Introduction of phytochrome:

The phytochrome is a pigment that photoreceptor in plants and some bacteria and fungi when use to detect light, it is sensitive to light in the red and far-red region of the visible spectrum. Biochemically is a protein with a billion chromosphere and this pigment controls the flowering and growth in many plants.

A plant pigment is any type of colored substance produced by a plant. In general, any chemical compound which absorbs visible radiation between about 380 nm (violet) and 760 nm (ruby-red) is considered a pigment.
There are many different plant pigments, and they are found in different classes of organic compounds.
Plant pigments give color to leaves, flowers, and fruits and are also important in controlling photosynthesis, growth, and development.
Phytochrome is a blue-green plant pigment which regulates plant development, including seed germination, stem growth, leaf expansion, pigment synthesis and flowering.

Phytochrome is a photoreceptor, a pigment that plants and some bacteria and fungi, use to detect light, it is sensitive to light in the red and far-red region of the visible spectrum, in other word a blue-green pigment found in many plants, in which it regulates various developmental processes.

Many flowering plants use it to regulate the time of flowering based on the length of day and night (photoperiodism) and to set the biological process rhythms. It also regulates other responses including the germination of seeds (photoblasty), elongation of seedlings, the size, shape and number of leaves, the synthesis of chlorophyll and the straightening of the epicotyl (the region of an embryo or seedling stem above the cotyledon) or hypocotyl (the part of the stem of an embryo plant beneath the stalks of the seed leaves, or cotyledons, and directly above the root) hook of dicot seedlings. It is found in the leaves of most plants.

This pigment has a regulatory role in all phases of plant growth and development (photomorphogenesis) and is apparently ubiquitous in all taxonomic groups of eukaryotic plants with the exception of fungi.

Light, in addition to providing the energy which drives photosynthesis,also acts as a regulatory environmental stimulus.

Many light-controlled plant responses are now believed to be mediated by the photoreceptor, phytochrome. Other plant photoreceptors include cryptochromes, phototropins and UVR8, which are sensitive to light in the blue and ultra-violet regions of the spectrum.

Forms of phytochrome:

Borthwick *et al*. (1952) discovered presence of phytochrome (s) in plants, the results of their stunning now classic finding suggested that light regulated seed germination in lettuce (*Lactuca sativa*) operates through a red/far–red photoreversible process. The phytochrome family consists of five members [Phytochrome A (Phy A) to Phytochrome E]. The phytochromes can exist in two spectrally distinct forms, (i.e. Pr and Pfr). Red light activates phytochrome by converting it from the Pr form to Pfr form.

Conversely, far–red light inactivates phytochrome by converting Pfr to Pr. This photoconvertible nature of phytochromes enables plant to monitor the ratio of red to far–red light which is greatly reduced in the shade. The phytochromes have the capacity to undergo light–induced, reversible interconversion between two forms: Pr, which absorbs red Photons most efficiently (λmax, 665 nm) and Pfr, which absorbs far red (FR) photons most efficiently (λmax, 730 nm).

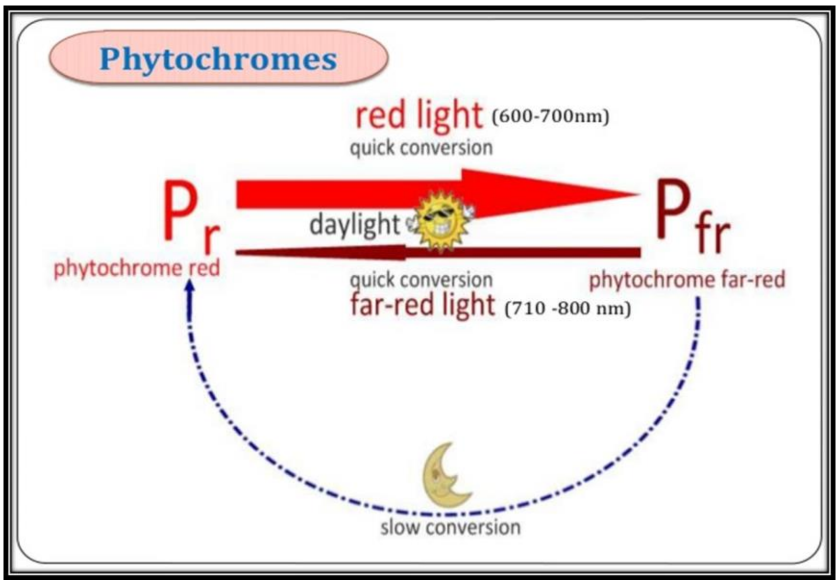
Forms of phytochrome control

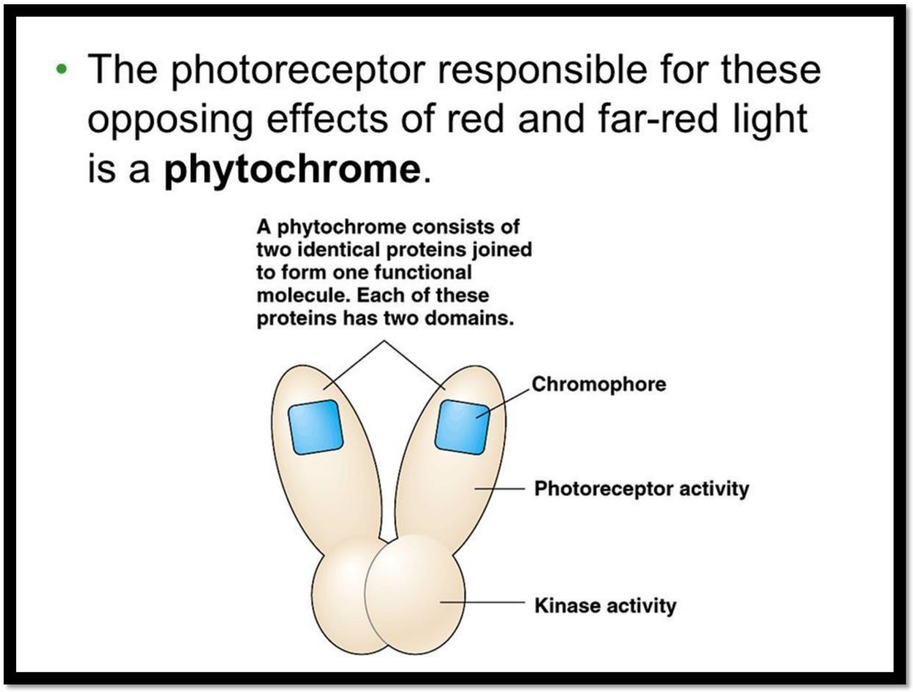
- **Pr form:**

Absorbs at a peak of 660nm, is the form synthesized in dark-grown seedlings, when Pr absorbs red light, it is converted to the Pfr form.

- **Pfr form:**

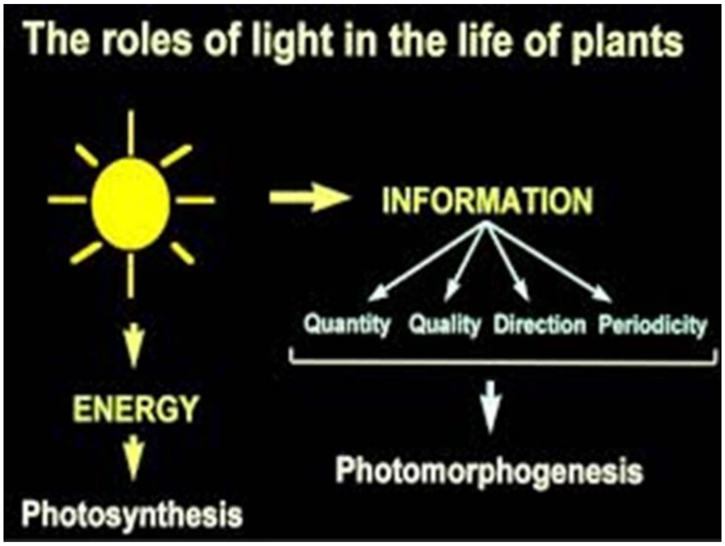
Absorbs at a peak of 730 nm, Pfr form is the active form that initiates biological responses, when Pfr absorbs far red light, it is converted to the Pr form.





Photomorphogenesis:

The process by which plant development is controlled by light is called photo- morphogenesis, typically photomorphogenic responses are most obvious in germinating seedlings but light affects plant development in many ways throughout all stages of development.



Light has profound effects on the development of plants .Most striking effects of light are observed when a germinating seedling emerges from the soil and exposed to light for first time .Normally the seedling radicle (root) emerge first from the seed, And shoot appears as the root becomes established . Later, with growth of the shoot (particularly when it emerges into the light) there is increased secondary root formation and branching simply it's a coordinated progression of developmental responses.

In this phenomena where the root affects the growth of the shoot and vice versa, to a large degree, the growth responses are hormones mediated.

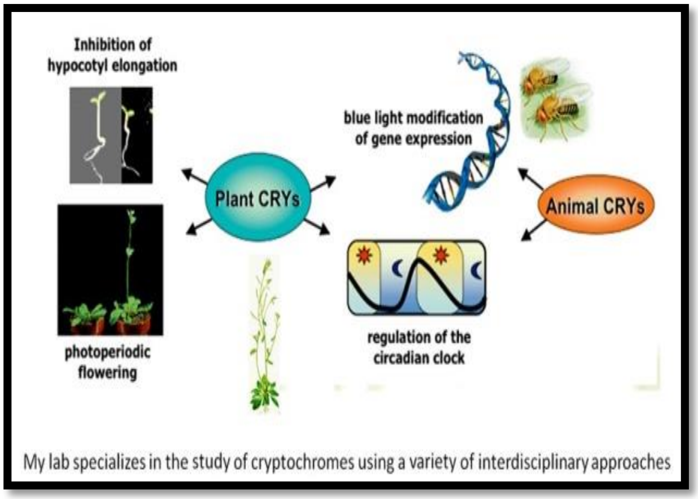
Cryptochromes:

The word Cryptochrome is derived from Greek word crypto = hidden, chrome = colors

Cryptochromes are photoreceptors that regulate entrainment by light of the circadian clock in plants and animals.

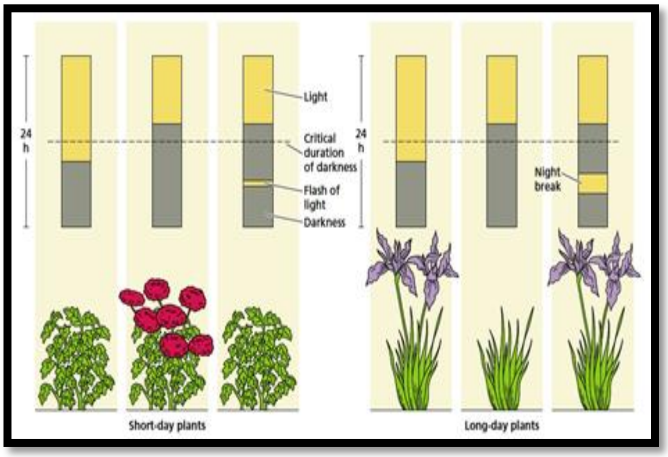
They also act as integral parts of the central circadian oscillator in animal's brains and as receptors controlling photomorphogenesis in response to blue or UV light in plants. Cryptochromes are flavoprotein photo- receptors first identified in Arabidopsis thaliana, Cryptochrome play key roles in growth and development.

A plant pigment that absorbs mainly blue and UV light and also involved in various plant responses to light. Including phototropism and hypocotyl elongation.



Photoperiodism:

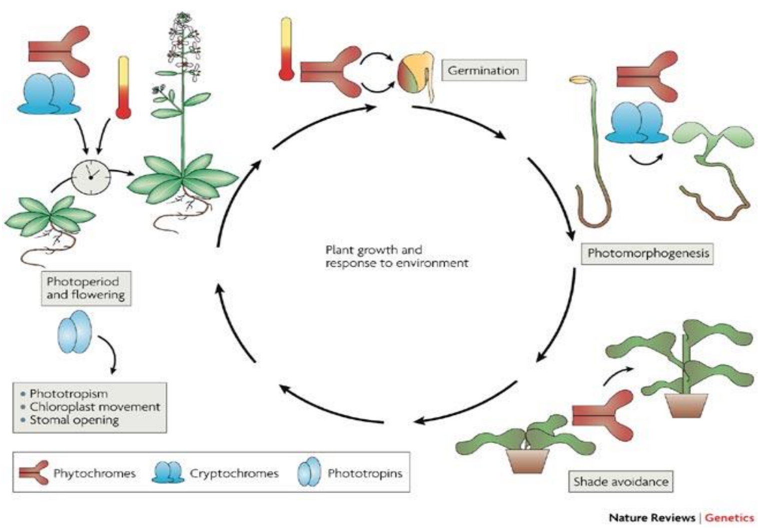
The response of an organism to seasonal changes in day length. Many flowering plants (angiosperms) use a photoreceptor protein, such as phytochrome or cryptochrome, to sense seasonal changes in night length, or photoperiod, which they take as signals to flower.

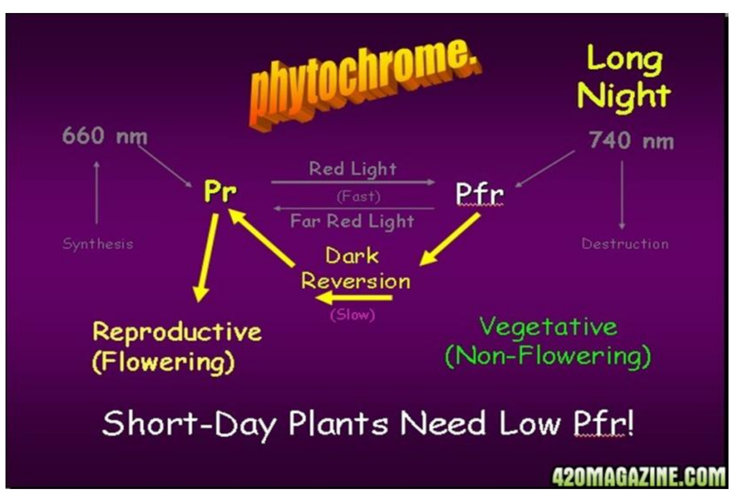


The phytochrome system acts as a biological light switch. It monitors the level, intensity, duration, and color of environmental light.

The biologically-inactive form of phytochrome (Pr) is converted to the biologically-active form Pfr under illumination with red light. Far-red light and darkness convert the molecule back to the inactive form.

Pfr can slowly revert to Pr in the dark or break down over time and then physiological response induced by red light is reversed. The active form of phytochrome (Pfr) can directly activate other molecules in the cytoplasm, or it can be trafficked to the nucleus, where it directly activates or represses specific gene expression.





It has been discovered that duration of light also plays a major role in inducing flowering in plants.

This flowering response in plants to the relative length of light and dark periods within a 24 hour cycle is called **'Photoperiodism'**.

Every plant has a specific critical period of light duration needed for flowering. In order to flower they must be exposed to either more or less light hour than that of critical period. Based on flowering response to light duration, plants have been classified into Long day plants, short day plants and day neutral plants.

Long day plants (LDP): They are plants which produce flower only when they are exposed to light duration more than the critical period. They produce flower in summer. E.g. Oat and Rye plants.

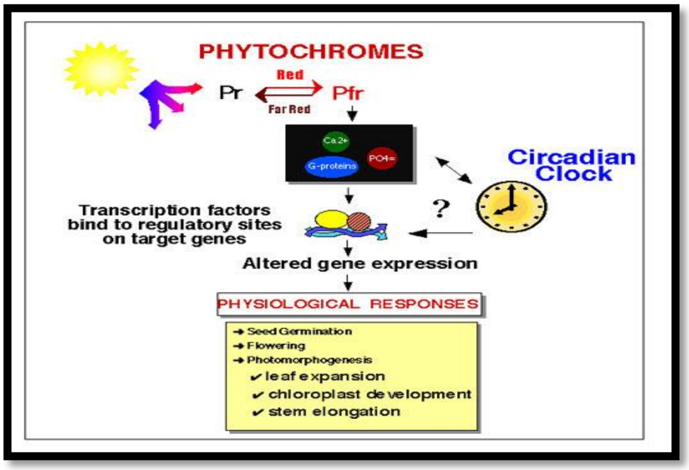
Short day plants (SDP): They are plants which produce flower only when they are exposed to light duration shorter than the critical period. They produce flower in spring or winter. E.g. Chrysanthemum, Tobacco and Coffee.

Day neutral plants: They produce flowers throughout the year irrespective of length of light hours to which they are exposed. E.g. Tomato.

Vernalization: Some biennials like carrot, cabbage and sugar beet need a cold/low temperature treatment before they flower. This is called 'vernalizaion'.
In other words, Vernalization is promotion of flowering by low temperature treatment.
Spraying gibberellins is a substitute to cold treatment and biennials can be made to flower in one year without the cold treatment.

Circadian clock in plants:

Circadian rhythms govern many plant processes, including movements of organs such as leaves and petals, stomata opening, stem elongation, sensitivity to light of floral induction, metabolic processes such as respiration and photosynthesis and expression of a large number of different genes.



Regulation of Flowering:

One of the most plastic developmental decisions in the life cycle of plants is the timing of the floral transition. To achieve reproductive success, plants must select the most favorable season to initiate reproductive development. This selection requires the existence of molecular mechanisms to continuously monitor environmental factors to properly respond to the adequate conditions. Many environmental factors influence flowering time. Those ranging in a predictable fashion along the year, such as light and temperature, are the most relevant in terms of the selection of flowering season. These predictable factors show complex patterns of variations and interaction in different temporal range (i.e. diurnal versus annual variation in light and temperature). However, even less predictable factors such as nutrient or wind can also modulate flowering time, depending on species. Environmental factors display patterns of variation in the short (i.e. diurnal variation) and long ranges (i.e. seasonal annual fluctuation). Plants are able to perceive all this environmental variation and modulate their growth and development with responses that can be in the short term such as growth response to ambient temperature or in long terms like the flowering response to vernalization.

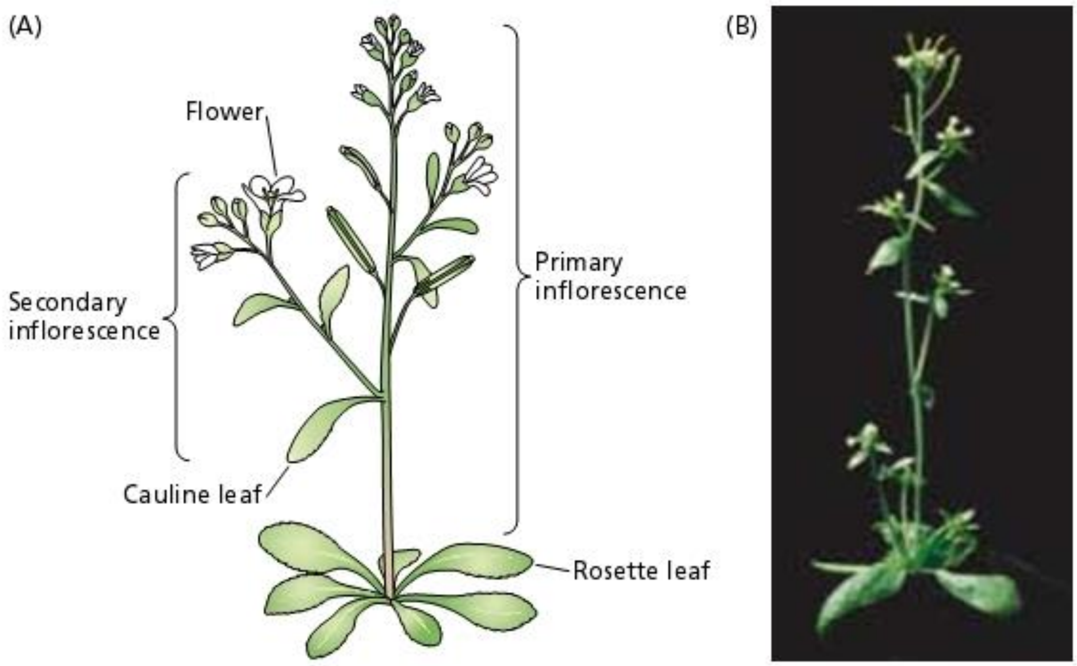


Figure 15- (A) The shoot apical meristem in *Arabidopsis thaliana* generates different organs at different stages of development .early in development the shoot apical meristem forms a rosette of basal leaves. When the plant makes the transition to flowering, the shoot apical meristem is transformed into primary inflorescence meristem that ultimately produces an elongated stem bearing flowers leaf primordia initiated prior to the floral transition becomes cauline leaves ,and secondary inflorescence develop in the axil of the cauline leaves.(B) Photograph of *Arabidopsis thaliana*.

Physiological control of flowering time:

In the natural temperature regimes, many factors in the environment influence flowering time. These factors are either predictable or not predictable and hence can or cannot be used reliably by plants to time their reproduction. Factors that are highly predictable are considered to be the most specific or primary controlling factors, these include the annual change in day length and the period of winter cold. Less predictable climatic factors, such as ambient temperature, light integral (day length x irradiance) and water availability are usually viewed as secondary factors that can modulate the effects of primary factors.

Finally unpredictable or tertiary factors are those that the plant has to face locally, such as mineral availability, wind and neighbors. The effects of neighborhood have some times have limited to the response to light quality although they also involve competition for light, water and minerals.