14.3: Photoperiodism

Learning Objectives

• Describe the mechanism of photoperiodism with respect to flowering.
• Distinguish among short-day, long-day, and day-neutral plants.
• Define circadian rhythms and provide examples in plants.

Detection of seasonal changes is crucial to plant survival. Although temperature and light intensity influence plant growth, they are not reliable indicators of season because they may vary from one year to the next. Day length is a better indicator of the time of year. Many angiosperms flower at about the same time every year. This occurs even though they may have started growing at different times. Their flowering is a response to the changing length of day and night as the season progresses. It helps promote cross pollination. The biological response to the timing and duration of day and night is called photoperiodism.

The Phytochrome System and the Red/Far-Red Response

Plants use the phytochrome system to sense the change of season, which can control flowering. The phytochromes are a family of photoreceptors. They are chromoproteins with a linear tetrapyrrole chromophore (a molecule that absorbs light), similar to the ringed tetrapyrrole light-absorbing head group of chlorophyll. A phytochrome is a homodimer: two identical protein molecules, each conjugated to a light-absorbing molecule (compare to rhodopsin). Plants make 5 phytochromes: PhyA, PhyB, as well as C, D, and E. There is some redundancy in function of the different phytochromes, but there also seem to be functions that are unique to one or another. The phytochromes also differ in their absorption spectrum; that is, which wavelengths (e.g., red vs. far-red) they absorb best. Phytochromes have two
photo-interconvertible forms: Pr and Pfr. Pr absorbs red light (~667 nm) and is immediately converted to Pfr. Pfr absorbs far-red light (~730 nm) and is quickly converted back to Pr. Absorption of red or far-red light causes a massive change to the shape of the chromophore, altering the conformation and activity of the phytochrome protein to which it is bound. Pfr is the physiologically active form of the protein; therefore, exposure to red light yields physiological activity. Exposure to far-red light inhibits phytochrome activity. Together, the two forms represent the phytochrome system (Figure \(\PageIndex{1}\)).

The phytochrome system acts as a biological light switch. It monitors the level, intensity, duration, and color of environmental light. The effect of red light is reversible by immediately shining far-red light on the sample, which converts the chromoprotein to the inactive Pr form. Additionally, Pfr can slowly revert to Pr in the dark, or break down over time. In all instances, the 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 transported to the nucleus, where it directly activates or represses specific gene expression.

Unfiltered sunlight is rich in red light but deficient in far-red light. Therefore, at dawn, all the phytochrome molecules in a leaf quickly convert to the active Pfr form, and remain in that form until sunset. In the dark, the Pfr form takes hours to slowly revert back to the Pr form. If the night is long (as in winter), all of the Pfr form reverts. If the night is short (as in summer), a considerable amount of Pfr may remain at sunrise. By sensing the Pr/Pfr ratio at dawn, a plant can determine the length of the day/night cycle. In addition, leaves retain that information for several days, allowing a comparison between the length of the previous night and the preceding several nights. Shorter nights indicate springtime to the plant; when the nights become longer, autumn is approaching. This information, along with sensing temperature and water availability, allows plants to determine the time of the year and adjust their physiology accordingly.

In 1920 two employees of the U. S. Department of Agriculture, W. W. Garner and H. A. Allard, discovered a mutation in

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tobacco - a variety called Maryland Mammoth - that prevented the plant from flowering in the summer as normal tobacco plants do. Maryland Mammoth would not bloom until late December. Experimenting with artificial lighting in winter and artificial darkening in summer, they found that Maryland Mammoth was affected by photoperiod. Because it would flower only when exposed to short periods of light, they called it a **short-day** plant. Examples of other short-day plants include chrysanthemums, rice (*Oryza sativa*), poinsettias, morning glory (*Pharbitis nil*), and cocklebur (*Xanthium*).

Experiments with the cocklebur have shown that the term short-day is something of a misnomer; what the cocklebur needs is a sufficiently **long night** (Figure \(\PageIndex{2}\)). Short-day (long-night) plants flower in the late summer and early fall, when nights exceed a critical length (often eight or fewer hours). In short-day plants, the active form of phytochrome (Pfr) suppresses flowering. During long periods of darkness (long nights), Pfr is converted to Pr. With Pfr no longer present, flowering is not suppressed, and short-day plants flower. If a flash of light interrupts the dark period, Pr is converted back to Pfr, and flowering is suppressed.

### Five experiments with photoperiodism in the cocklebur

![Diagram of cocklebur photoperiod experiments](https://bio.libretexts.org/Bookshelves/Botany/Botany_(Ha_Morrow_and_Algiers)/Unit_3%3A_Plant_Physiology_and_Regulati...)

**Figure \(\PageIndex{2}\):** Cockleburs (adapted to the latitude of Michigan) will flower only if they have been kept in the dark for at least 8.5 hours — the **critical period** (A and B). Interruption of an otherwise long night by light — red (660 nm) rays are particularly effective — prevents flowering (C). Unless it is followed by irradiation with far-red (730 nm) light (D). An intense exposure to far-red light at the start of the night reduces the dark requirement by two hours (E).

**Long-day** (short-night) plants flower during the spring, when darkness is less than a critical length (often eight to 15 hours). Examples include spinach, *Arabidopsis*, sugar beet, and the radish flower.

Flowering in **day-neutral** plants, such as the tomato, is not regulated by photoperiod.

Photoperiodism also explains why some plant species can be grown only in a certain latitude. Spinach, a long-day plant, cannot flower in the tropics because the days never get long enough (14 hours). Ragweed, a short-day plant, fails to thrive in northern Maine because by the time the days become short enough to initiate flowering, a killing frost in apt to occur before reproduction and the formation of seeds is completed.

Some plants do not neatly fit into the categories of short day, long day, or day neutral. In 1941, Marie Taylor Clark found that flowering in scarlet sage did not flower under daylengths longer than 16 hours, suggesting it was a short-day plant; however, days that were too short (6 hours) slowed flower development. Flower development was optimal with daylengths of 10 hours.

The leaves produce a chemical signal called **florigen** that is transmitted to the apical meristems to start their conversion...
into floral meristems. The chemical nature of florigen has been sought for decades. The most recent evidence suggests that at least one component is the protein encoded by the gene FLOWERING LOCUS T (FT). Due to florigen signaling, the entire plant will bloom even if only a part of one leaf is exposed to the correct photoperiod (Figure \(\PageIndex{3}\)).

Figure \(\PageIndex{3}\): The cocklebur needs at least 8.5 hours of darkness in order to flower. Grafting a cocklebur (B) that receives the required period of darkness to one (A) that does not causes flowering in both. Evidently the florigen signal passes from B to A through their connected vascular systems.

**Career Connection: Horticulturist**

The word “horticulturist” comes from the Latin words for garden (hortus) and culture (cultura). This career has been revolutionized by progress made in the understanding of plant responses to environmental stimuli. Growers of crops, fruit, vegetables, and flowers were previously constrained by having to time their sowing and harvesting according to the season. Now, horticulturists can manipulate plants to increase leaf, flower, or fruit production by understanding how environmental factors affect plant growth and development.

Greenhouse management is an essential component of a horticulturist’s education. To lengthen the night, plants are covered with a blackout shade cloth. Long-day plants are irradiated with red light in winter to promote early flowering. For example, fluorescent (cool white) light high in blue wavelengths encourages leafy growth and is excellent for starting seedlings. Incandescent lamps (standard light bulbs) are rich in red light, and promote flowering in some plants. The timing of fruit ripening can be increased or delayed by applying plant hormones. Recently, considerable progress has been made in the development of plant breeds that are suited to different climates and resistant to pests and transportation damage. Both crop yield and quality have increased as a result of practical applications of the knowledge of plant responses to external stimuli and hormones.

Horticulturists find employment in private and governmental laboratories, greenhouses, botanical gardens, and in the production or research fields (Figure \(\PageIndex{4}\)). They improve crops by applying their knowledge of genetics and plant physiology. To prepare for a horticulture career, students take classes in botany, plant physiology, plant pathology, landscape design, and plant breeding. To complement these traditional courses, horticulture majors add studies in economics, business, computer science, and communications.
Circadian Rhythms

Circadian rhythms are changes based on a 24-hour cycle. For example, flowers might open every morning and close every evening or vice versa. In Oxalis and silk tree (Albizia julibrissin), leaflets expand during the day and retract at night. Circadian rhythms may also involve physiological processes like photosynthetic rate or the production of floral scent compounds.

Under constant conditions, circadian rhythms may drift out of phase with the environment (figure \(\PageIndex{5}\)). However, when exposed to environmental changes (e.g., alternating day and night), the rhythms become entrained; that is, they now cycle synchronized with the cycle of day and night with a period of exactly 24 hours. Internal circadian clocks also adjust to changing photoperiods. Suppose a plant that flowers throughout the spring opens its flowers every morning. The sun rises earlier in the late spring compared to the early spring (photoperiod increases in late spring). As time passes and the plant detects the changing photoperiod (technically, plants measure the length of the night rather than daylength; see above), the circadian clock would adjust such that its flowers opened earlier. In Arabidopsis, the entrainment of circadian rhythms requires that light is detected by phytochromes (absorb red light) and cryptochromes (absorb blue light).
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