III. Timing Mechanisms in plants:

A. The plant way of life revisited.

Recall that a stationary organism like a plant must be able to accurately predict when the environment is going to change. Since plants can't move they must respond to these changes by relatively slow growth responses/movements that take time. Thus, plants must have an accurate sense of time to distinguish daily and seasonal changes and respond to them.

B. Examples of timing mechanisms in plants:

Timing mechanisms include: (1) Flowering - recall that plants must flower at the appropriate time of the season; (2) Bud break and seed germination - timing mechanism to determine when spring has arrived; develop too soon and they risk freeze injury, develop too late and they may not have enough time to complete the life cycle.

C. Requirements for a biological clock.

The clock must be:

1. Accurate (keep good time or be reset each day).
2. Insensitive to capricious events in the environment (those that are not predictable such as temperature, wind speed, precipitation).
3. Have a transducing mechanism to couple the clock to a physiological response.

The timers in plants include:

1. Ripeness-to-flower. Essentially the life of the plant can be considered to be an hourglass timer that isn't reset.
2. Induction/reversion phenomena due to phytochrome (*i.e.*, seed germination).
3. Seed germination/bud break - many seeds and buds measure the amount of inhibitor present and develop when the level drops below some critical value.

D. Oscillating or rhythmic timers.

These measure time intervals between regular oscillations, such as the sweeps of a pendulum. Many events in plants show rhythmic oscillations such as the opening/closing of flowers, leaf movements (**Nyctinasty**, which means: Nyctinasty it refers to the **nastic movement of leaves or petals of higher plants in response to darkness** (or the alternation of day and night). The closing of a flower at dusk, for example, is a biological rhythmic event, another, is the sleep movement of the legume leaves during the night, and even growth rates.

1. Anatomy of an oscillation

Period refers to the time between repeating points of the cycle, or in other words, the time it takes to complete one cycle. Period is symbolized by tau. Most biological rhythms have a period of 24 hours though they vary from 21-27. Hence, they are called circadian, because they last approximately about one day.

Amplitude - intensity of oscillations, or in other words, the difference between the peaks and troughs.

2. Oscillating timers.

Plants must be able to set their oscillating timer to correspond to environmental changes. This is called **entrainment** and the signal that synchronizes the rhythm is the **zeitgeber**. Light is the zeitgeber. Both blue and red light are important. The red light sensitive species show red/far-red reversibility suggesting that phytochrome is the receptor for the response.

3. The nucleus is the site of an endogenous, oscillating timer.

IV. Transducing mechanism for photoperiodism.

A. Photoperiodism as an hourglass timer.

What is pfr in plant flowering mean? (Pfr is the physiologically-active form of the protein; exposure to red light leads to physiological activity in the plant. Exposure to far-red light converts the Pfr to the inactive Pr form, inhibiting phytochrome activity. Together, the two forms represent the phytochrome system**)**.

What is the difference between Pr and Pfr plants?

(The purified phytochrome from dark-grown plants is blue in color and absorbs red light (termed Pr, absorbs maximally at 660 nm). On exposure to red light, the (Pr) form converts to the far-red light absorption form (Pfr) which is olive-green in color and absorbs maximally at 730 nm (Quail, 1997, Figure 2).

What is the difference between Pr and Pfr?

(Phytochrome is red-light photoreceptors that undergo reversible photoconversion between a red-light-absorbing state (Pr) and a far-red-light-absorbing state (Pfr), and thereby they regulate a wide range of physiological responses in plants, fungi, and photosynthetic bacteria.

According to this hypothesis, plants measure the ratio of Pfr/Pr. an LDP would flower when the ratio is high (i.e., more Pfr) and but SDP would flower when the ratio is low (more Pr). Since Pfr is labile and is broken down at night or reverts back to Pr - the longer the night, the lower the phytochrome (Pfr) content. Thus, phytochrome is like the sand in an egg timer; the relative amount of Pfr remaining at the end of the night would be an indication of the day length. To "reset" an egg timer, you simply turn it over. Similarly, the flowering timer would be reset during the day when Pfr levels are re-established.

Problems with this hypothesis:

(a) The half-life of Pfr breakdown is too short.

(b) If phytochrome degradation is involved, the process should be temperature sensitive, but it is not.

B. Photoperiodic Control of Plant Growth.

Other aspects of plant growth and development are affected by photoperiod including:

1. Seed germination (some like long days, others short days).
2. Stem growth (promoted by long days).

3. Root and storage organ formation (induced by short days in potato, dahlia and radish, long days in onion).
4. Vegetative reproduction (long days – strawberry runners, *Bryophyllum* plantlets).
5. Sexual reproduction (flower induction and development).
6. Autumn response.
7. Flowering.

D. Photoperiodism summary.

Plants are affected by photoperiod in many ways;

1. There is a wide diversity of responses of flowering to photoperiodism (*i.e.*, LDP, SDP); Plants must be ripe-to-flower before they will respond;
2. Dark period is important;
3. An hourglass timer may be involved;
4. An oscillating timer is surely involved;
5. A flowering hormone is involved;
6. Flowering can be induced by exogenous hormone application.

E. Temperature and flowering

A. Overview.

Many plants require a cold treatment to induce flowering. This is termed **Vernalization** and is a "smart" way to time when winter is over (type of hourglass timer). **Vernalization** is common in biennials and winter annuals (such as winter wheat). The effect can be qualitative or quantitative. **Vernalization** usually works in concert with photoperiod - in other words, **Vernalization** is required to make the plants sensitive to photoperiod. Thus, this acts as a "fail-safe" system to insure flowering at the appropriate time of year (after winter!).

B. Signal.

Cold, actual temperature varies from -5 to 15 °C.

C. Receptor.

1. Some seeds can be vernalized (data for rye). However, they must be hydrated (dry, unimbibed seeds are insensitive). Biennials not responsive as seeds.
2. The meristem perceives cold treatment - grafting experiments and tissue culture experiments with rye.
3. Some plants (henbane) need to reach a certain size to be responsive to cold treatment, whereas others (rye) can be treated as seeds.

D. Transducing mechanism

1. Plants can "remember" the signal. In other words, cold-treated plants will grow vegetative for quite a while before flowering. This suggests that the induced state must be permanent, or at the least be relatively stable, in many species.
2. A hormone doesn't seem to be absolutely required since the meristem is the source of the receptor and it could pass the permanent change on to future cells.
3. A chemical signal may be involved - the transmission of a signal through grafts has been noted with some. This hormone has been termed vernalin, but not yet isolated.

4. Plants can be de-vernalized if the cold treatment is followed by a heat. In rye, 30 °C for 3-5 days will do the job. Rye can also be devernalized by drying and anaerobic conditions.
5. GA can substitute for cold in some cold-requiring species. But, GA may primarily affect bolting (stem elongation).
6. Vernalization of isolated embryos requires oxygen and carbohydrate - suggests an energy-dependent process.

Bryophyllum

Henbane plant

Rye plant

What is nyctinasty in plants?

Nyctinastyهي الحركة الإيقاعية اليومية للنباتات البقولية استجابةً لبداية الظلام، وهي ظاهرة فريدة ومثيرة للاهتمام جذبت الانتباه لعدة قرون.

What is the meaning of nictinasty?

علم النبات .حركة مفاجئة، مثل انغلاق البتلات، تحدث استجابةً لتناوب النهار والليل.

What is nyctinasty in ecology?

في علم الأحياء النباتية، nyctinasty هي الحركة الإيقاعية القائمة على الإيقاع اليومي للنباتات العليا استجابةً لبداية الظلام، أو "نوم" النبات .ترتبط الحركات النكتينية بالضوء النهاري وتغيرات درجة الحرارة ويتم التحكم فيها بواسطة الساعة البيولوجية.