

## Lecture 17:

### Vernalization –

#### Promoting flowering with cold

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### A role of temperature in the plant calendar

Changes in day length are a reliable indicator of seasonal progression, but day length *per se* is not completely informative of the time of year.

Some plants discriminate between equivalent photoperiods in the beginning of autumn and spring by flowering under long-day conditions only when these are preceded by a prolonged exposure to cold →

#### VERNALIZATION

Vernalization – the process whereby flowering is promoted by a cold treatment given to a fully hydrated seed (i.e., a seed that has imbibed water) or to a growing plant.

- dry seeds do not respond to cold treatment
- without cold treatment, plants that require vernalization show delayed flowering or remain vegetative (plants grow as rosettes with no elongation of stem)

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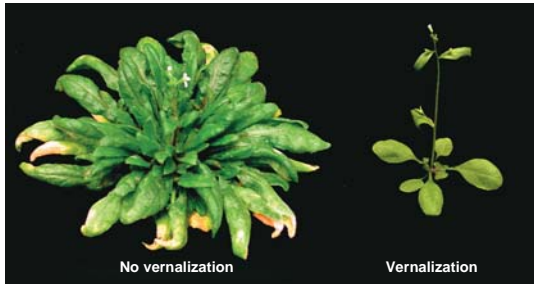
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### Vernalization induces flowering in winter-annual ecotypes of *Arabidopsis thaliana*



No vernalization

Vernalization

Plants are genetically identical.

Exposed as a seedling to 4°C for 40 days.

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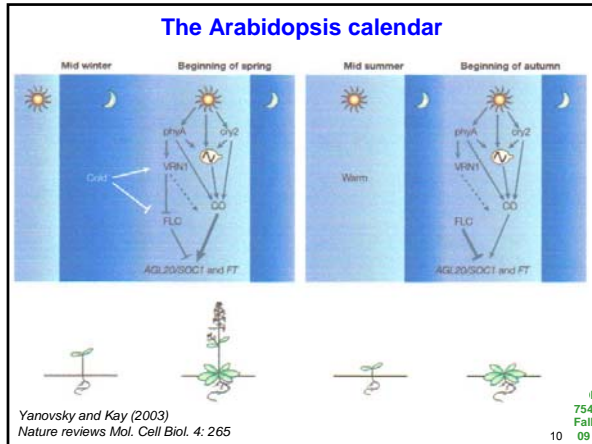
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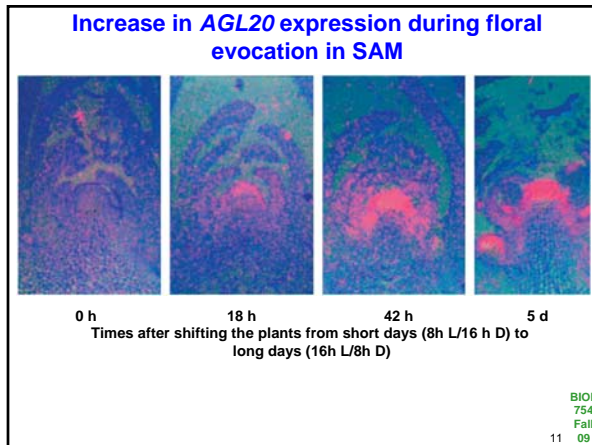
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### Biochemical signaling involved in flowering

**Grafting studies have provided evidence for a transmissible floral stimulus**

- 1930s: Mikhail Chailakhyan postulated the existence of a universal flowering hormone, "florigen"
- **Example:** *Perilla*, a SDP;
  - Left:** grafting an induced leaf from a plant grown under short days onto non-induced shoot causes the axillary shoots to produce flowers.
  - Right:** grafting a non-induced leaf from a plant grown under long days results in generation of vegetative branches only

Floral stimulus seems to be the same in plants with different photoperiodic requirements:  
**Example:** grafting an induced leaf from LDP *Nicotiana sylvestris*, grown under long days, onto the SDP Maryland Mammoth caused the latter to flower under long day

*Perilla crispata* (beefsteakplant), SDP

Induced graft donor      Uninduced graft donor

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**Successful transfer of a flowering induction signal by grafting between plants of different photoperiodic responses**

**Transmissible factors regulate flowering.**

Donor plants maintained under flower-inducing conditions	Photoperiod type <sup>a,b</sup>	Vegetative receptor plant induced to flower	Photoperiod type <sup>a,b</sup>
<i>Helianthus annuus</i>	DNP in LD	<i>H. tuberosus</i>	SDP in LD
<i>Nicotiana tabacum</i> Delcrest	DNP in SD	<i>N. sylvestris</i>	LDP in SD
<i>Nicotiana sylvestris</i>	LDP in LD	<i>N. tabacum</i> Maryland Mammoth	SDP in LD
<i>Nicotiana tabacum</i> Maryland Mammoth	SDP in SD	<i>N. sylvestris</i>	LDP in SD

Note: The successful transfer of a flowering induction signal by grafting between plants of different photoperiodic response groups shows the existence of a transmissible floral hormone that is effective.  
<sup>a</sup>LDPs = Long-day plants; SDPs = Short-day plants; DNP = Day-neutral plants.  
<sup>b</sup>LD, long days; SD, short days.

Leaves of day-neutral plants also produce a graft-transmissible floral stimulus

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**Successful transfer of the floral stimulus between different genera**

Example:

Grafting a shoot from LDP *Petunia hybrida* (right branch, the scion) onto the cold-requiring biennial *Hyoscyamus niger* (henbane) caused the latter to flower under long days, even though it was non-vernalized.



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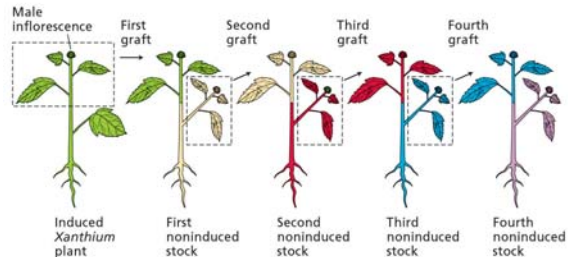
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**Indirect induction implies that the floral stimulus is self-propagating**

(A) Indirect induction can be demonstrated in serial grafting experiments in *Xanthium*.



In *Xanthium* (SDP), *Bryophyllum* (LSDP) and *Silene* (LDP), the induced state appears to be self-propagating → young leaves that develop on the receptor plant after it has been induced to flower by a donor leaf can themselves be used as a donor even though these leaves have never been subjected to an inductive photoperiod → indirect induction

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### Indirect induction does not occur in *Perilla*

(B) Grafting of induced leaf to uninduced shoot causes flowering in multiple grafts in *Perilla*.

Induced plant

Uninduced stock

Uninduced stock

Uninduced stock

Uninduced leaves removed from stock to promote source sink movement to axillary bud from induced leaf

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### Evidence for antiflorigen found in some LDPs

Grafting studies implicated transmissible inhibitors in flowering regulation → antiflorigen

Antiflorigen (like florigen) may consist of multiple compounds

**Example:**  
Grafting uninduced leafy shoot from LDP *Nicotiana sylvestris* onto day neutral cultivar Trapezond suppresses flowering in the day neutral plant under short days but not long-day conditions

Long days

Short days

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### Multiple developmental pathways for flowering in *Arabidopsis*

See part 2

LD

SD

Morning

Evening

Red

Far red

Blue

PHYB

PHYA

CRY

CO

GI

Clock genes

FT mRNA

FT protein

LDPs

Phloem translocation

Evening

Morning

Far red

Red

PHYA

PHYB

Clock genes

Hd1

Hd3a mRNA

Hd3a protein

SDPs

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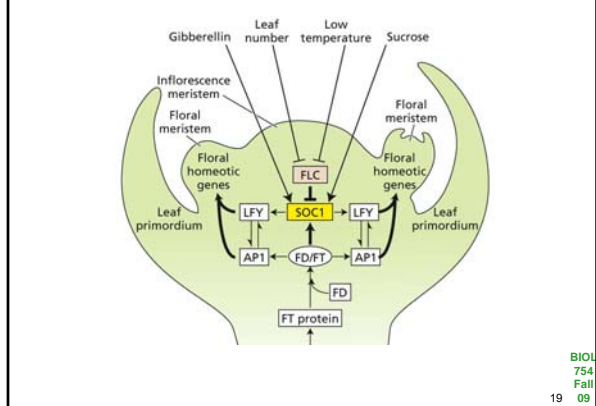
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**Multiple developmental pathways for flowering in Arabidopsis**



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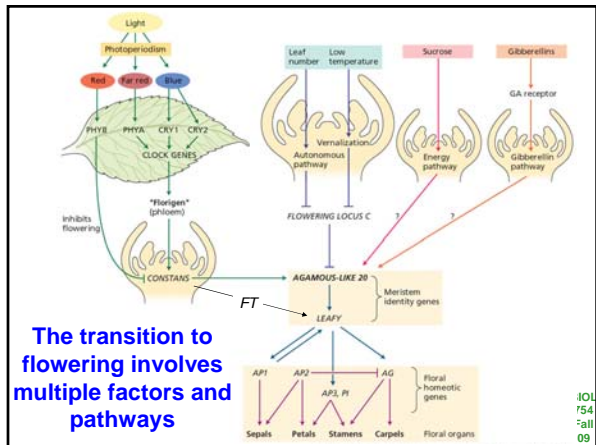
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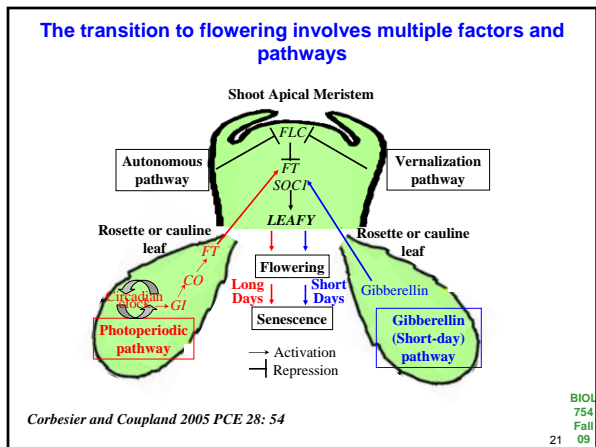
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