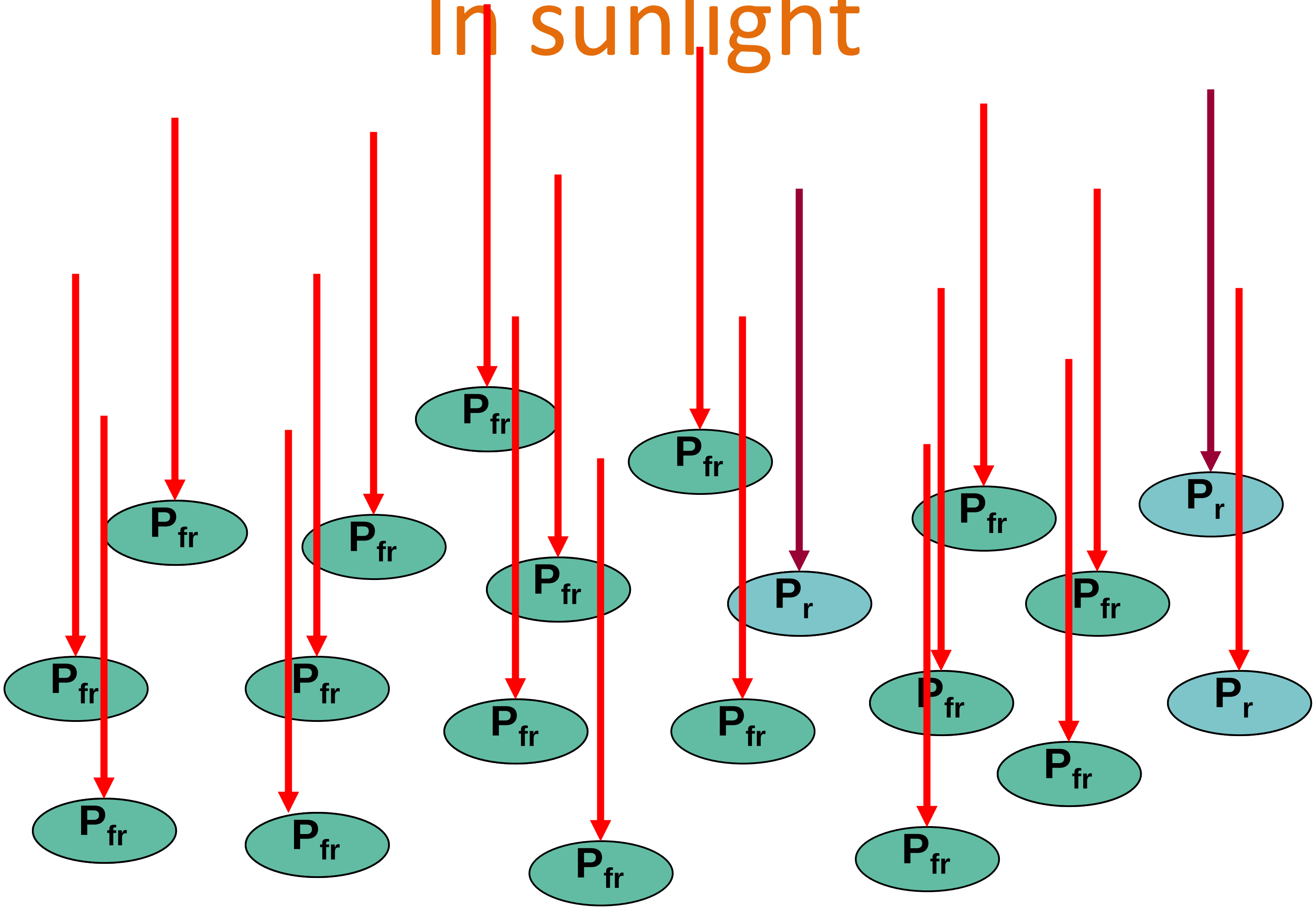
Sunlight



Mostly red

A little far red

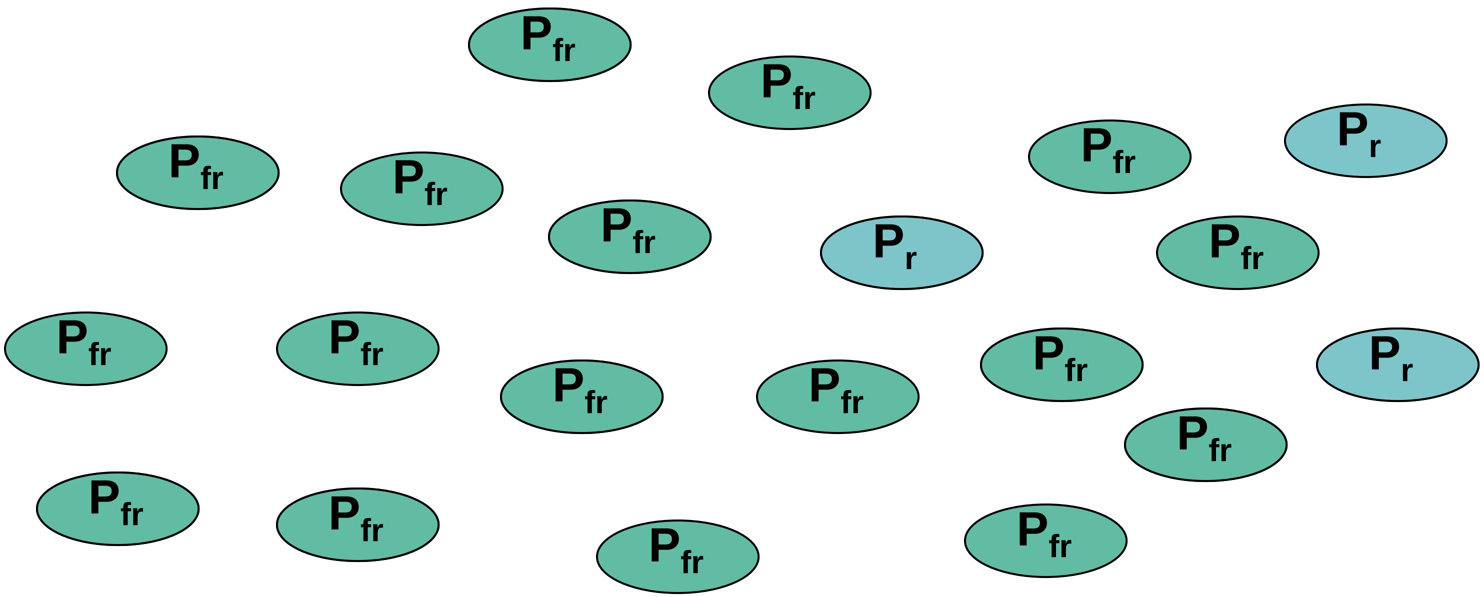
In sunlight



In sunlight most P gets converted to P_{fr} form.

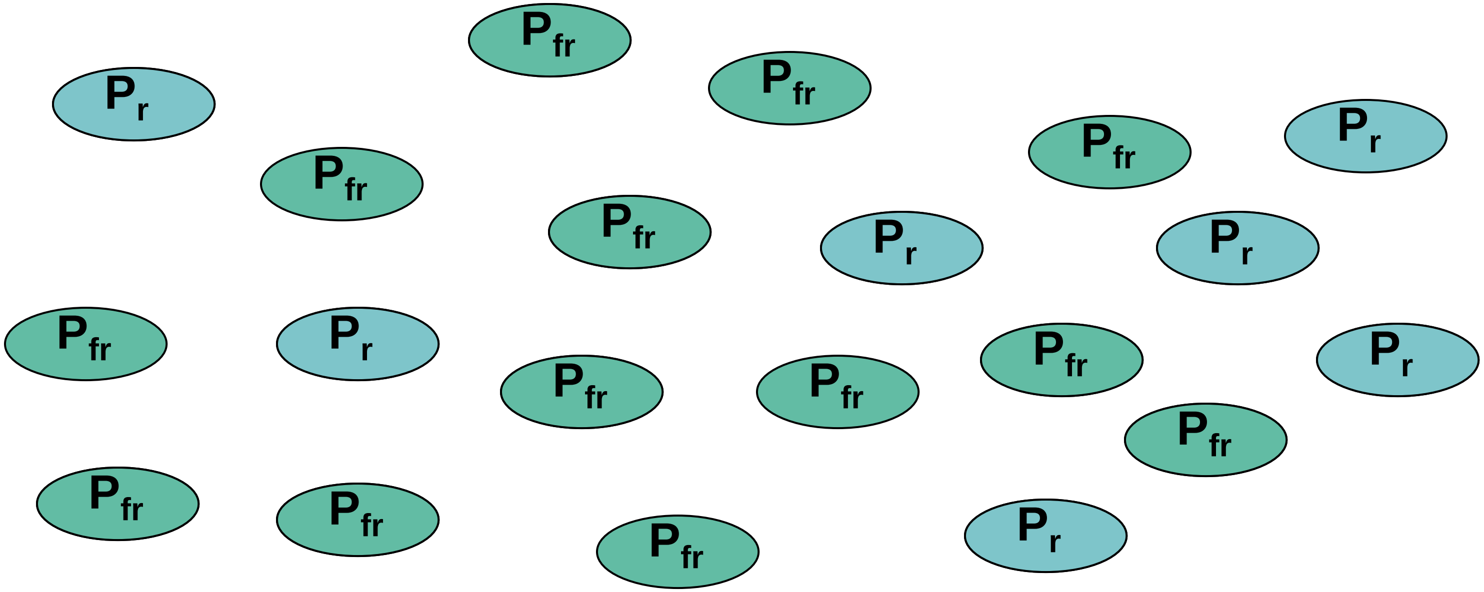
Start of night

Most P in P_{fr} form.



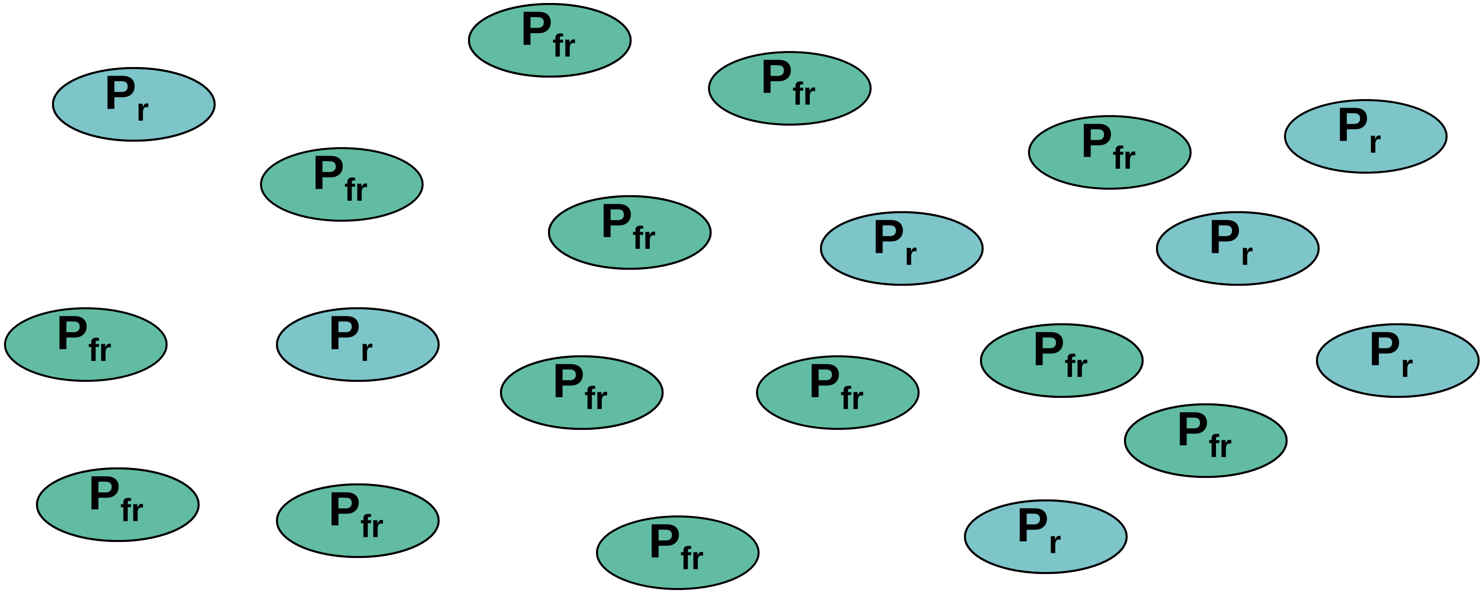
In the dark

P_{fr} form changes gradually to P_r form.



After a short night

P_{fr} still left.

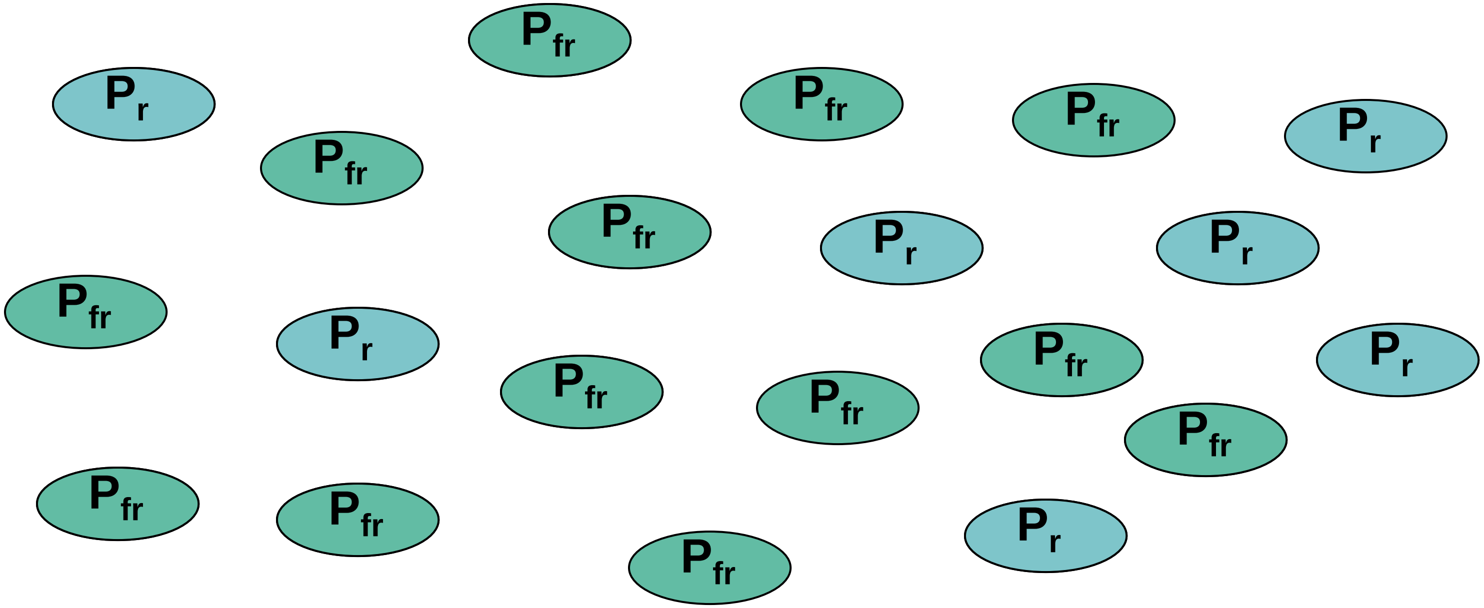


LDP = SNP

- Needs short night
- Needs P_{fr} still present at end of night
- P_{fr} promotes flowering for LDPs

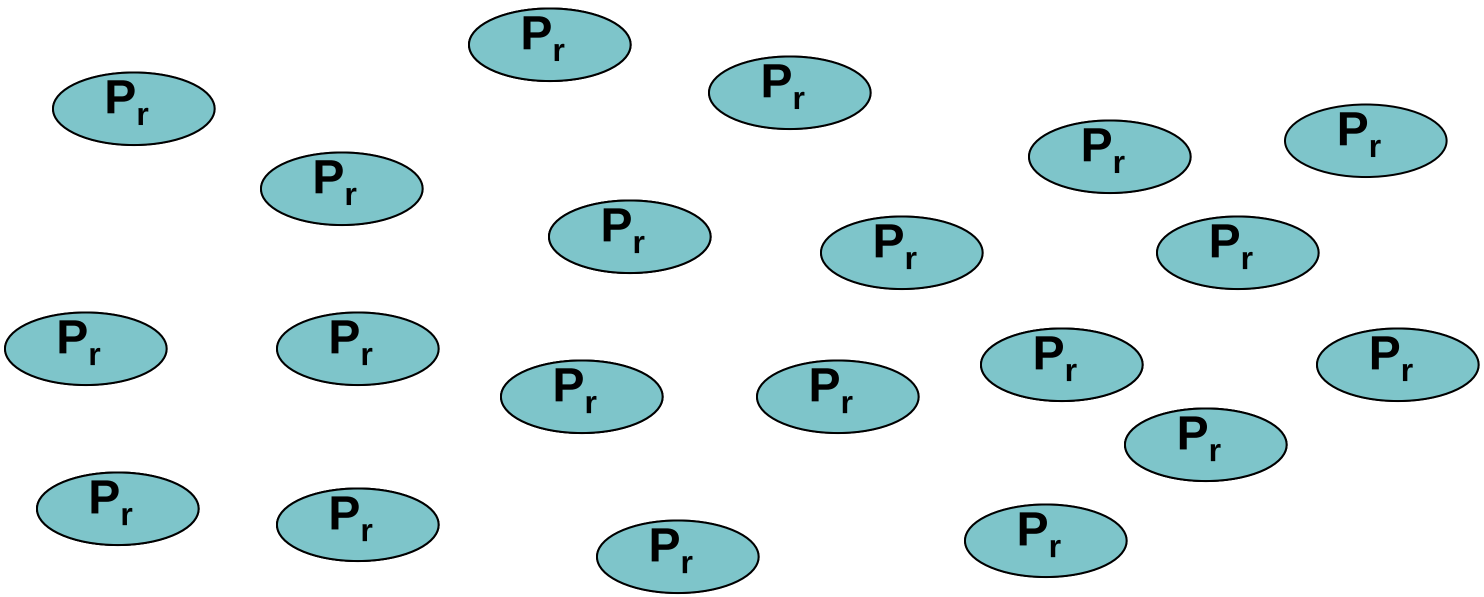
Later in the night

More P_{fr} changes to P_r.

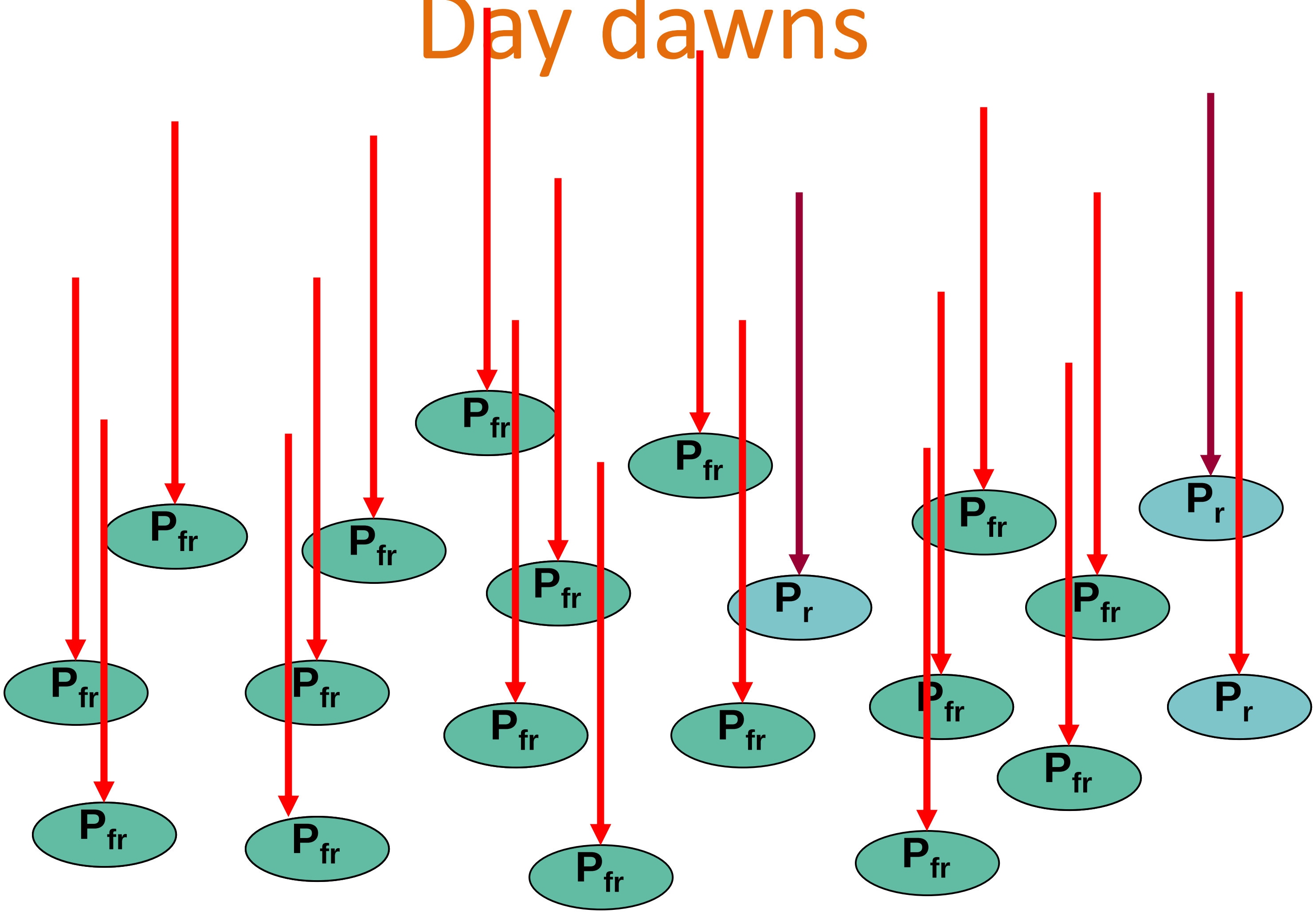


After a long night

All the P_{fr} is gone.



Day dawns

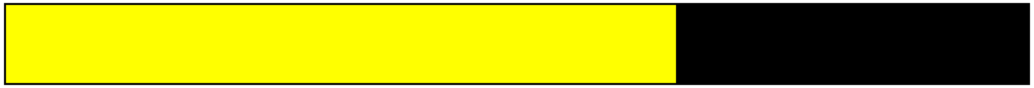


Most P gets converted to P_{fr} form again.

SDP = LNP

- Needs long night
- Needs P_{fr} gone at end of night
- P_{fr} inhibits flowering for SDPs

LDP SDP



Long day: P_{fr} left at end of short night.

P_{fr} promotes flowering for LDPs.

P_{fr} inhibits flowering for SDPs.

Short day: P_{fr} gone at end of long night.

No P_{fr} to promote flowering for LDPs.

No P_{fr} to inhibit flowering for SDPs.

Waiting for the right time

- Plants grow leaves until it is time to flower
- LDPs wait until the day is long enough
  - Really night short enough

- SPDs wait until the day is short enough
  - Really night long enough

  Flower opening happens later

Day neutral plants

- Flower when mature enough
- Maybe other environmental signals (temp?)
- Day length (dark length) doesn't matter

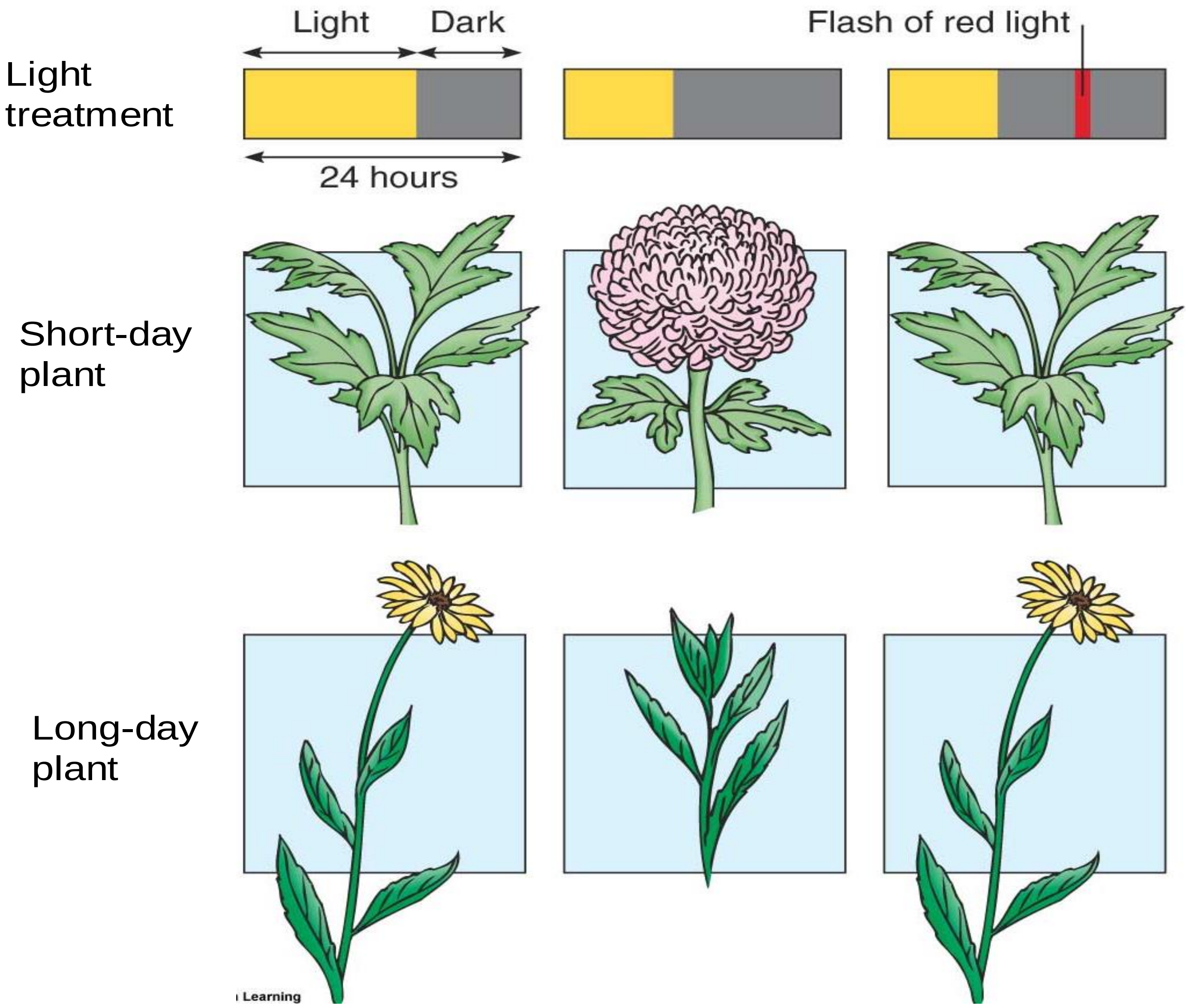
Phytochrome tells plants

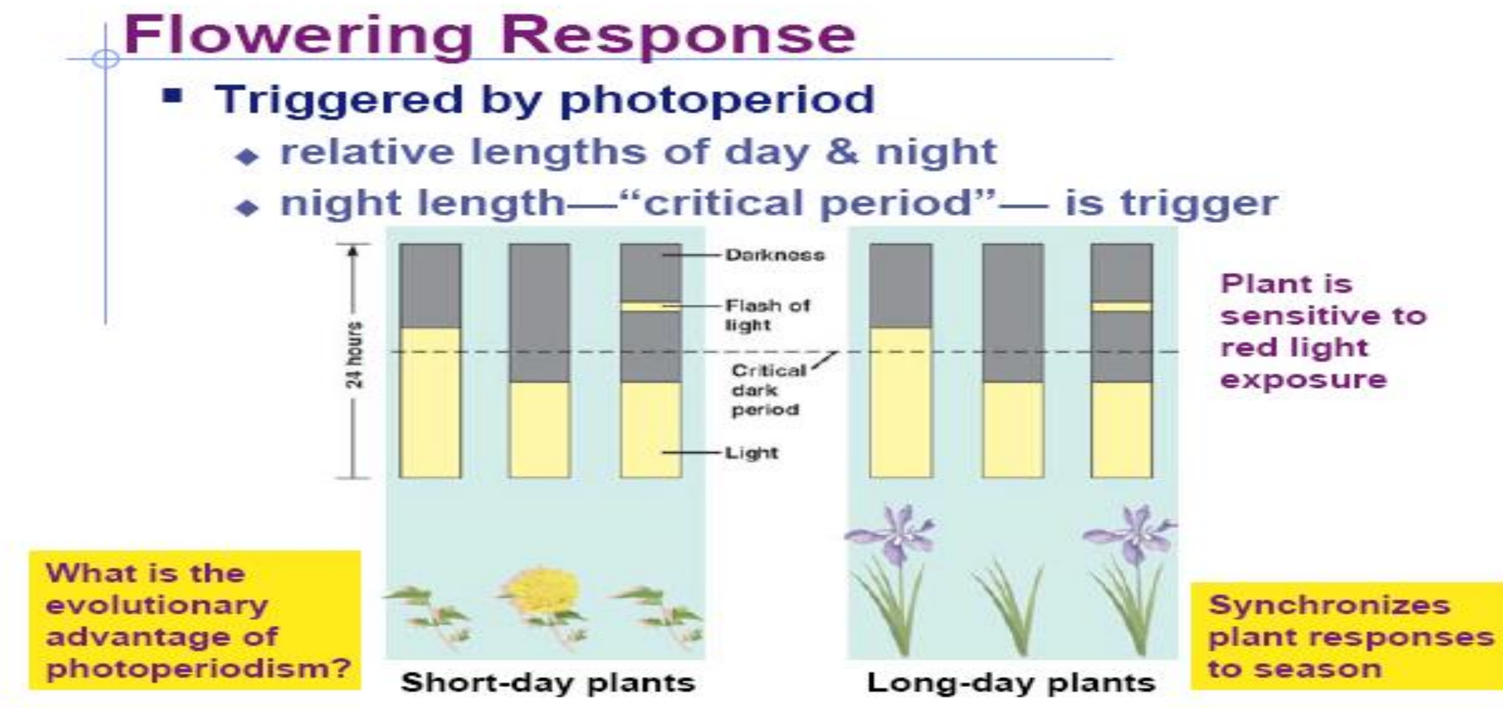
- If they are near the surface
- About their plant neighbors
- Whether it is time to flower
- And lots more

- Photoperiodism is any response of plants to the duration and timing of light and dark
  - In many plants, flowering is a photoperiodic response
    - Short-day plants
    - Long-day plants
    - Intermediate-day plants

Biology, **Seventh Edition**

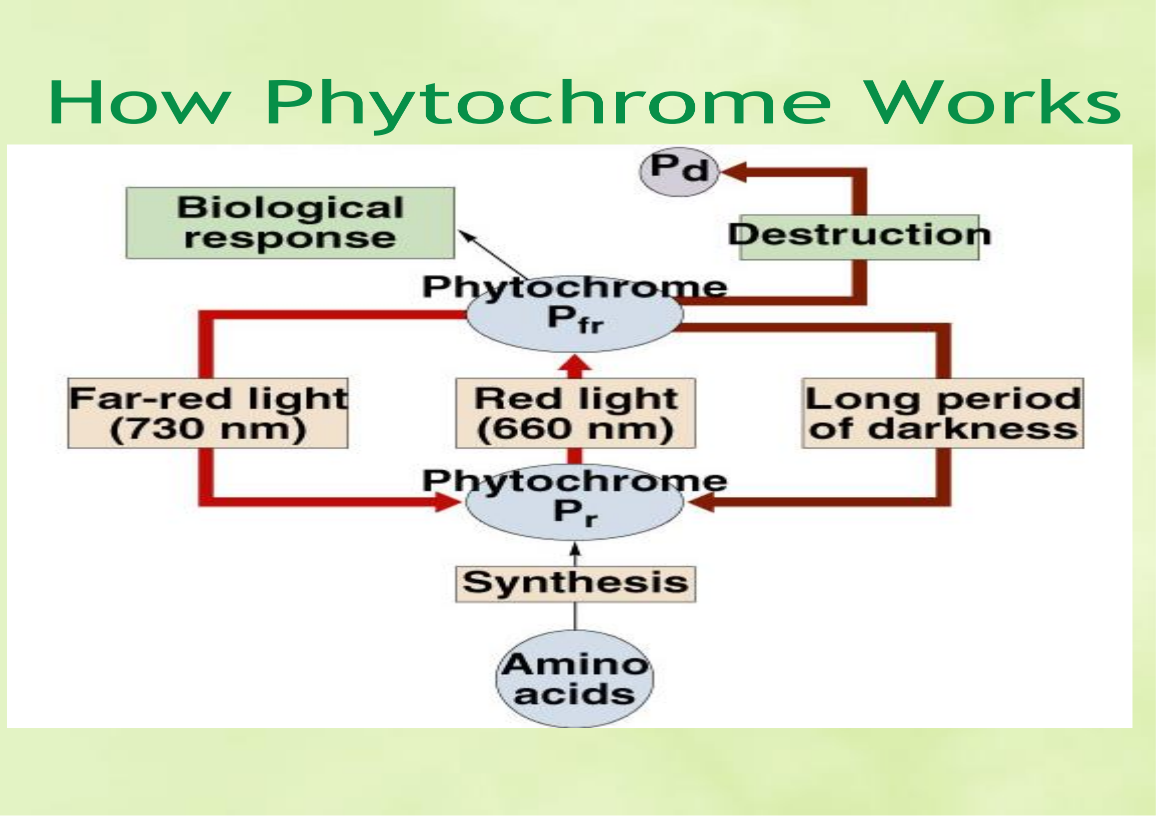
Photo-periodic responses of short-day and long-day plants





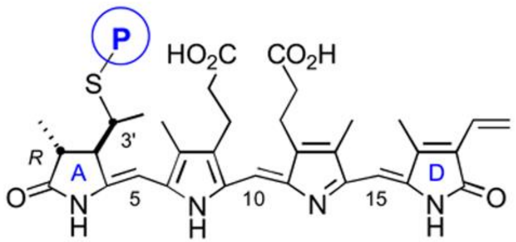
Because of photoperiodism, flowering and other responses within an **ecotype population of plants are synchronized in time**. This is certainly an advantage if the plants require cross pollination; it is essential that all bloom at the same time.

The phytochrome photoreceptors are proteins that bind a tetrapyrrole chromophore, allowing them to **absorb light**. These phytochromes exist in two photo-interconvertible forms: an inactive, red-absorbing “Pr” form and an active, far-red–absorbing “Pfr” form.

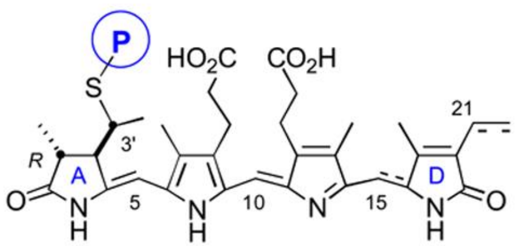


Tetrapyrroles

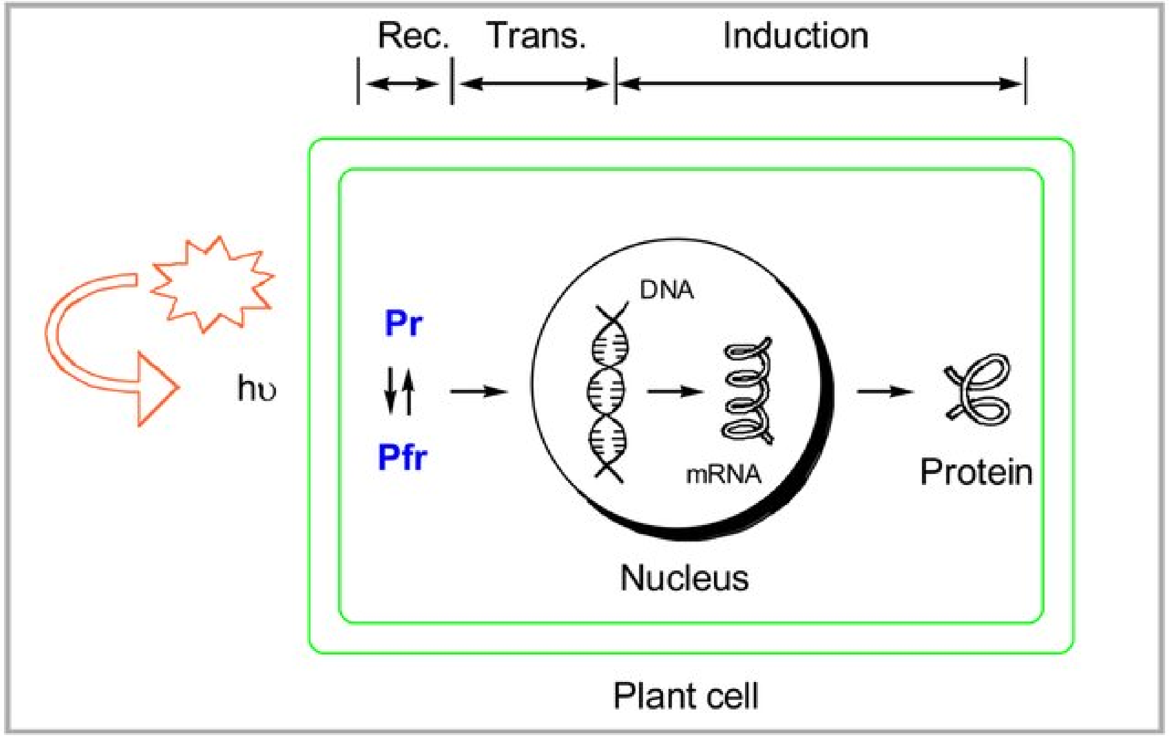
- Tetrapyrroles are a **class of chemical compounds that contain four pyrrole or pyrrole-like rings**. The pyrrole/pyrrole derivatives are linked by (=(CH)- or -CH. - units), in either a linear or a cyclic fashion. Pyrroles are a five-atom ring with four carbon atoms and one nitrogen atom.



Phytochrome (**1**)

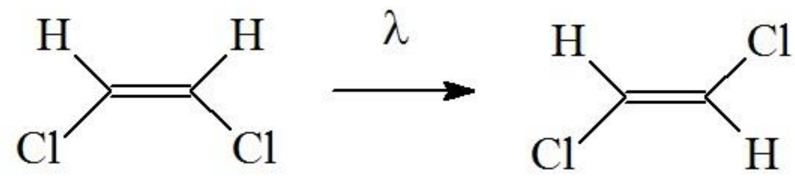


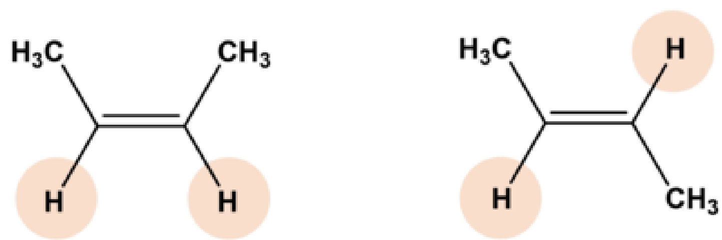
Phycocyanins (**2**, sat'd-C_{21}). Phycoerythrins (**3**, sat'd-C_{15}).



Schematic representation of photomorphogenesis: (a) Pr undergoes photoisomerization to a mixture of Pr and Pfr (reception); (b) the formation of Pfr initiates transduction, where the light signal is communicated to plant genes in the cell nucleus; and (c) certain activated (induced) genes undergo transcription to mRNA and translation to proteins that govern plant growth cycles.

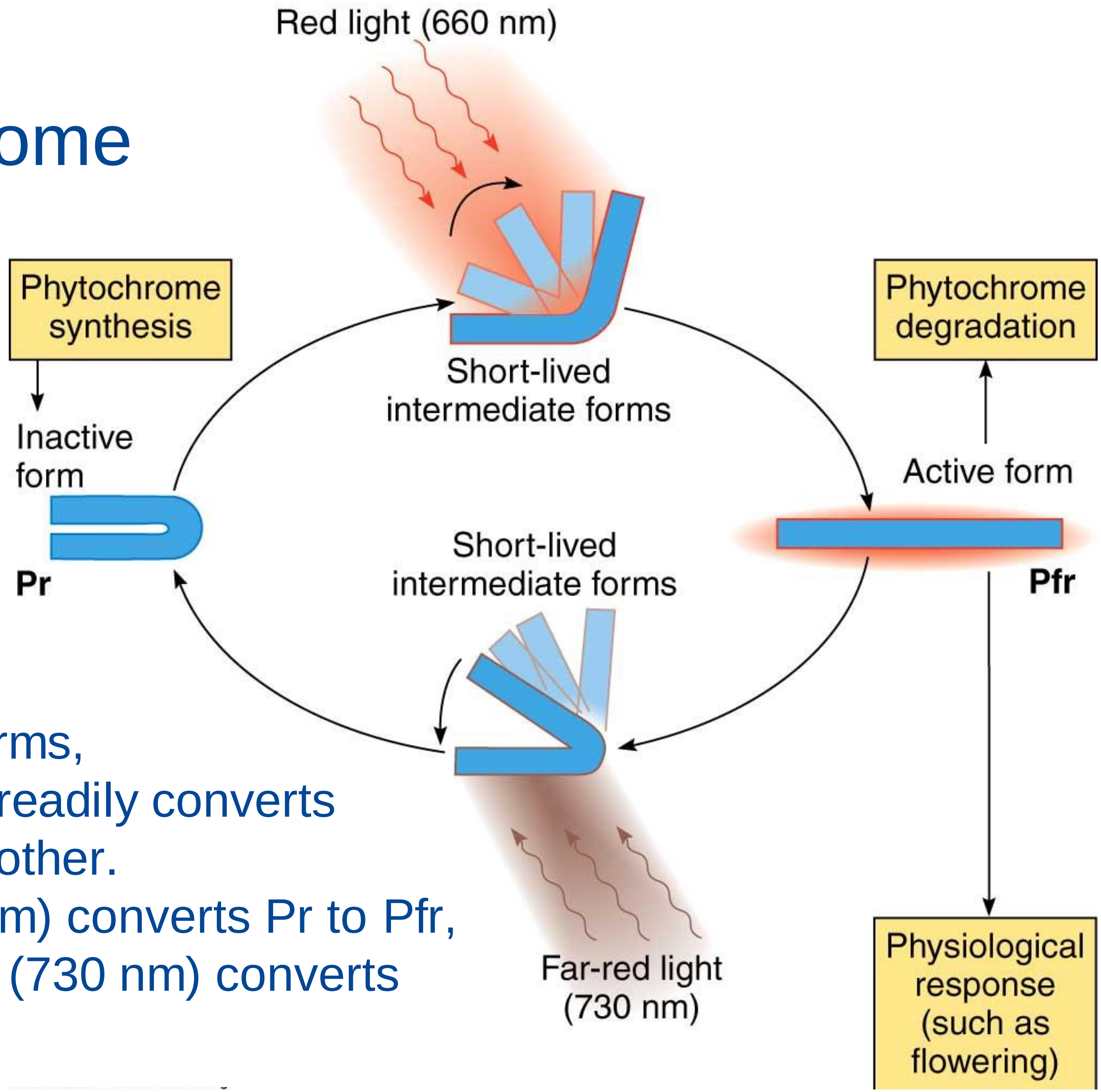
Photoisomerization is the **photochemical cis-trans isomerization of organic molecules with a double bond in their structure**. This reaction is a common photo-reaction. During photoisomerization one isomer is converted into another by light. **Light with the proper energy can convert one isomer into another.**





cis trans

Phytochrome



This pigment
occurs in two forms,
Pr and Pfr, and readily converts
from one to the other.
Red light (660 nm) converts Pr to Pfr,
and far-red light (730 nm) converts
Pfr to Pr

Practical Application

- Why do you plant lettuce seed by scattering them on the ground instead of burying seed?
- What is the evolutionary advantage to lettuce seeds?

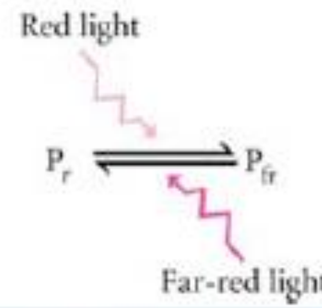
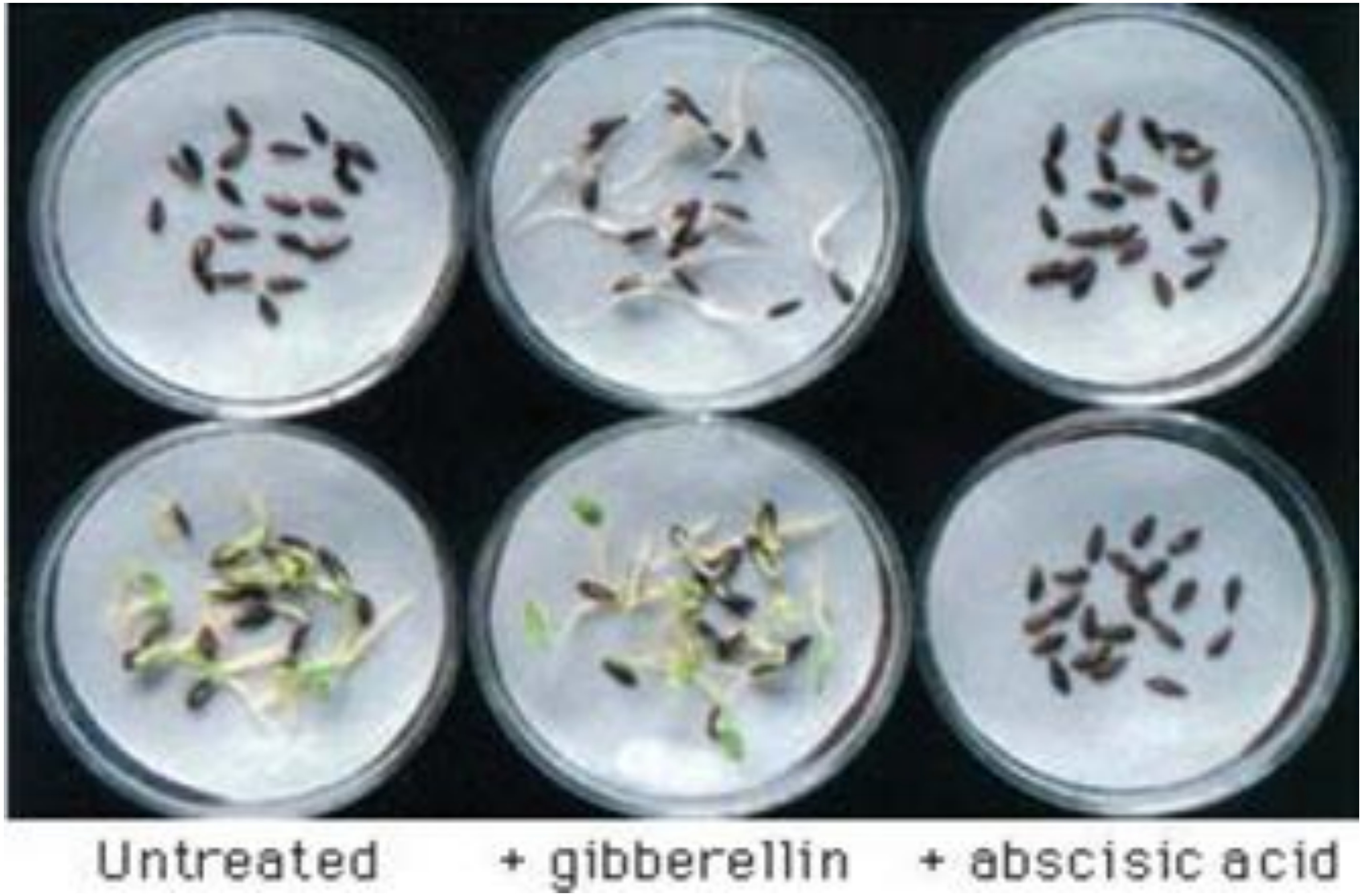


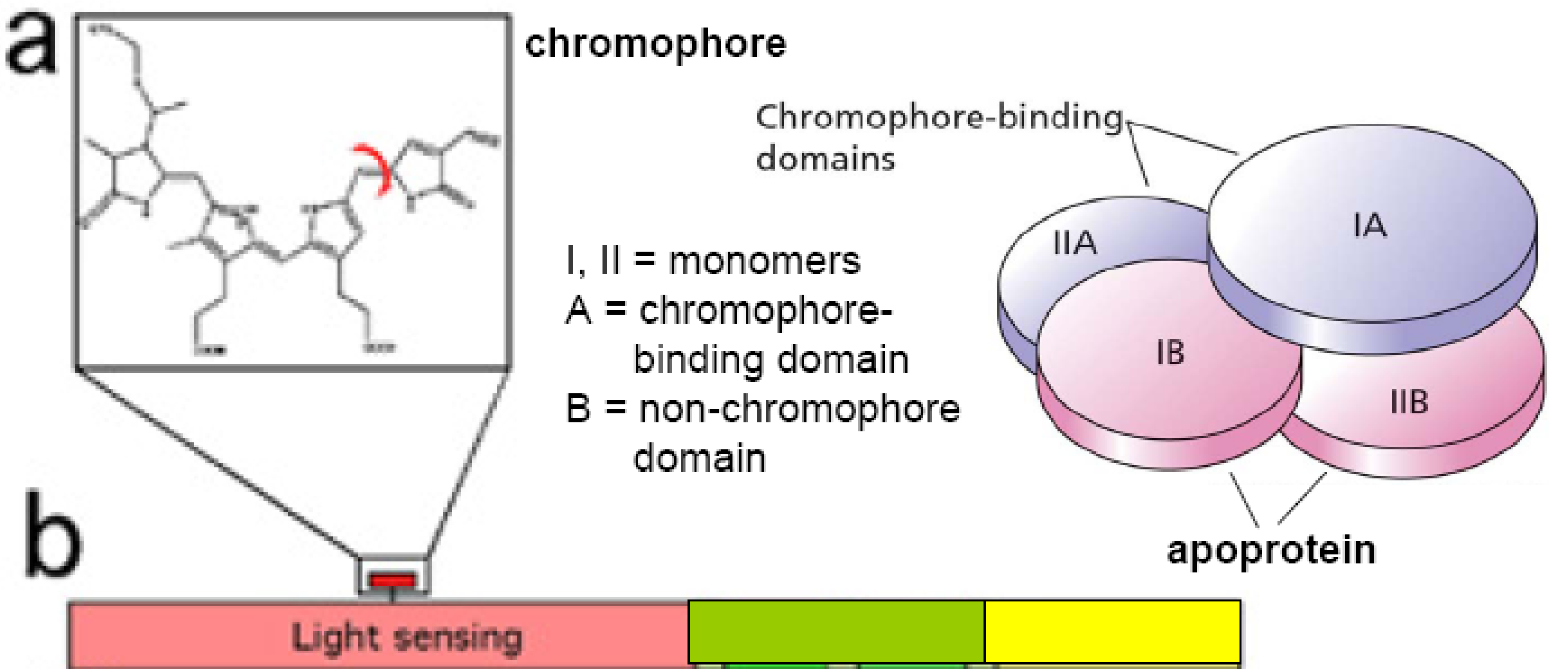
Figure shows the effect of light on germination of seeds



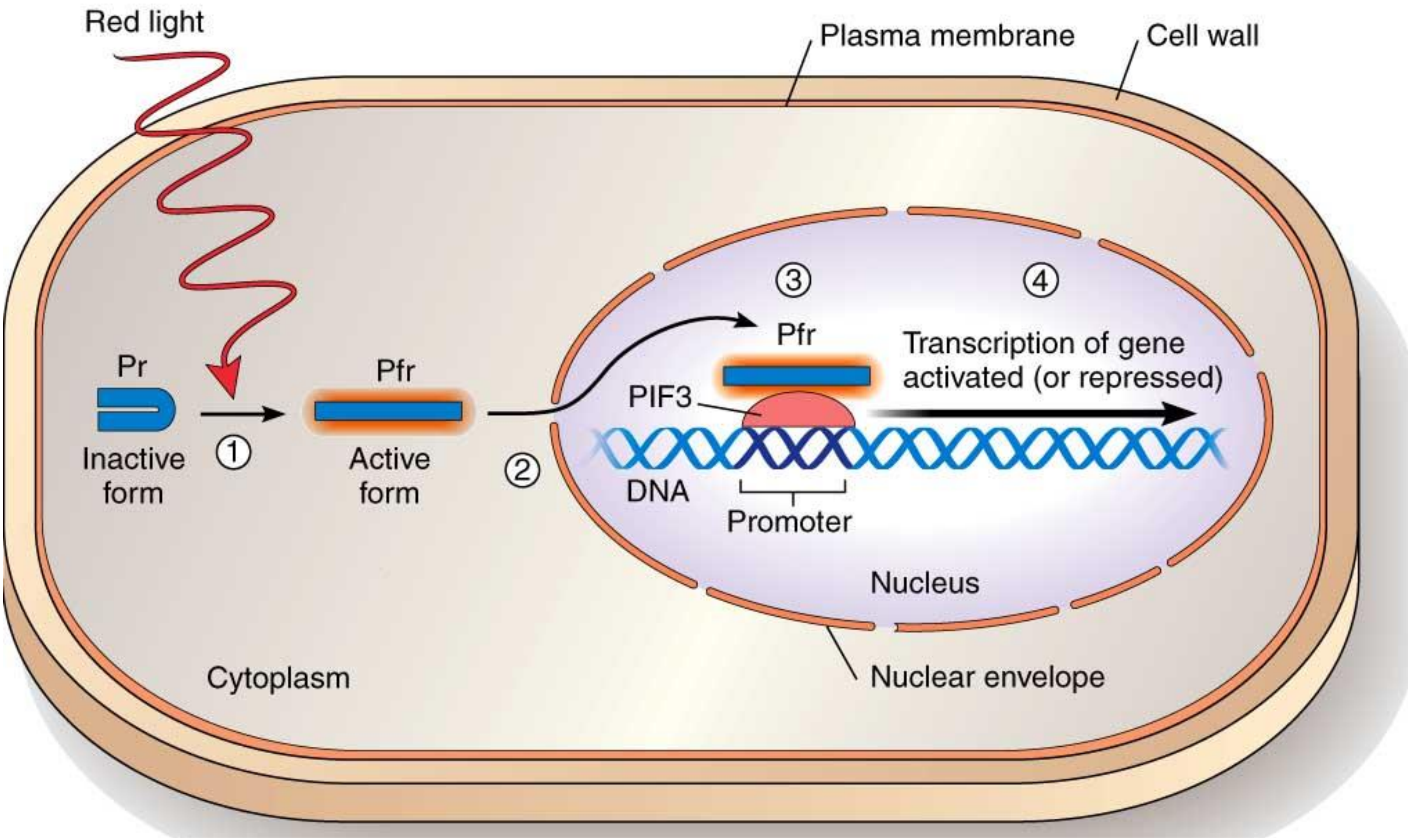
Light –induced germination of lettuce seeds. The seeds in top row were placed in darkness, and the seeds in the bottom row were placed in light.

Phytochrome structure

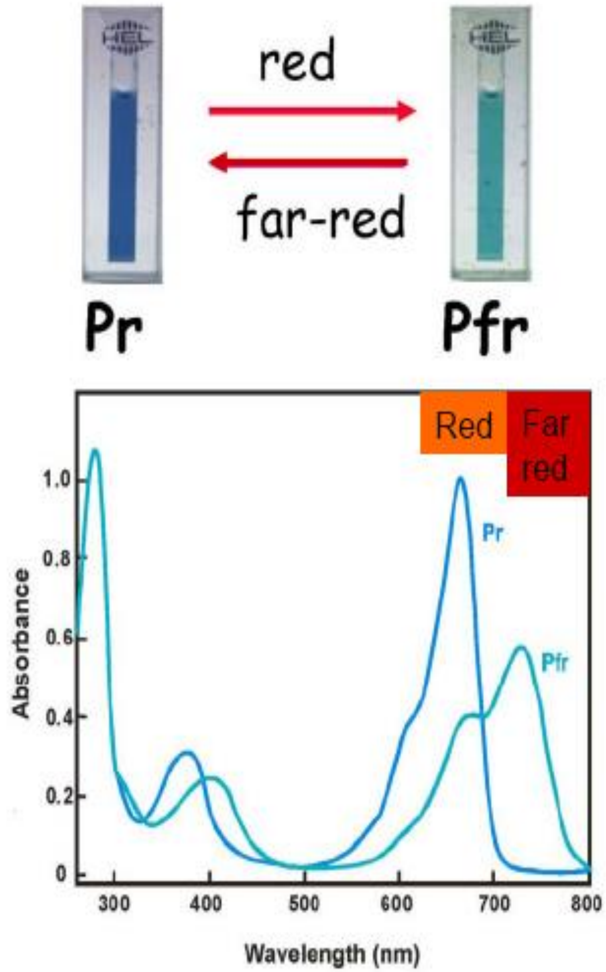
- soluble protein of ~ 250 kDa
- Dimer composed of two polypeptides
- each monomer consists of two components: chromophore and apoprotein = holoprotein



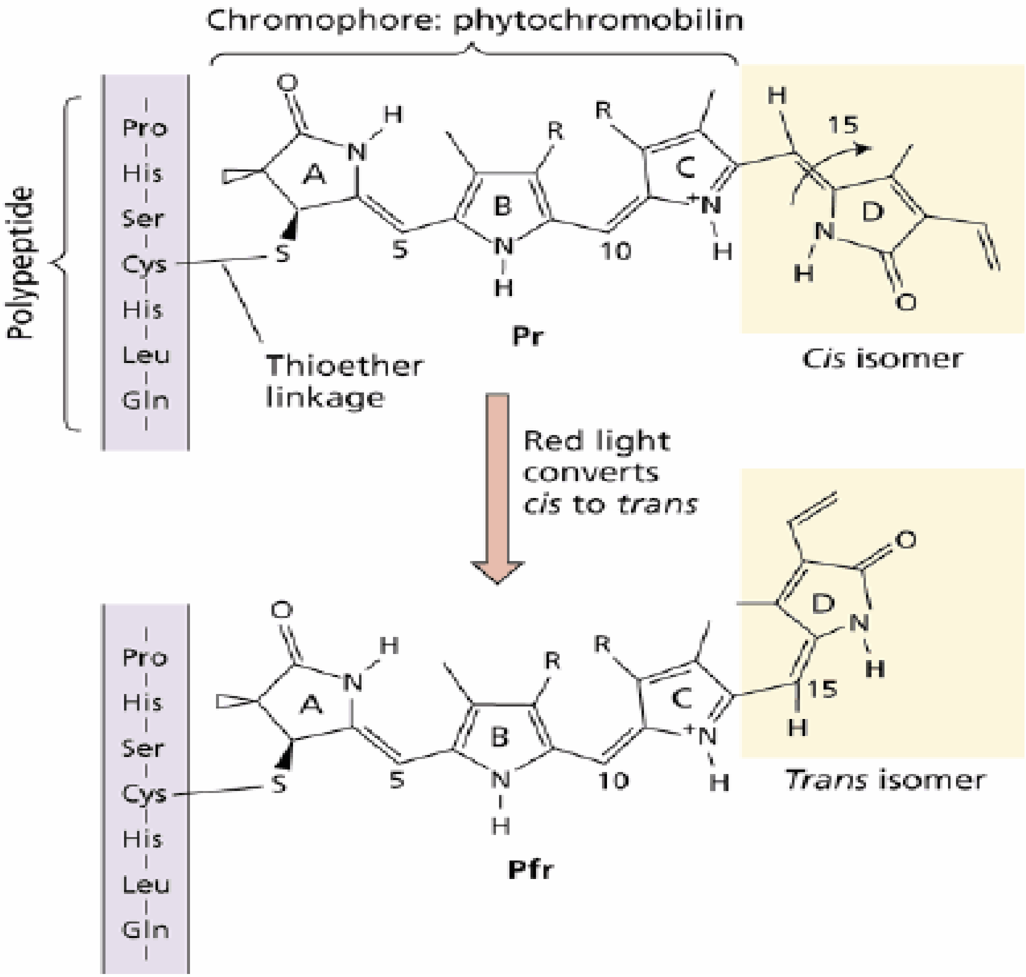
Phytochrome signal transduction



Absorption spectra of purified phytochrome

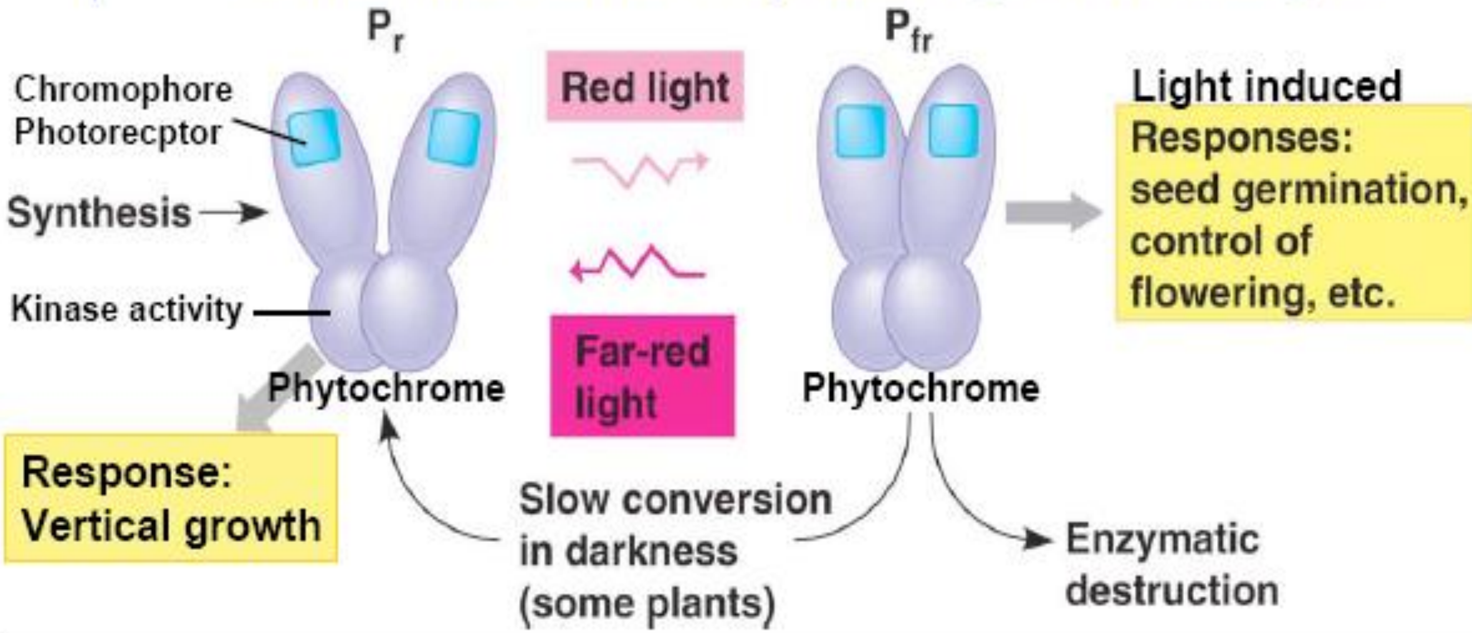


Structure of the Pr and Pfr forms of the chromophore (phytochromobilin)



Phytochrome photoreceptors

- **Molecular switch reaction to red light**
  - conversion of $P_r \rightarrow P_{fr}$ in sunlight stimulates germination, flowering, branching…
  - conversion of $P_{fr} \rightarrow P_r$ in dark inhibits response, & stimulates other responses: growth in height



Phytochrome responses can be distinguished by the amount of light required

- **Very low fluence response (VLFR):** PHYA, PHYE
  Example: **seed germination**

- **Low fluence response (LFR):** PHYB, PHYC, PHYD, PHYE
  Example: **hypocotyl and petiole elongation**

- **High irradiance response (HIR):** PHYA, PHYB
  Example: **flowering**

Fluence = amount of light, the number of photons impinging on a unit surface area