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NAAC ACCREDITED 'A' GRADE



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# BIOLOGICAL CLOCK AND BIORHYTHM

## *Introduction:*

In general, once a plant attains the adult phase, they exhibit an increasing tendency to flower with age. For eg, in plants, controlled by day length to flower, the number of short day on long day cycles necessary to achieve flowering is often fewer in older plants. This observation suggests that the effect of day length could accelerate a flowering process that is occurring already at a slow pace, so it is the question of how plants measure time.

This topic is now -a-day known as chronobiology or the study of biological clocks. The best example of a biological clock is circadian rhythm.

## **CIRCADIAN RHYTHM:**

It is a biological activity that shows a cycle of high activity and low activity independent of external stimuli with a regular period of about 24 hrs ( latin; "circadium" means about a day)

Plants are subjected to a daily cycle of light and darkness and they often exhibit a rhythmic behaviour in association with those changes, such as, leaf and petal movements in response to day and night, stomatal opening and closing, metabolic processes like photosynthesis etc. When plants are

transferred to daily light - dark cycle to continuous darkness, many of these rhythms continue to be expressed at least for several days. Under such uniform conditions the periodicity of the rhythm is then close to 24hrs. and consequently the term circadian rhythm is applied. Because they continue in a constant light or dark environment, this circadian rhythm can not be direct responses to presence or absence of light but must be based on an endogenous pacemaker, i.e self sustaining. This pace - maker is often called an endogenous oscillator. The endogenous oscillator is coupled to a variety of physiological processes such as photosynthesis or leaf movement and maintains the rhythms.

For this reason the endogenous oscillator can be considered as the clock mechanism and the physiological functions that are being regulated are sometimes referred to as the hands of the clock.

Circadian rhythms arises from a cyclic phenomenon that are defined by 3 parametres :

### **1 . PERIODS:**

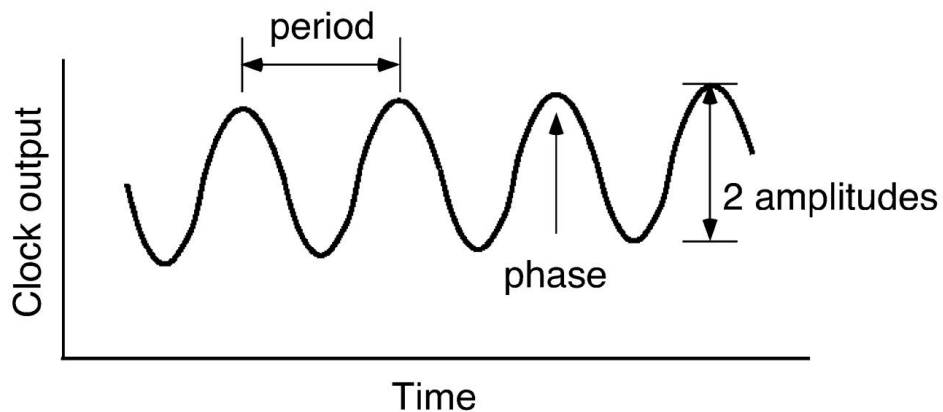
The time between comparable points inthe repeating cycles . Typically the period is measured as the time between consecutive maxima ( peaks) or minima ( troughs).

## **2 . PHASE :**

Any point in the cycle that recognisable by its relationship to the rest of the cycle is called phase. The most obvious phase points are the peak and trough positions.

## **3 . AMPLITUDE :**

It is usually considered to be the distance between peak and trough.



Parametres of circadian rhythm

In constant light or darkness, rhythm departs from an exact 24 hrs period.

The rhythms then drift in relation to solar time, either gaining or losing the time depending on whether the period is shorter or longer than 24 hrs.

Under natural conditions, the endogenous oscillator is synchronized or entrained to the true 24 hrs period by environmental signals. The most important of which are the light to dark transition at dusk, and the dusk to

light transition at dawn. Such environmental signals are termed as **zeitgebers**. When such signals are removed, for e.g by transfer to continuous darkness, the rhythm is said to be free running and reveals to the circadian periods i.e characteristic to the particular organism.

Although the rhythms are generated internally. They normally require an environmental signals such as exposure to light, to initiate their expression. In addition, many rhythms damp out when an organism is in a constant environment for sometime and then require an environmental zeitgeber such as a transfer from light to dark to be restarted.

The circadian clock would have no value to organisms if it could not keep accurate time under fluctuating temperature experienced in natural condition. The feature that enables the clock to keep time at different temperature is called temperature compensation.

### *Florigen and biological clock:*

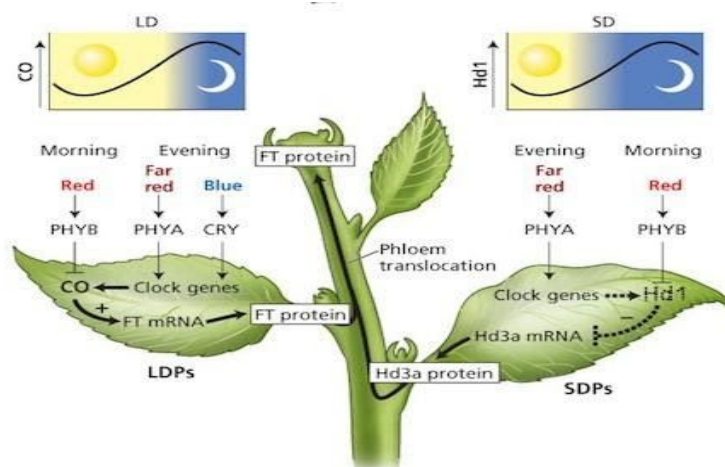
The so-called biological clock in plants is set primarily in the leaves by phytochromes, which are sensitive to red and far-red light. They get help from blue-light-sensitive cryptochromes. These photoreceptors interact with “clock-genes” that cause some proteins in plant cells to cycle with a circadian rhythm.

One of these proteins regulates the gene that codes for florigen (FT in *Arabidopsis* and Hd3a in rice, for instance).

Thus, florigen cycles in the leaves also with a circadian rhythm.

Briefly, in LD (“short-night”) plants florigen apparently peaks not long after sundown, then slowly degrades during the night. If the nights are too long, the florigen level is below the threshold level to induce flowering at dawn, when the leaves begin to transport material via the phloem. (Please note: florigen appears to be synthesized primarily by leaf vein cells adjacent to the phloem.)

Conversely, in SD (“long-night”) plants, the florigen apparently peaks long after sundown. So, if the night is too short, at dawn, the florigen hasn’t exceeded the threshold level to trigger flowering.



## *Photoreceptors and circadian clock :*

The transition to flowering involves multiple factors and pathways – The photoperiodic pathways involve Phytochromes and Cryptochromes. The interaction of these photoreceptors with a circadian clock initiates a pathway that eventually results in the expression of the gene, CONSTANS (CO), which encodes a zinc-finger transcription factor that promotes flowering.

- CO acts through other genes to increase the expression of the floral meristem identity gene LEAFY (LFY).
- All pathways for floral initiation are covered by increasing the expression of the key floral meristem identity gene AGAMOUS 4KE (AGL20).
- The role of AGL20, A MADS box – containing transcription factor, is to integrate the signals coming from all pathways into a unitary output. Obviously the strongest output signal occurs when all pathways are activated.
- Once turned on by AGL20, LFY activates the floral homeotic genes – APETALA1 (AP1), APETALA3 (AP3), PISTILLATA (PI) and AGAMOUS (AG) that are required for floral organ development.
- APETALA2 (AP2) is expressed in both vegetative and floral meristems and is therefore not affected by LFY. However, as AP2, exerts a negative effect on AG expression.

## The Blue Light photoreceptor :

- It is involved in sensing inductive photoperiods in *Arabidopsis* that mutations in one of the cryptochrome genes, CRY2, caused a delay in flowering and an inability to perceive inductive photoperiods.
- In some long day plants, such as *Arabidopsis*, blue light can promote flowering, Cry1 and Cry2 are two *Arabidopsis* genes involved in blue light dependent inhibition of stem elongation, cotyledon expansion, anthocyanin synthesis, the control of flowering, and the setting of circadian rhythms.
- It has been proposed that CRY1 and CRY2 are apo-proteins of flavin containing pigment proteins that mediate blue-light photo reception.
- The Cry1 and Cry2 gene products have sequence similarity to photolyase but no photolyase activity.
- The Cry1 protein and to lesser extent Cry2 accumulates in the nucleus and might be involved in gene expression.
- The Cry1 protein also regulates anion channel activity at the plasma membrane.
- In many long – day plants blue light is more effective than red light. Cry2 mutants will flower much later during long days but not in short days. Cry2 has a role in photoperiodic regulation of flowering time in long day plants.

The whole process is given below in a flow chart manner:-

