

# Plant Responses to Environmental Cues

## Tropisms, Photoperiodism, and Plant Hormones



### Plant Responses to Environmental Cues

**Phototropism** - plant growth response to light  
shoots bend toward light - positive phototropism  
roots sometimes bend away from light - negative phototropism  
allows shoots to capture more light  
mediated by the plant hormone auxin

**Gravitropism** - plant growth response to gravity  
shoots bend away from gravity - negative gravitropism  
mediated by auxin - causes lower side of stem to elongate  
roots grow toward gravity - positive gravitropism  
mediated by gravity sensing cells in root cap

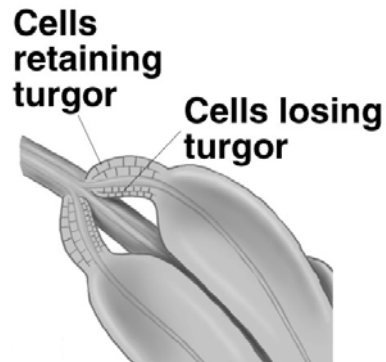
**Thigmotropism** - plant growth response to touch  
causes coiling of tendrils  
mediated by auxin and ethylene



## Turgor Movement

Turgor is pressure within a living cell resulting from water diffusion.

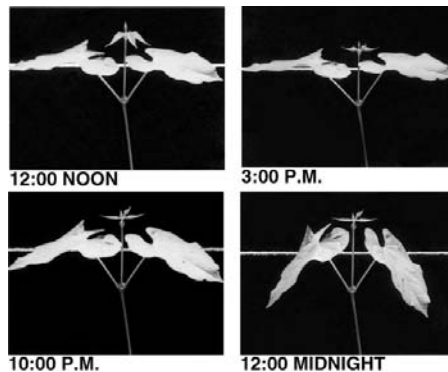
After exposure to a stimulus, changes in leaf orientation are mostly associated with rapid turgor pressure changes in pulvini - multicellular swellings located at base of each leaf or leaflet  
turgor movements are reversible



**Circadian clocks** are endogenous timekeepers that keep plant responses synchronized with the environment.

circadian rhythm characteristics

- must continue to run in absence of external inputs
- must be about 24 hours in duration
- can be reset or entrained
- can compensate for temperature differences



### **Plant Hormones**

*Auxin* - indole acetic acid (IAA) - causes stem elongation and growth - formation of adventitious and lateral roots, inhibits leaf loss, promotes cell division (with cytokinins), increases ethylene production, enforces dormancy of lateral buds

produced by shoot apical meristems and other immature parts

*Cytokinins* - stimulate cell division (with auxin), promote chloroplast development, delay leaf aging, promote formation of buds, inhibit formation of lateral roots

produced by root apical meristems and immature fruits

*Gibberellins* - promote stem elongation, stimulate enzyme production in germinating seeds

produced by roots and shoot tips, young leaves, seeds

### **Plant Hormones**

*Ethylene* - controls abscission (shedding) of leaves, flowers, fruits, promotes fruit ripening

produced by apical meristems, leaf nodes, aging flowers, ripening fruit

*Abscissic acid* - inhibits bud growth, controls stomate closing, enforces seed dormancy, inhibits other hormones

produced by leaves, fruits, root caps, and seeds

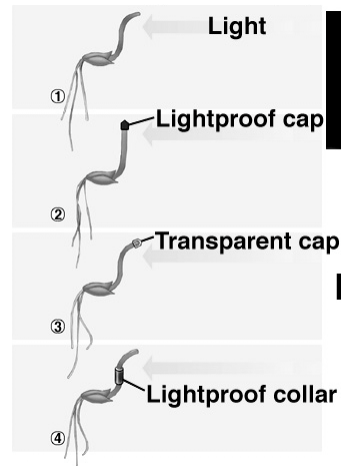
## Auxin

Responsible for phototropism

Charles and Francis Darwin wondered what caused plants to bend toward light

They demonstrated that growing tips of plants sense light

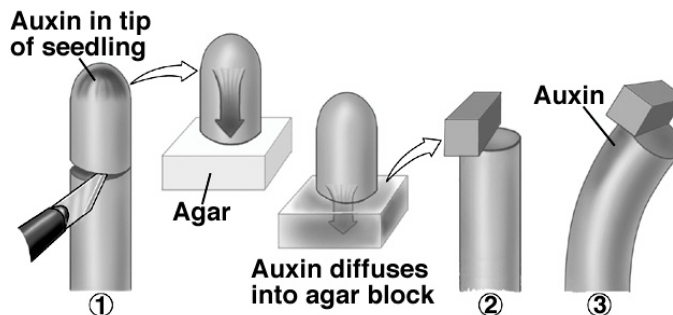
The ability to sense light is not present in areas behind the shoot apex



Went demonstrated that a chemical produced in the shoot tip is responsible for the shoot bending - he called it "auxin"

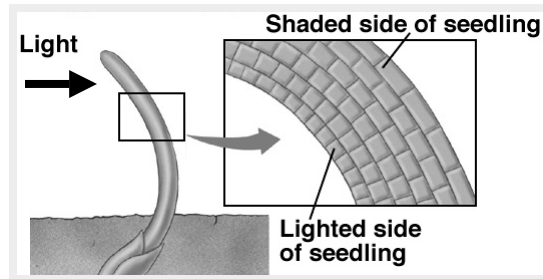
An agar block can absorb chemicals below a growing shoot tip

When the block is applied to an immature shoot, the shoot elongates more on the side where the agar block is applied



Auxin is produced uniformly by growing shoot tips but is transported to the unlighted side of the shoot

It causes cells on the unlighted side to elongate more than cells on the lighted side - it does this by making cell walls softer and more easily stretched by expansion of the cell's cytoplasm



### **Other effects of auxins**

Stimulates formation of fruits

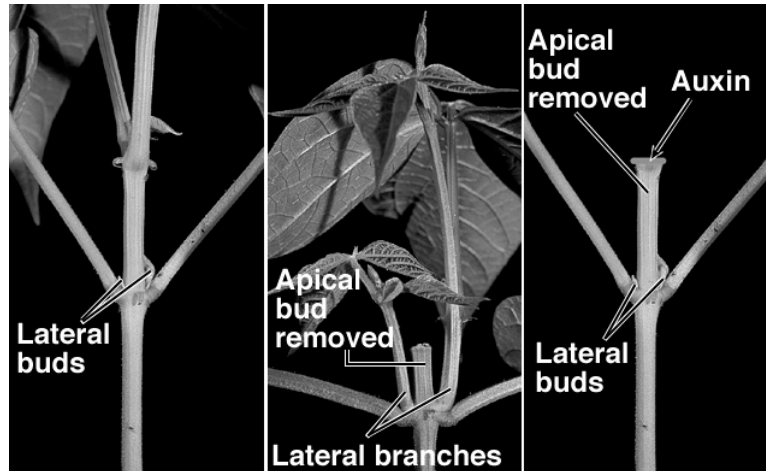
pollen contains large amounts of auxin - pollen's auxin is a chemical signal that pollination has happened and fruit formation can begin - synthetic auxins can cause fruit formation without pollination

Addition of synthetic auxins to cuttings stimulates formation of roots in plant cuttings - "rooting hormone"

Auxin inhibits the growth of lateral buds in shoots - production of auxin by the shoot apex stops growth of neighboring lateral buds - "apical dominance"

Synthetic auxins can be used to control weedy dicots through the inhibition of growth of shoots - it doesn't harm monocots - most commonly used synthetic auxin is 2,4D - often used in lawn "weed and feeds"

Apical Dominance - the tip of a growing shoot (apical bud) produces auxin that inhibits the growth of lateral buds below the apical bud

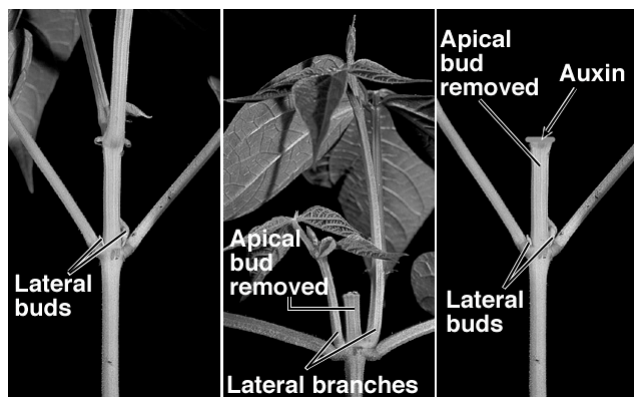


### Cytokinins

Produced in root apical meristem and by fruits

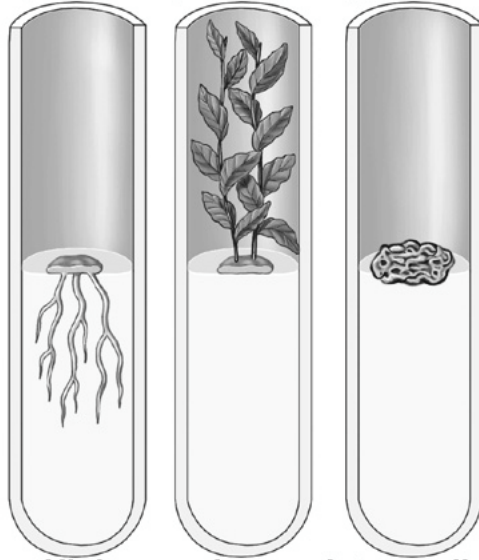
Inhibits lateral root growth and stimulates lateral bud growth

The combination of auxin, which inhibits lateral bud growth, and cytokinin, which stimulates lateral bud growth, produce the growth form of a plant



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## Plant Responses to Cytokinin/Auxin Ratios



Auxin:  
Cytokinin:

High  
Low

Low  
High

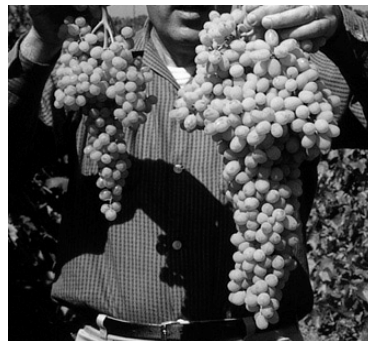
Intermediate  
Intermediate

## Gibberellins

Produced in apical portions of roots and shoots

Cause elongation of internodes in stems (with auxin)

### Gibberellin Effects



### **Ethylene**

Produced in mature fruit and in some apical meristems

Initial observation of ethylene gas inducing defoliation

Suppresses lateral bud formation when combined with auxin

Suppresses stem and root elongation

Plays major role in ripening of fruit

- Fruit forms separation layer at base of leaf petioles

- Hastens ripening, increases respiration

- Complex carbohydrates broken down into simple sugars

- Chlorophylls broken down

- Cell walls become soft

- Volatile chemicals produced, associated with flavor and scent of ripe fruit

Ethylene used commercially to ripen green fruits -

- Carbon dioxide has opposite effect, fruit is often shipped in CO<sub>2</sub> atmosphere, ethylene applied at destination

### **Abscissic Acid**

Produced by aging leaves and fruits

Application on leaves causes yellow spots and premature aging

May induce formation of winter buds

Suppresses growth of buds and formation of bud “scales” for protection



Suppresses growth of dormant lateral buds (with ethylene)

Counters effects of gibberellins

Promotes senescence (decline with age) by countering auxin







Causes dormancy of seeds

Controls opening and closing of stomata - produced when plants are stressed - causes loss of K<sup>+</sup> from guard cells

**Photoperiodism** - plant responses to day and/or night length

Long-day plants flower in the late Spring and early Summer, when days are long and nights are short

Short-day plants flower in the late Summer and early Fall, when days are short and nights are long  
 A single flash of light during a long night will undo the normal effect of a long night

	Long-day plants	Short-day plants
<b>Early summer</b> Midnight 6 P.M.      6 A.M. Noon		
<b>Late fall</b> Midnight 6 P.M.      6 A.M. Noon		
<b>Flash of light</b> 6 P.M.      6 A.M. Noon		
	Iris Short length of dark required for bloom	Goldenrod Long length of dark required for bloom

Long days: 12 - 16 hours, short nights 8-12 hours  
 Short days: < 14 hours, long nights > 8 hours

Day and night length are often manipulated in greenhouses to produce flowering out of season

Poinsettias normally flower in the Spring when day length is increasing - they can be grown indoors under artificial lighting that mimics the light conditions of Spring, just in time for Christmas



## Chemical Basis of the Photoperiodic Response

Two light wavelengths important in the response

Red 660 nm

Far-red 703 nm

Chemistry: two forms of phytochrome:  $P_r$  and  $P_{fr}$

$P_{fr}$  is biologically active,  $P_r$  is biologically inactive

$P_r$  absorbs red light, converted quickly to  $P_{fr}$ , during day

$P_{fr}$  absorbs far-red light and is converted slowly to  $P_r$ , at night

Low concentrations of  $P_{fr}$  indicate a long night (short day)

induces flowering in short-day plants,







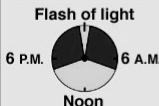


suppresses flowering in long-day plants

High concentrations of  $P_{fr}$  indicate a short night (long day)

induces flowering in long-day plants,

suppresses flowering in short-day plants

In a short day plant, a single flash of red light converts  $P_r$  to  $P_{fr}$  and flowering is suppressed

	Long-day plants	Short-day plants	
<b>Early summer</b> Midnight  6 P.M. 6 A.M. Noon			$[P_{fr}] \xleftarrow{\text{day}} [P_r]$ $\xrightarrow{\text{night}}$ High      Low
<b>Late fall</b> Midnight  6 P.M. 6 A.M. Noon			Low      High
<b>Flash of light</b>  6 P.M. 6 A.M. Noon			High      Low
	Iris Short length of dark required for bloom	Goldenrod Long length of dark required for bloom	

There must be a lengthy and continuous period of darkness for  $P_{fr}$  concentrations to become low