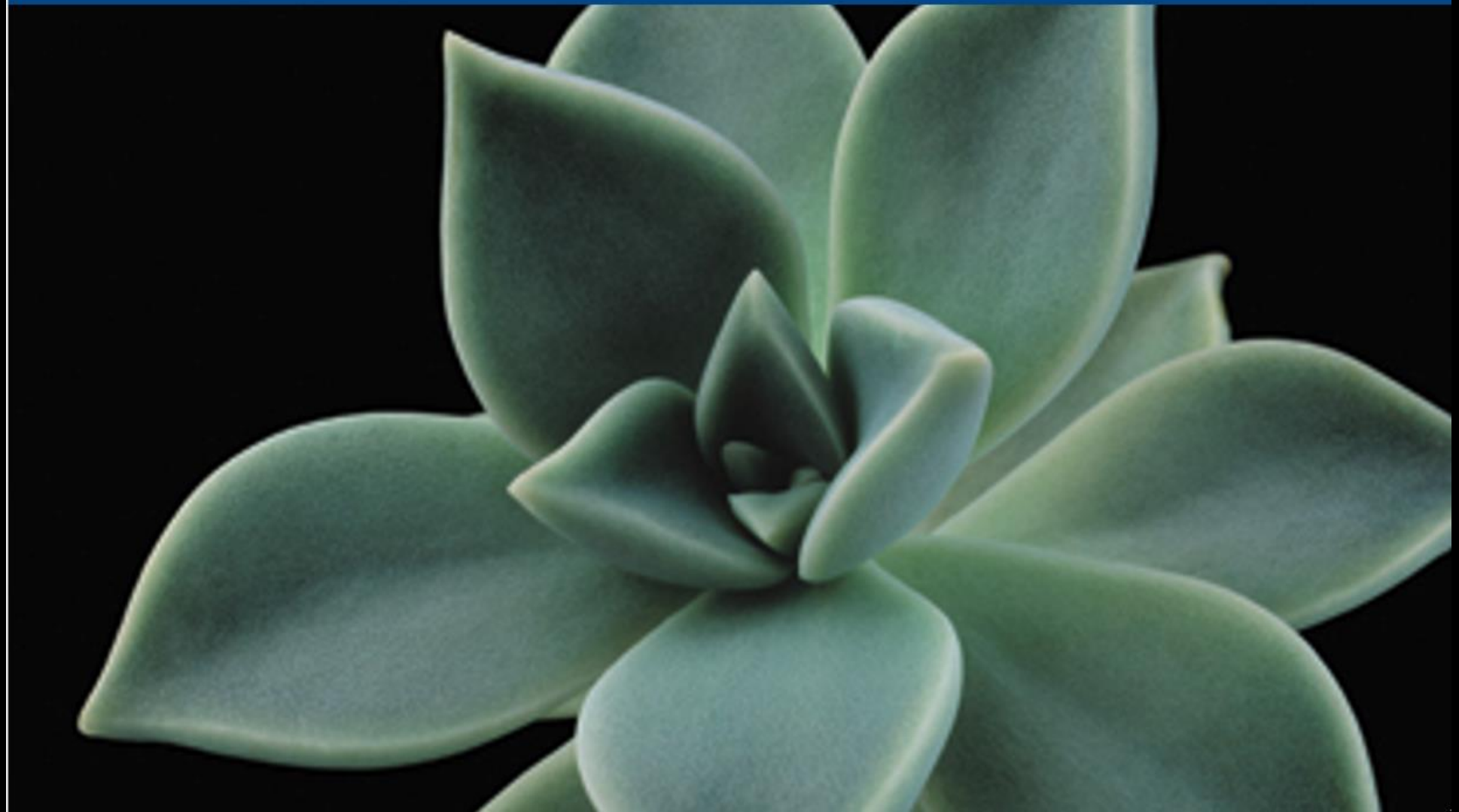
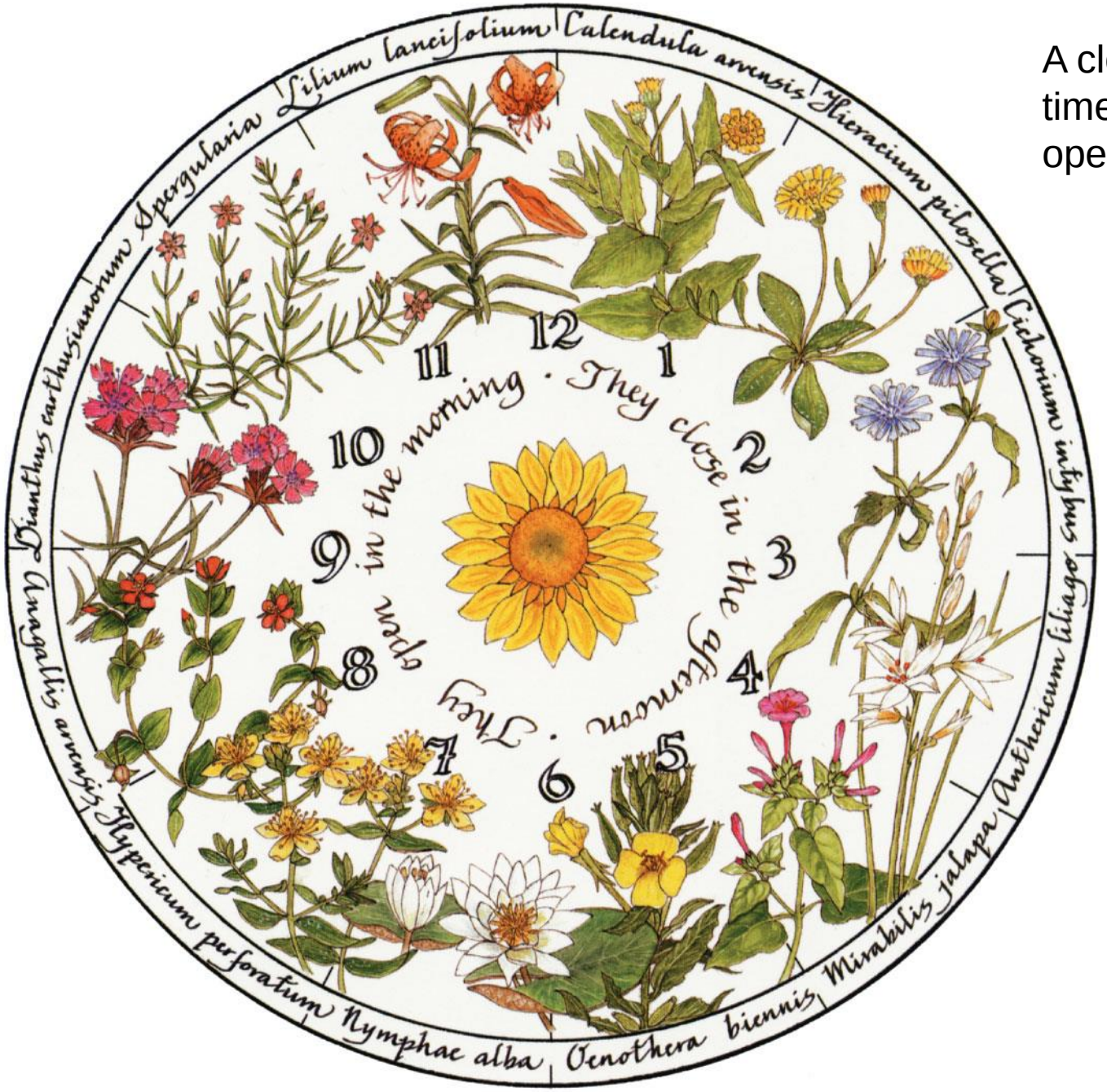
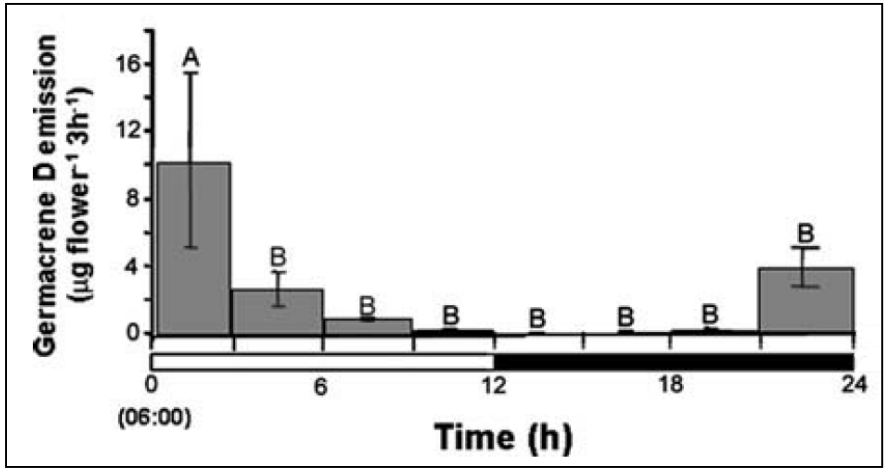
Plant Responses to Signals





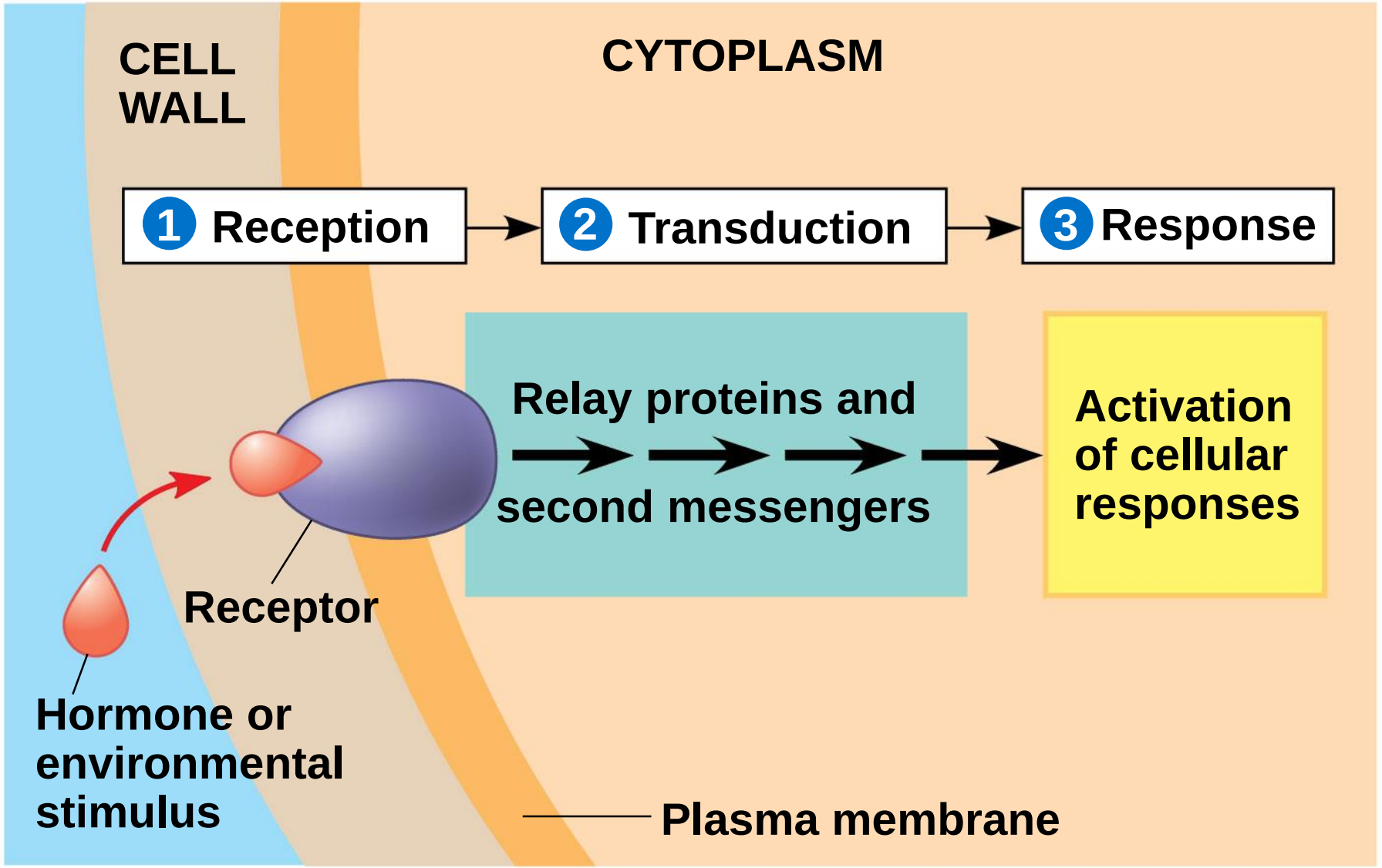
A clock based on the time at which flowers open and close

The release of perfume by roses in the morning



What do Plants Respond to?

- **Light**
- Temperature
- **Gravity**
- **Touch**
- Damage
- Infection/Herbivory
- Symbionts
- Water drought/flood
- Air e.g. CO_2 and O_2
- Circadian clock
- Endogenous hormones
- Developmental program
- Sugar and Nutrient levels
- Cell turgor
- …



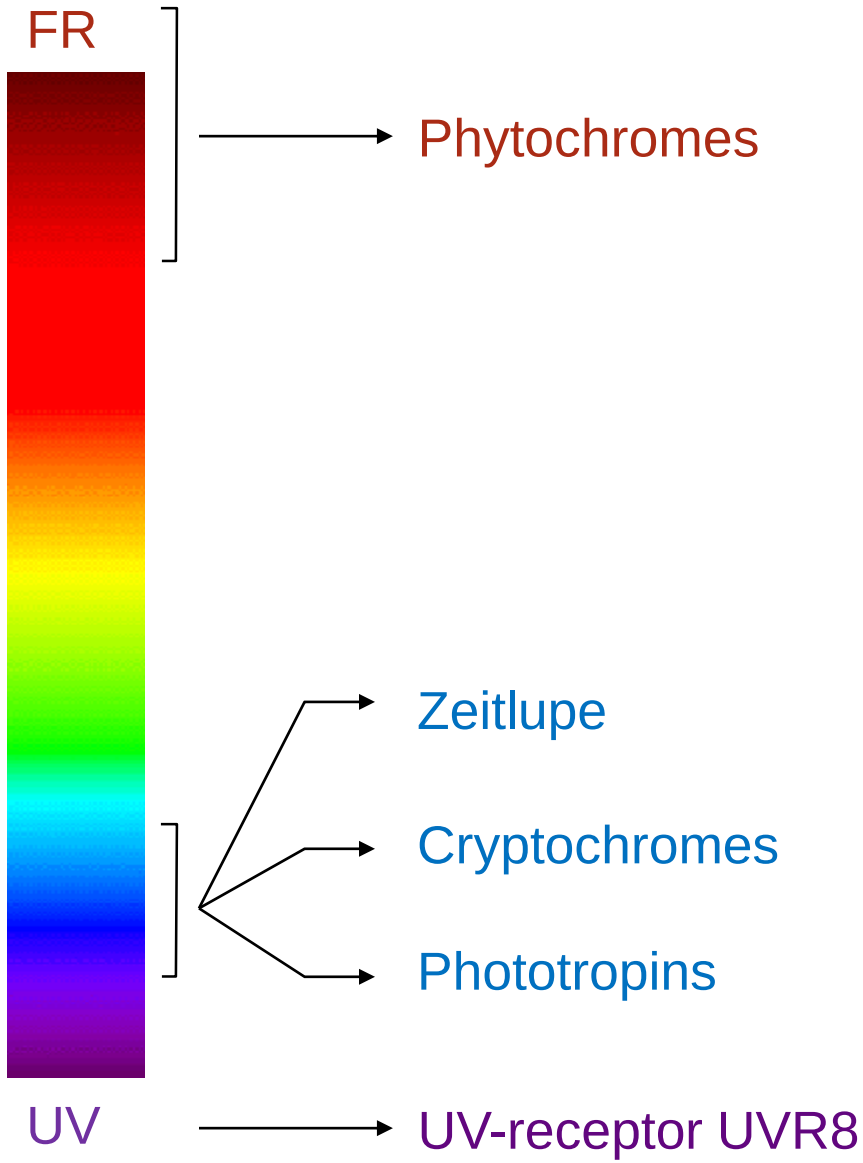
Responses to light

Before exposure to light

After a week's exposure to natural daylight

Responses to light

Plant photoreceptors

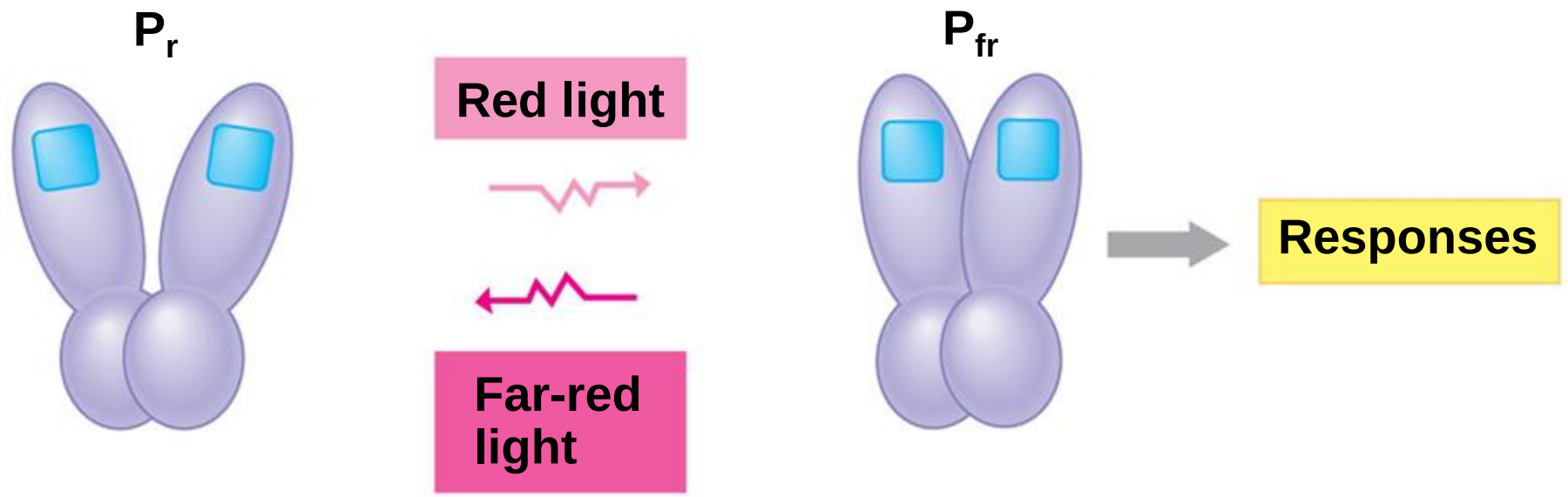


Plants can respond to…

- **far-red light (infra-red)**
- **red light**
- **blue light**
- **UV light**

Phytochromes – sensors of red and far red light

Photoreversible states of phytochrome:



Responses to light

FR → Phytochromes

Zeitlupe

Cryptochromes

Phototropins

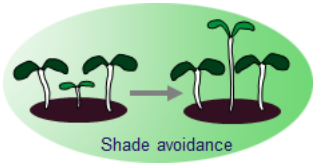
UV → UV-receptor UVR8

- Setting the circadian clock

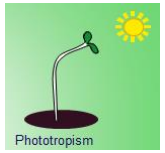
- Germination

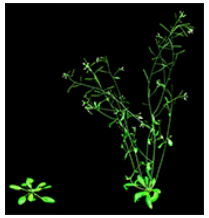
- Seedling development

- Shade avoidance

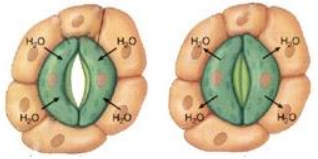


- Phototropism





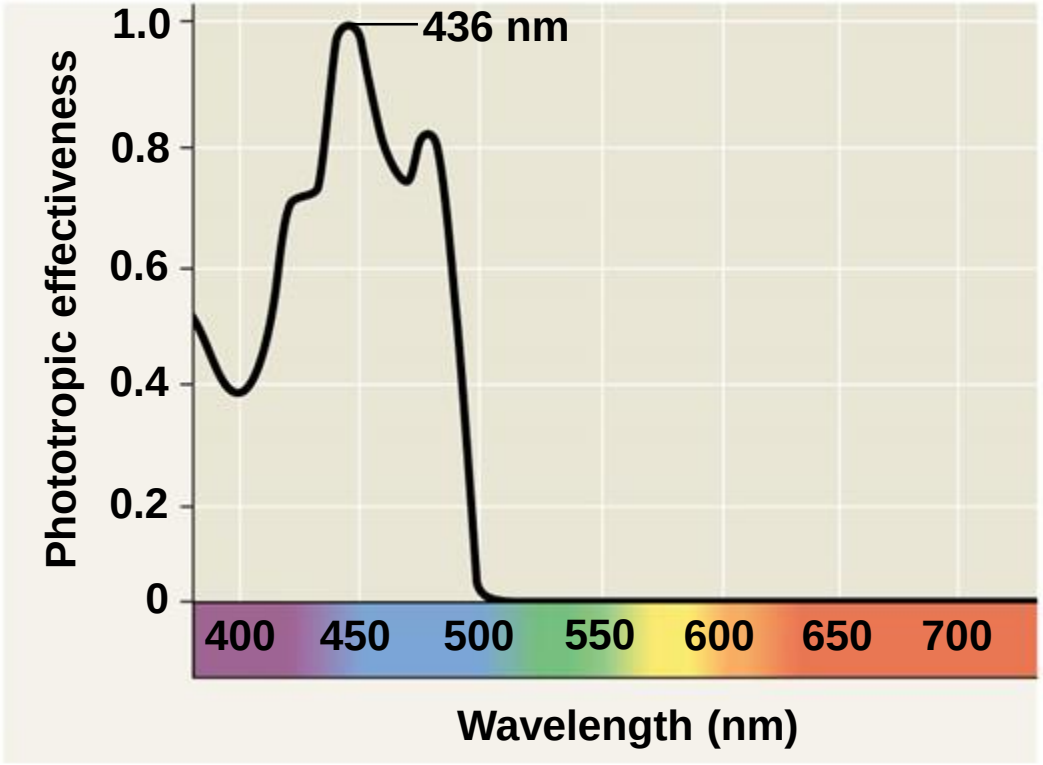
- Transition to flowering
- Stomatal movements



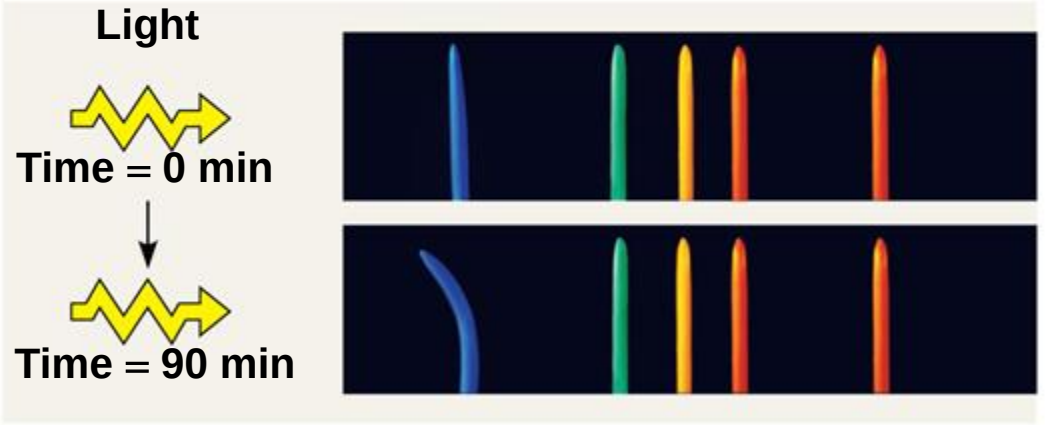
- Chloroplast movements

- Biochemical adaptations

Phototropism

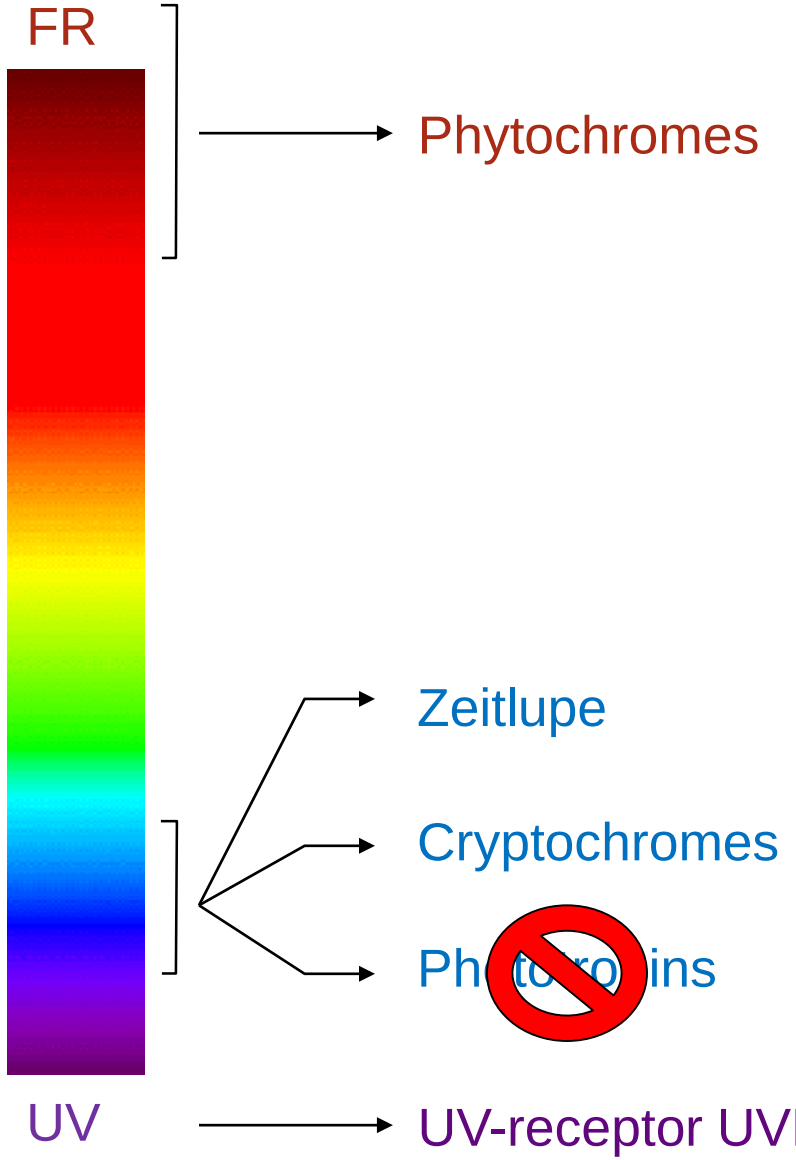


Phototropism action spectrum

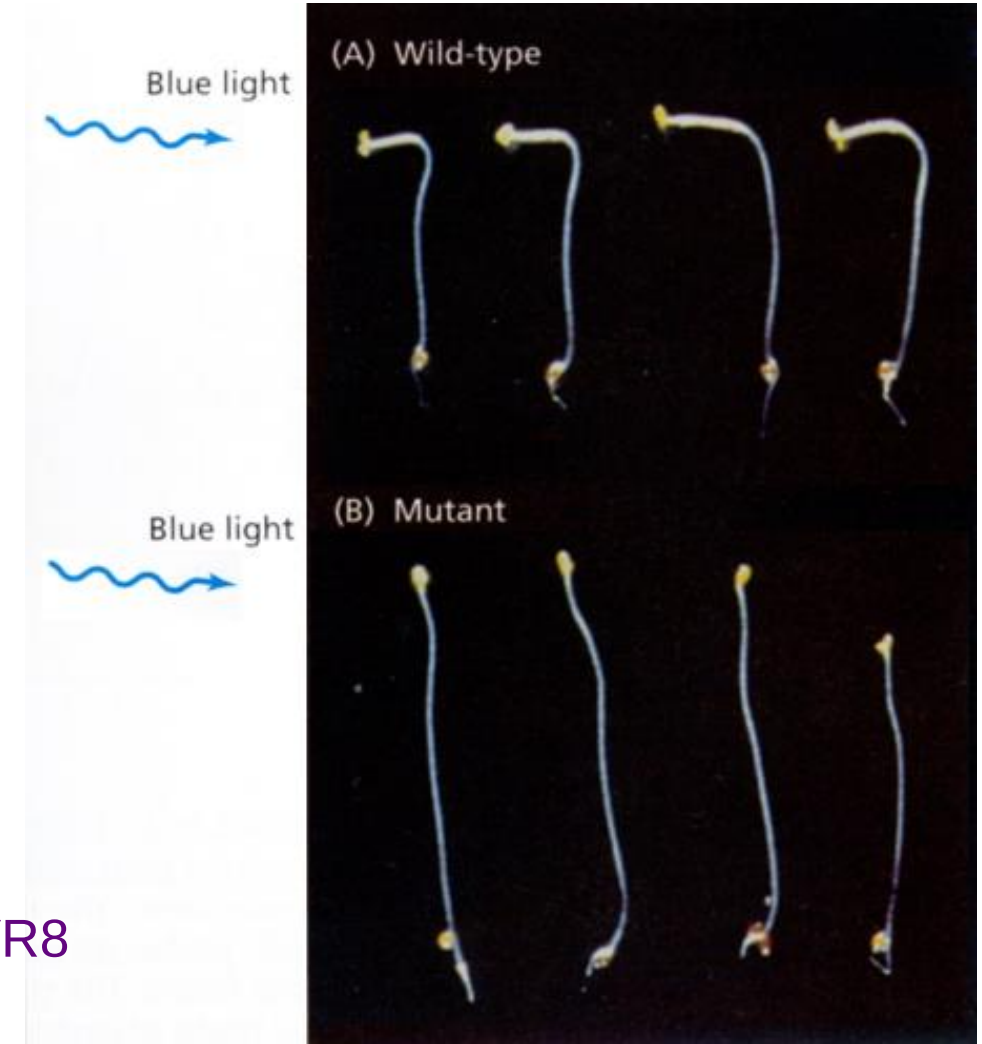


Coleoptiles before and after light exposures

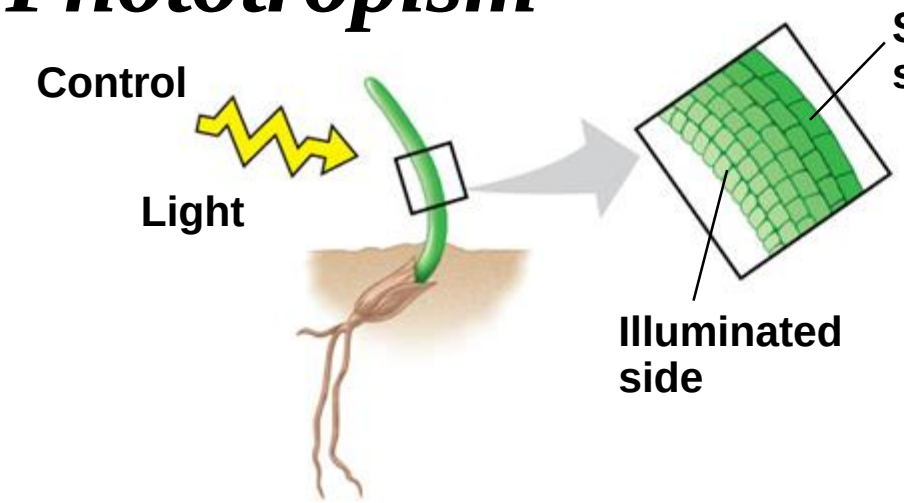
Phototropism



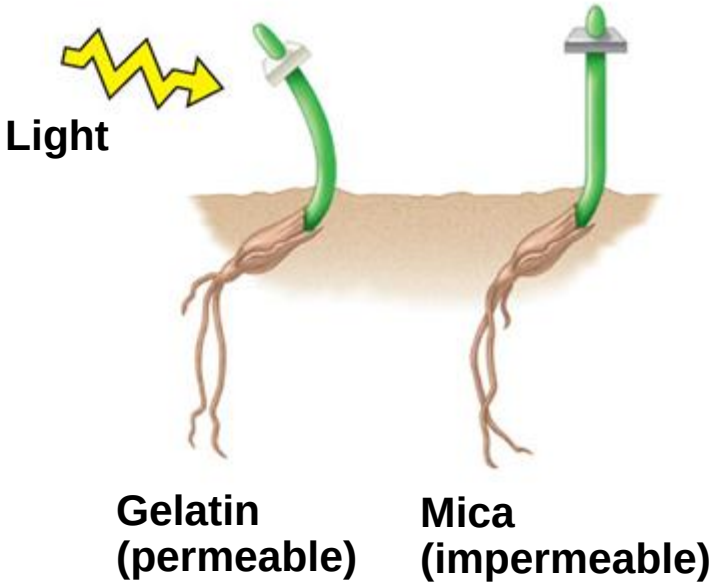
No phototropic response in phototropin mutants of *Arabidopsis thaliana*



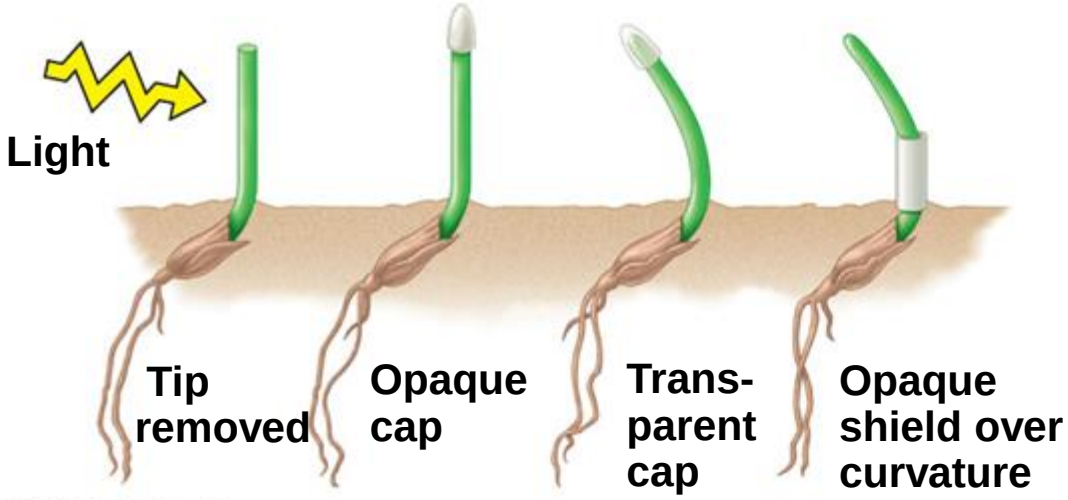
Phototropism



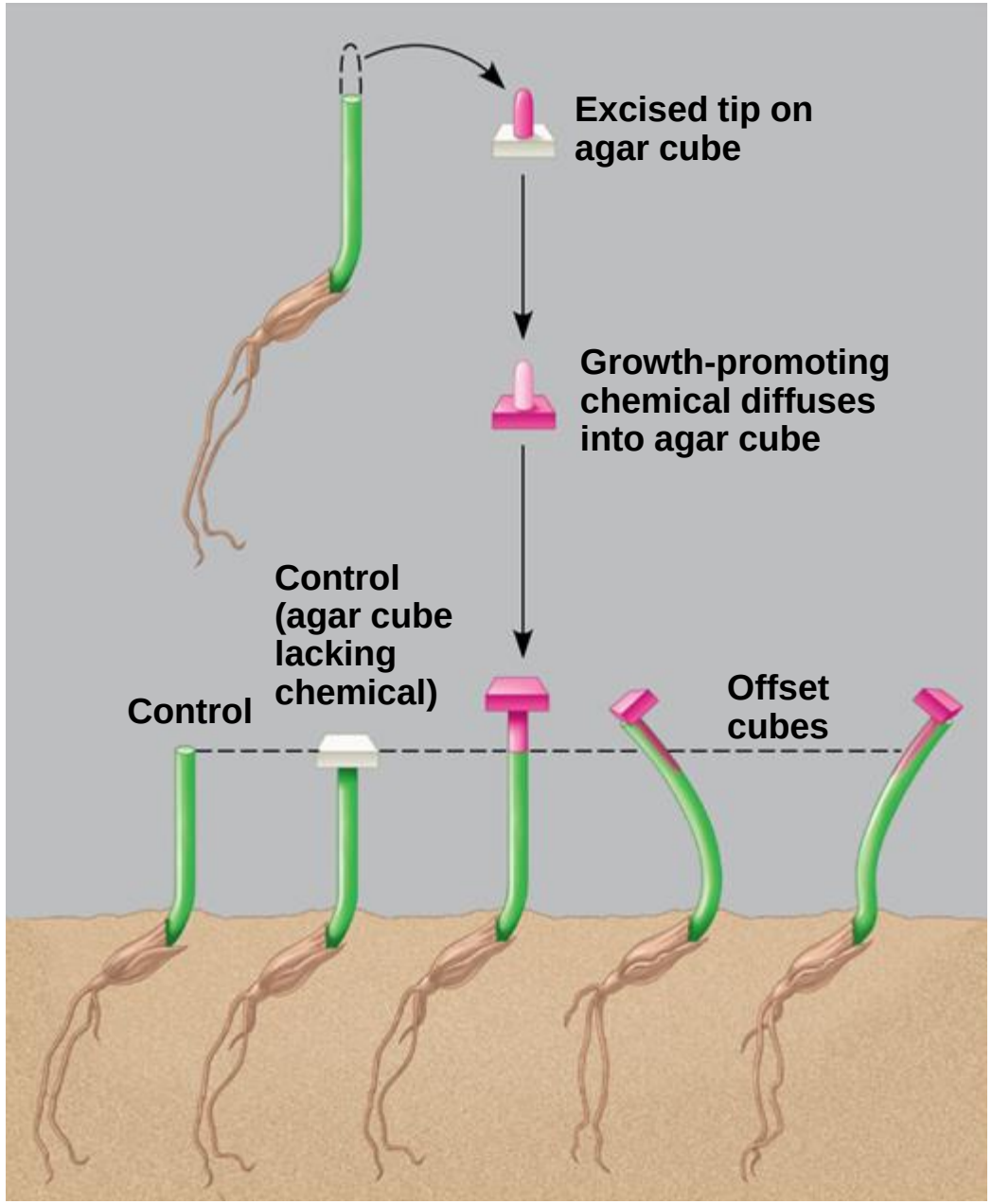
Boysen-Jensen



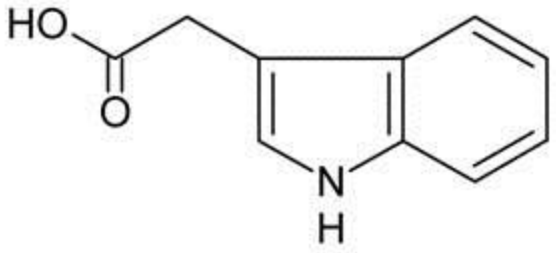
Darwin and Darwin

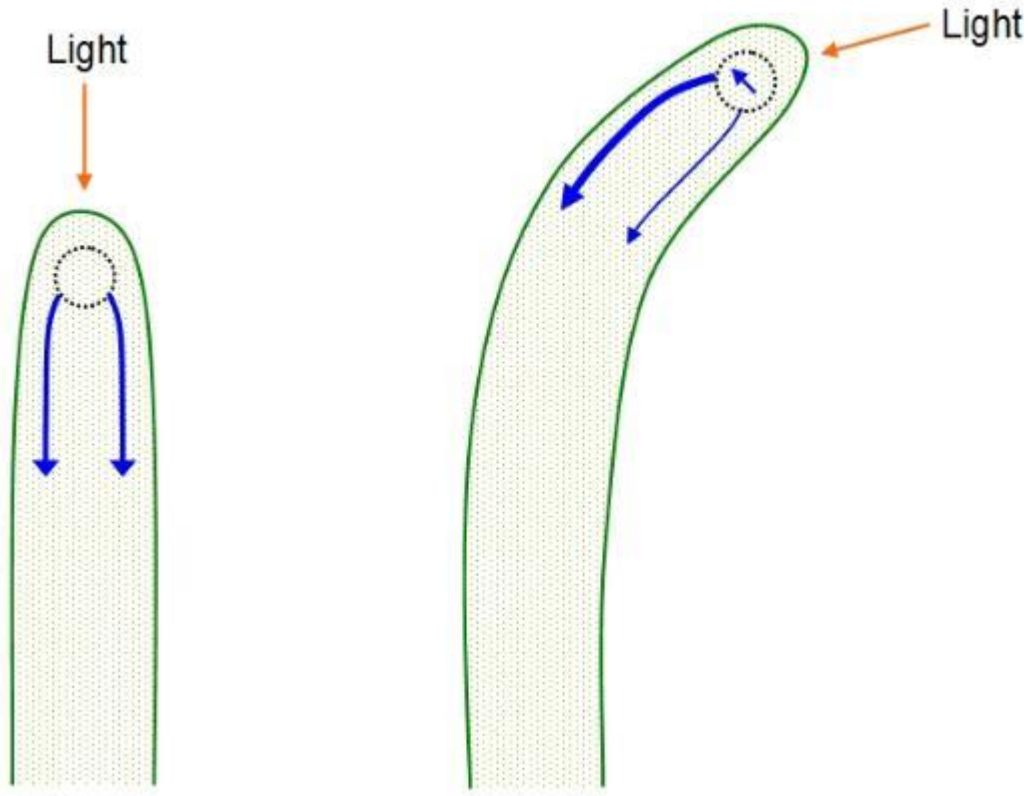


Phototropism



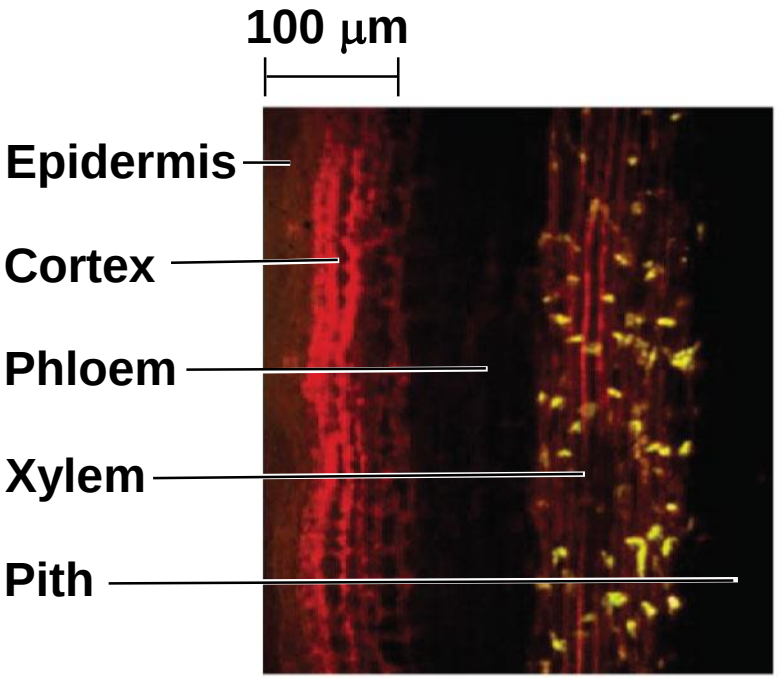
Phototropism

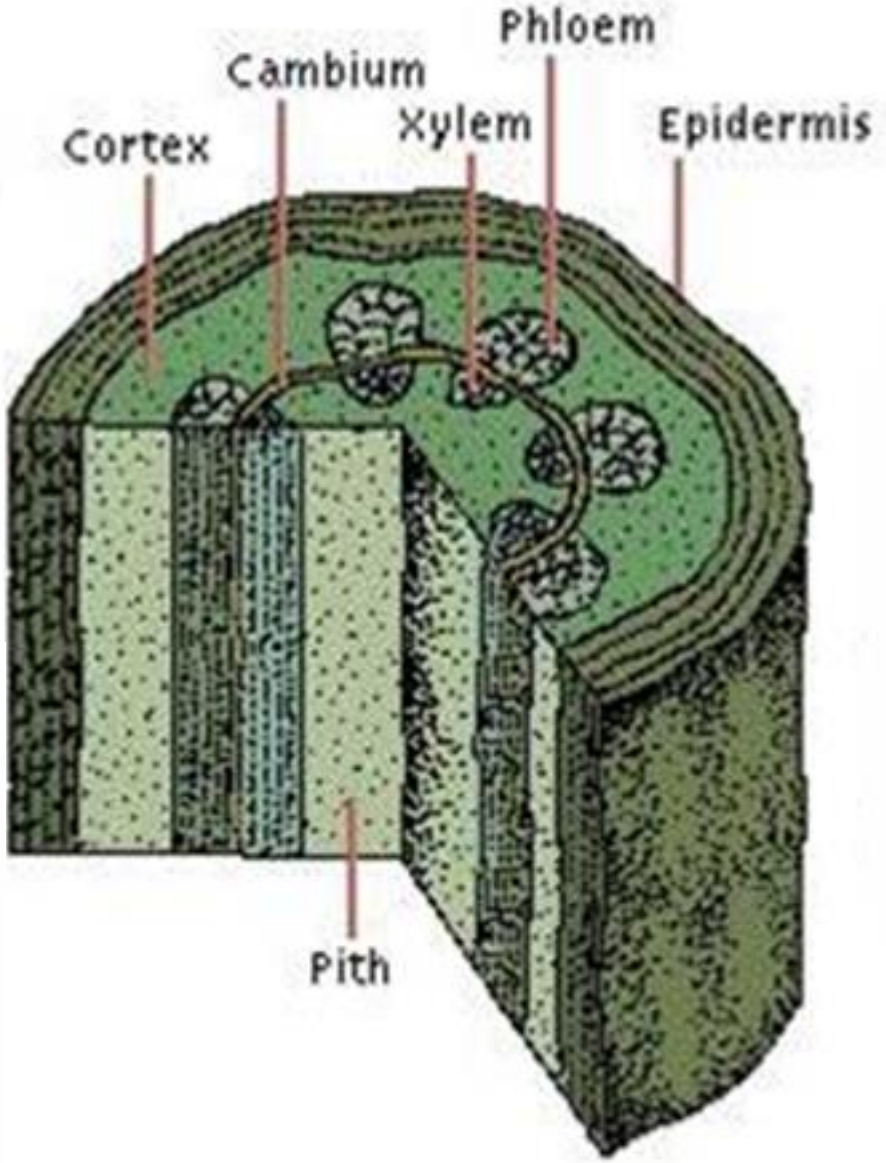




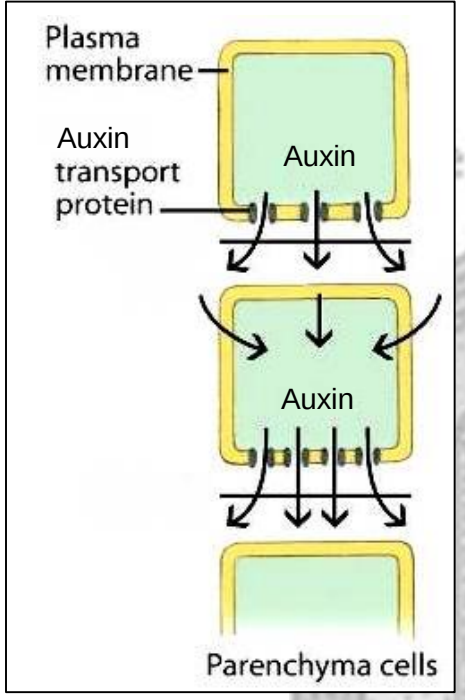
- The term **auxin** refers to any chemical that promotes elongation of coleoptiles
- Indoleacetic acid (**IAA**) is a common auxin in plants
- Auxin is produced in shoot tips and is transported down the stem

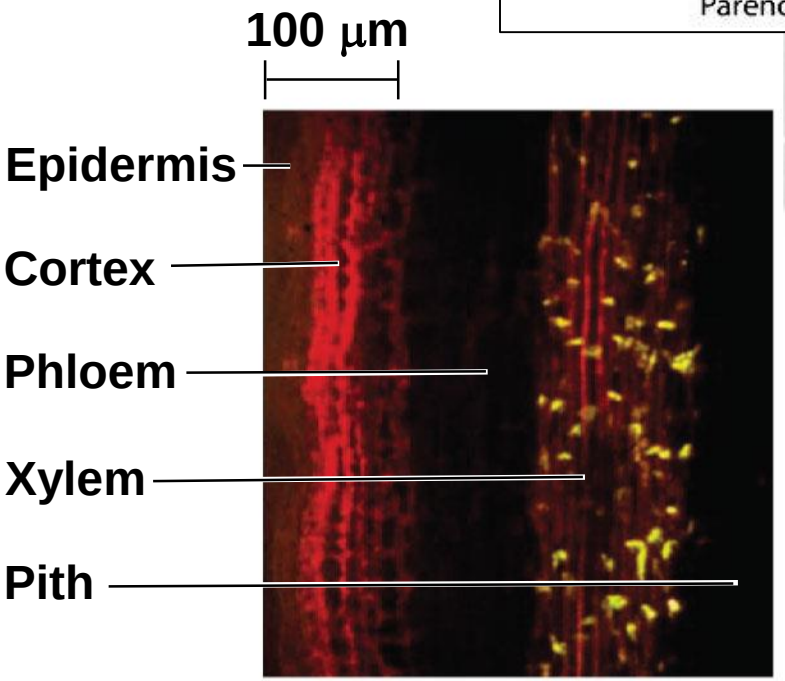
Polar auxin transport

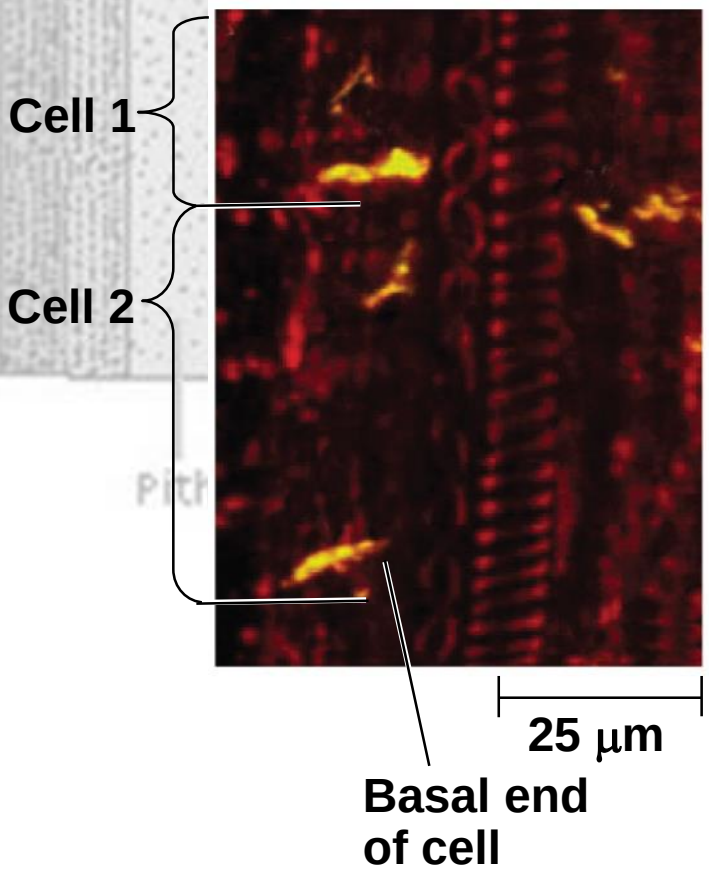




Polar auxin transport

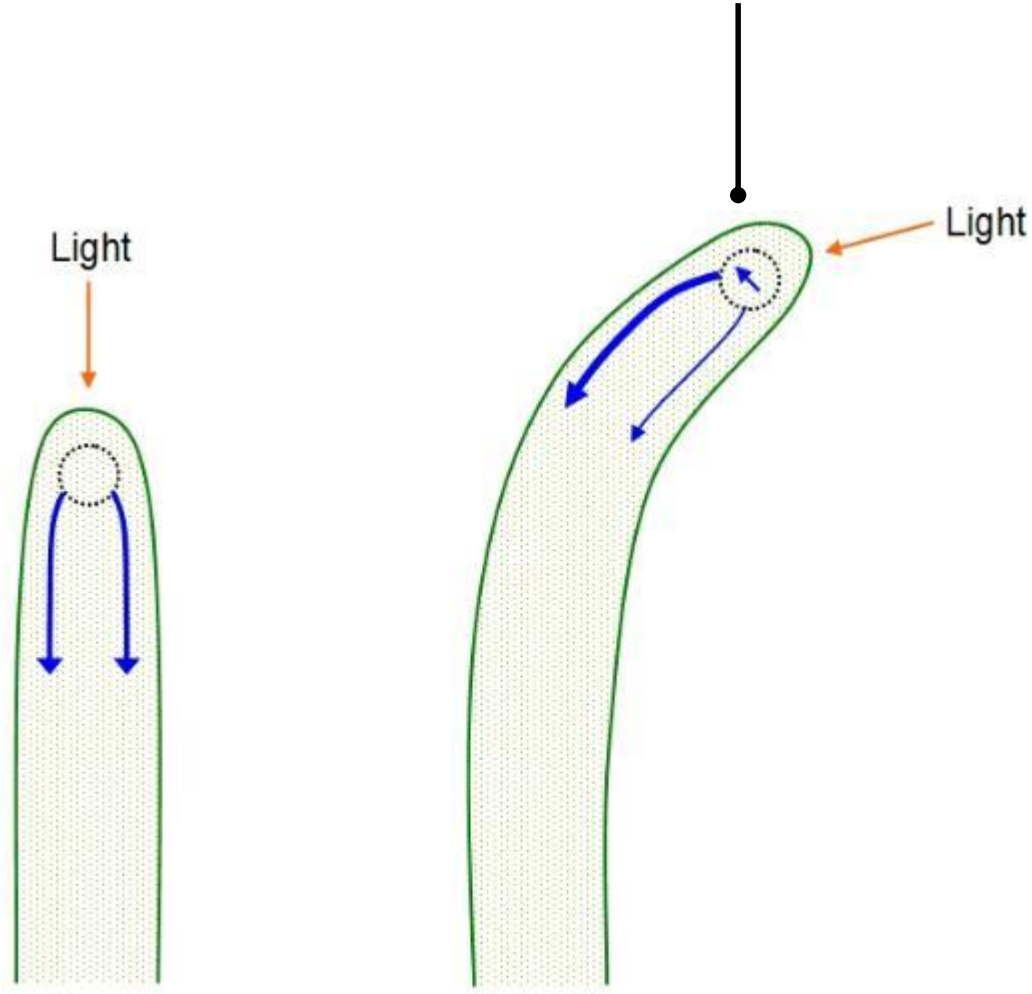






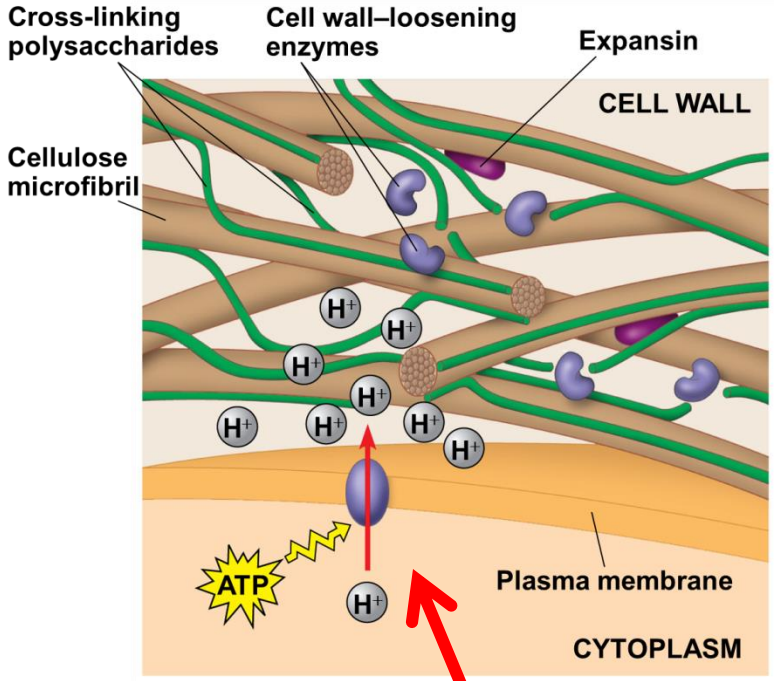
Phototropism

Re-distribution of transporters for the plant hormone AUXIN



The Role of Auxin in Cell Elongation

- The ‘acid growth’ hypothesis: auxin stimulates proton pumps in the plasma membrane
- This lowers the pH in the cell wall, activating **expansins** and enzymes that loosen the wall’s fabric
- With the cellulose loosened, the cell can elongate



Auxin

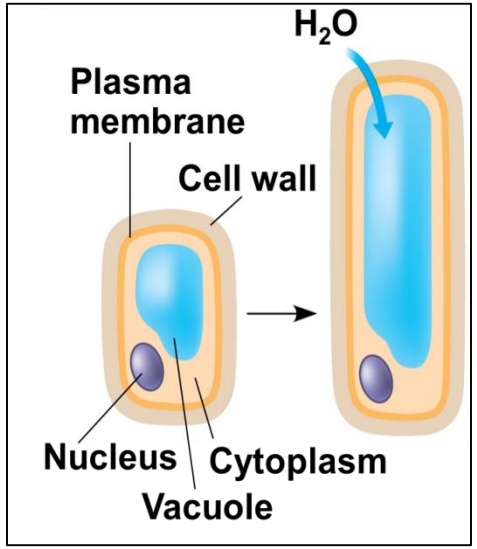


Table 39.1 Overview of Plant Hormones

Hormone	Where Produced or Found in Plant	Major Functions
Auxin (IAA)	Shoot apical meristems and young leaves are the primary sites of auxin synthesis. Root apical meristems also produce auxin, although the root depends on the shoot for much of its auxin. Developing seeds and fruits contain high levels of auxin, but it is unclear whether it is newly synthesized or transported from maternal tissues.	Stimulates stem elongation (low concentration only); promotes the formation of lateral and adventitious roots; regulates development of fruit; enhances apical dominance; functions in phototropism and gravitropism; promotes vascular differentiation; retards leaf abscission.
Cytokinins	These are synthesized primarily in roots and transported to other organs, although there are many minor sites of production as well.	Regulate cell division in shoots and roots; modify apical dominance and promote lateral bud growth; promote movement of nutrients into sink tissues; stimulate seed germination; delay leaf senescence.
Gibberellins	Meristems of apical buds and roots, young leaves, and developing seeds are the primary sites of production.	Stimulate stem elongation, pollen development, pollen tube growth, fruit growth, and seed development and germination; regulate sex determination and the transition from juvenile to adult phases.
Brassinosteroids	These compounds are present in all plant tissues, although different intermediates predominate in different organs. Internally produced brassinosteroids act near the site of synthesis.	Promote cell expansion and cell division in shoots; promote root growth at low concentrations; inhibit root growth at high concentrations; promote xylem differentiation and inhibit phloem differentiation; promote seed germination and pollen tube elongation.
Abscisic acid (ABA)	Almost all plant cells have the ability to synthesize abscisic acid, and its presence has been detected in every major organ and living tissue; may be transported in the phloem or xylem.	Inhibits growth; promotes stomatal closure during drought stress; promotes seed dormancy and inhibits early germination; promotes leaf senescence; promotes desiccation tolerance.
Strigolactones	These carotenoid-derived hormones and extracellular signals are produced in roots in response to low phosphate conditions or high auxin flow from the shoot.	Promote seed germination, control of apical dominance, and the attraction of mycorrhizal fungi to the root.
Ethylene	This gaseous hormone can be produced by most parts of the plant. It is produced in high concentrations during senescence, leaf abscission, and the ripening of some types of fruits. Synthesis is also stimulated by wounding and stress.	Promotes ripening of many types of fruit, leaf abscission, and the triple response in seedlings (inhibition of stem elongation, promotion of lateral expansion, and horizontal growth); enhances the rate of senescence; promotes root and root hair formation; promotes flowering in the pineapple family.

Table 39.1 Overview of Plant Hormones

Hormone	Where Produced or Found in Plant	Major Functions
Auxin (IAA)	Shoot apical meristems and young leaves are the primary sites of auxin synthesis. Root apical meristems also produce auxin, although the root depends on the shoot for much of its auxin. Developing seeds and fruits contain high levels of auxin, but it is unclear whether maternal	Stimulates stem elongation (low concentration only); promotes the formation of lateral and adventitious roots; regulates development of fruit; enhances apical dominance; functions in phototropism and gravitropism; promotes vascular differentiation; retards leaf abscission.
Cytokinins	These ar ported t minor sit	Regulate cell division in shoots and roots; modify apical dominance and promote lateral bud growth; promote movement of nutrients into sink tissues; stimulate seed germination; delay leaf senescence.
Gibberellins	Meristem developi	Stimulate stem elongation, pollen development, pollen tube growth, fruit growth, and seed development and germination; regulate sex determination and the transition from juvenile to adult phases.
Brassinosteroids	These co althoug different act near	Promote cell expansion and cell division in shoots; promote root growth at low concentrations; inhibit root growth at high concentrations; promote xylem differentiation and inhibit phloem differentiation; promote seed germination and pollen tube elongation.
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Stem elongation

Lateral & adventitious roots

Apical dominance

Fruit development

Phototropism

Gravitropism

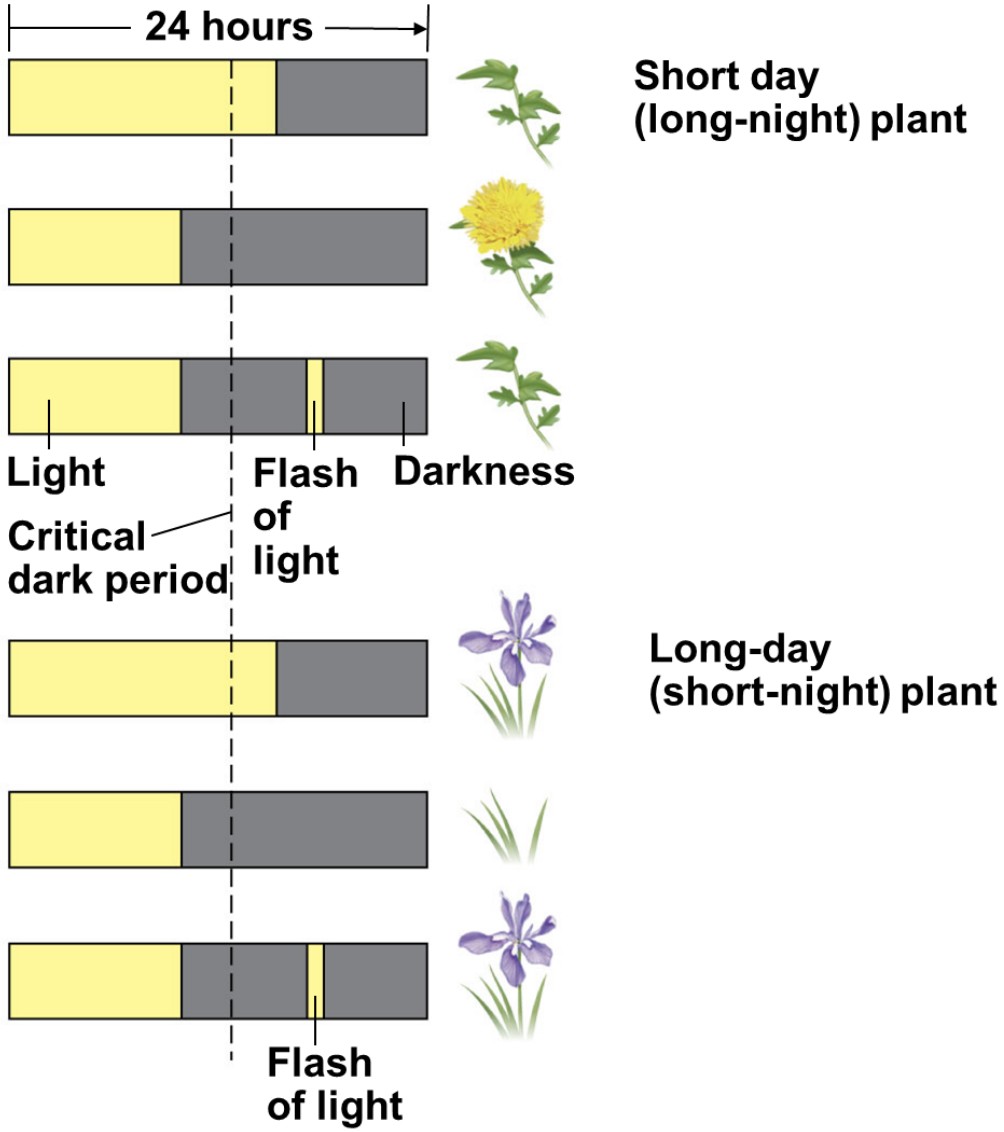
Vascular development

Phyllotaxis

Senescence

Other Responses to Light

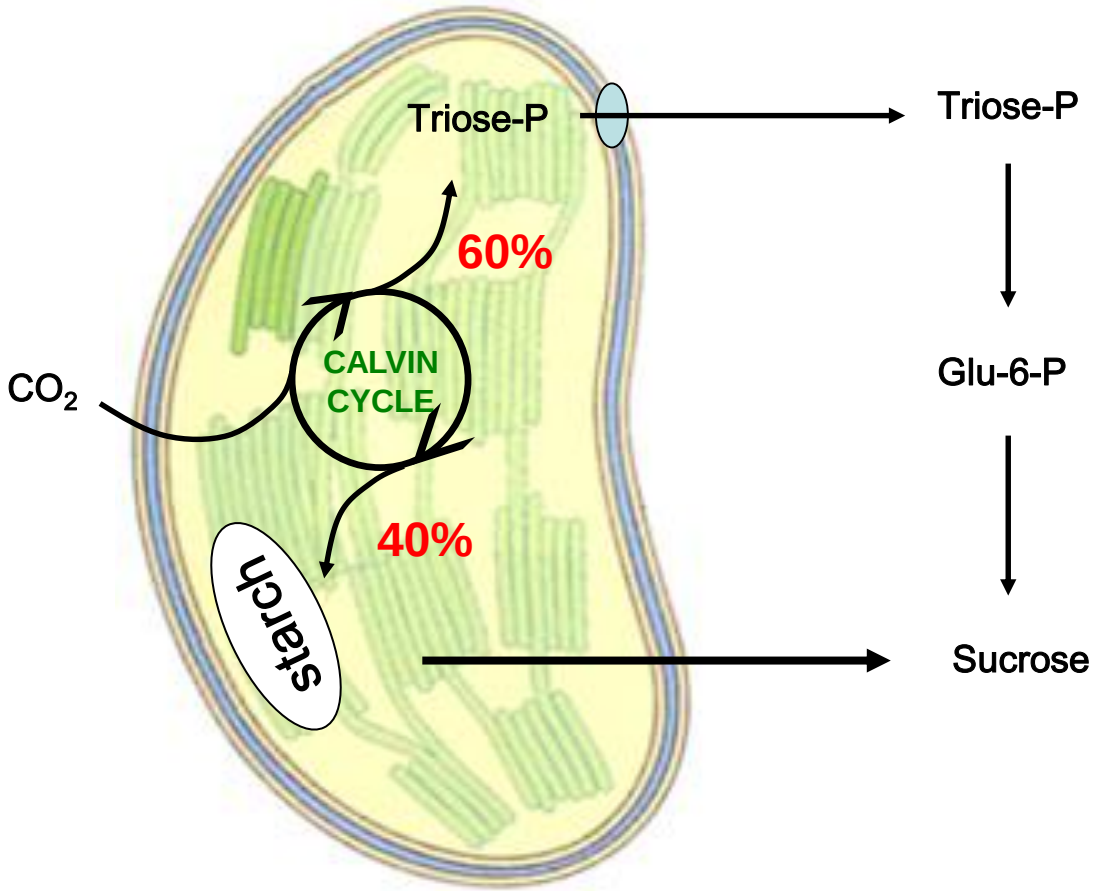
Induction of flowering

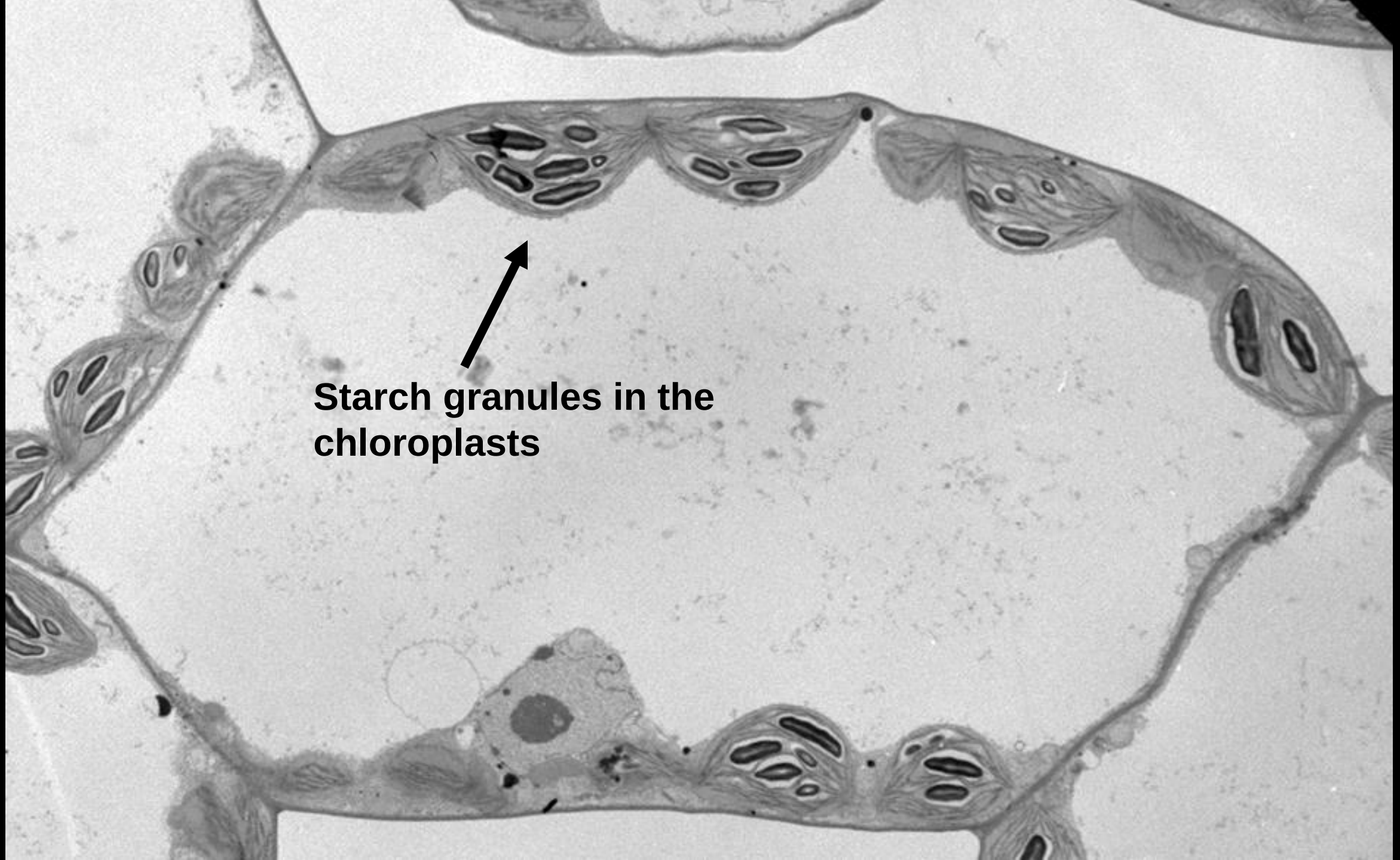


Other Responses to Light

Control of metabolism

Photosynthate is partitioned for growtrh and storage during the day

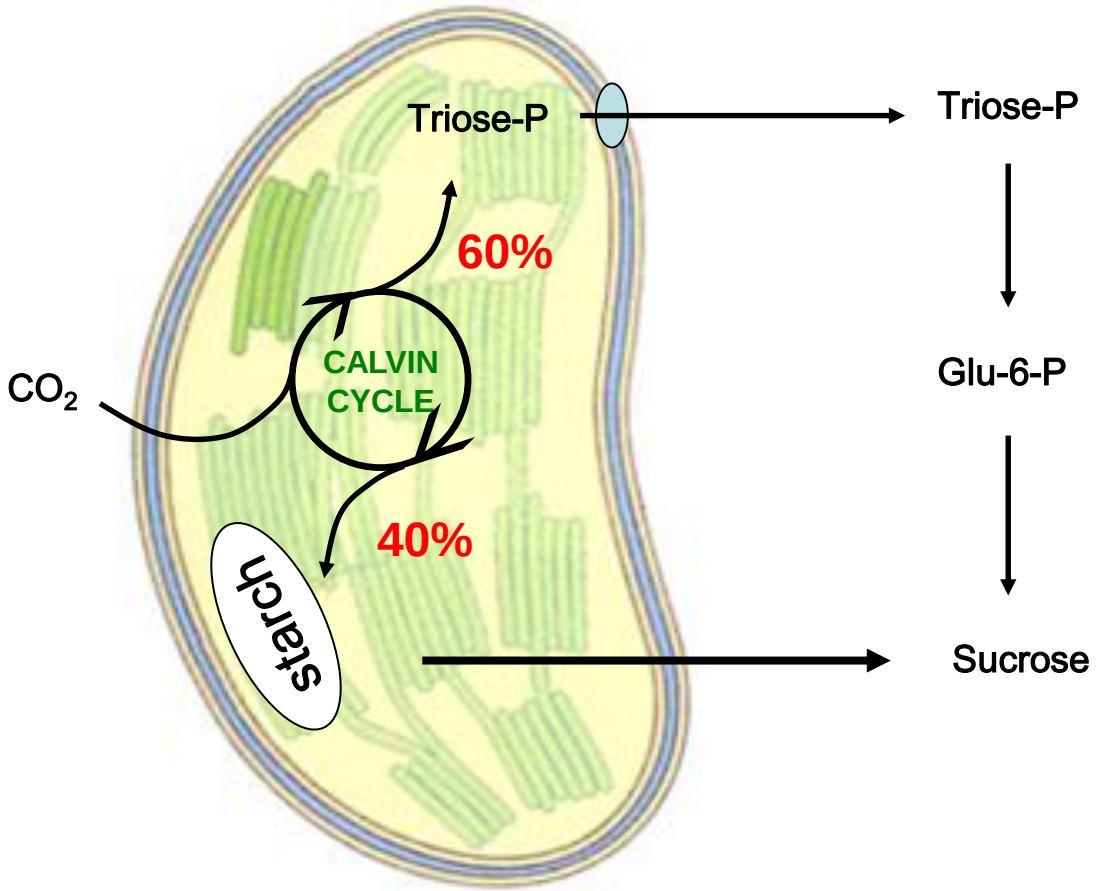


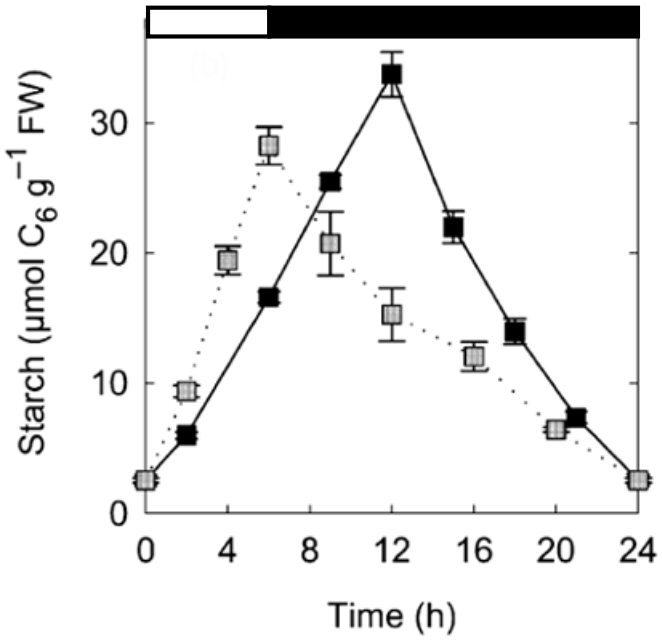

Starch granules in the chloroplasts

Other Responses to Light

Control of metabolism

Photosynthate is partitioned for growtrh and storage during the day



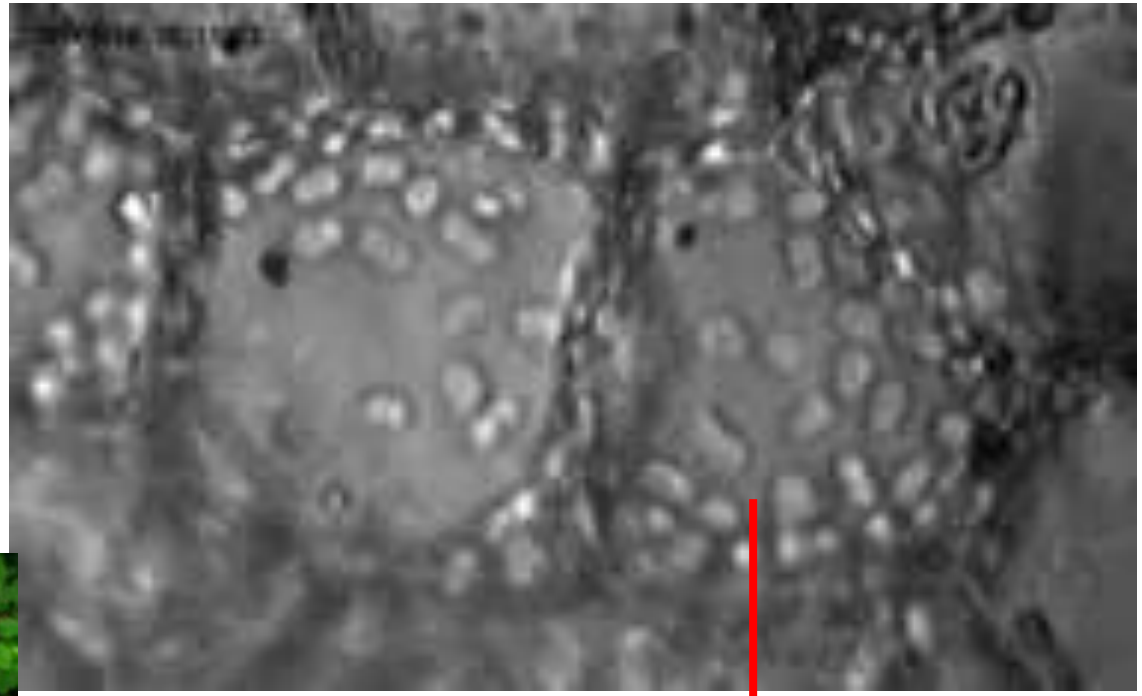


Starch is degraded at night to provide carbohydrate

Other Responses to Light

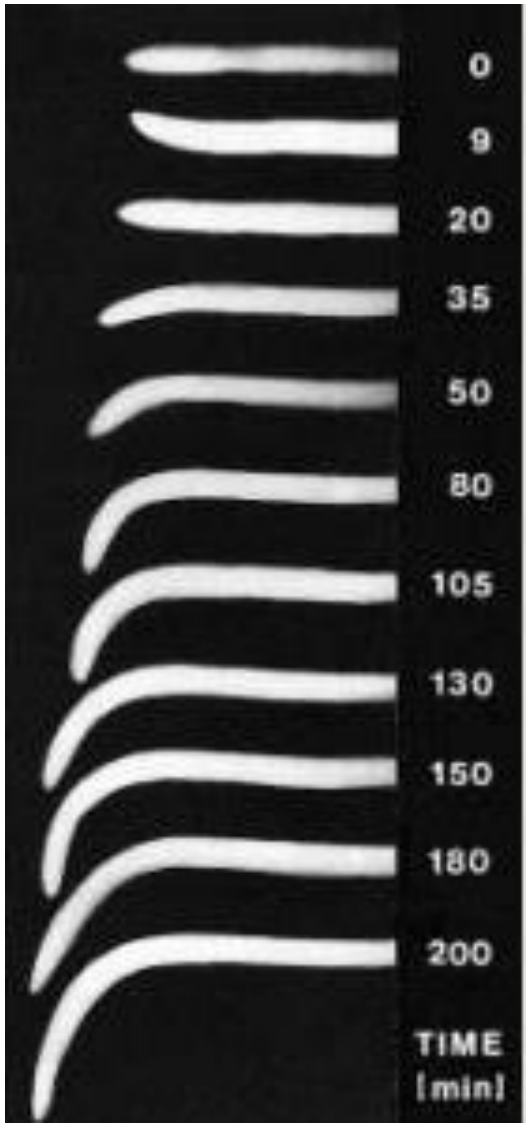
Chloroplast movements

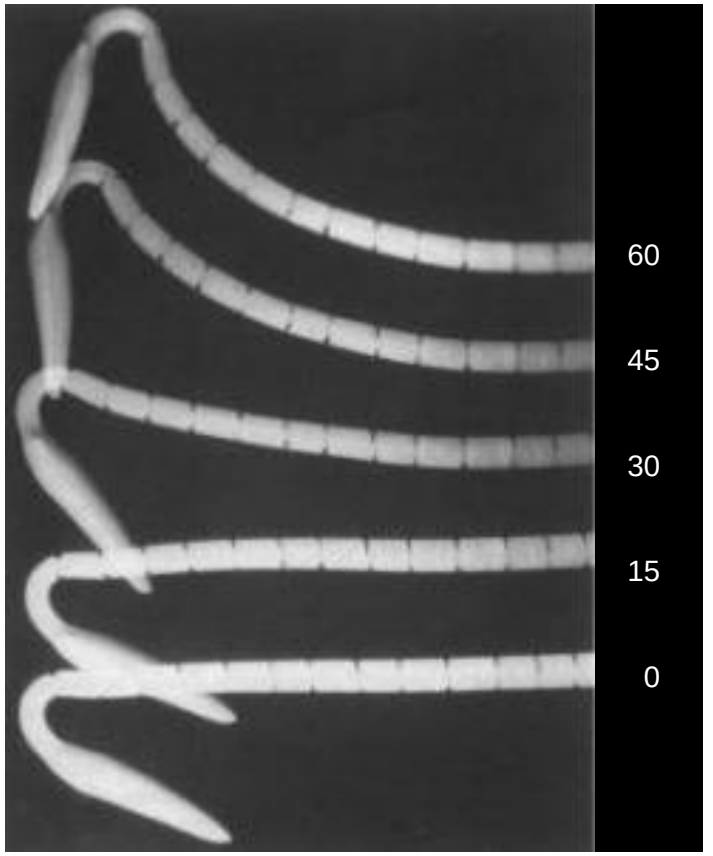
- Chloroplasts move into weak modest light and away from high light
- A blue light response in angiosperms
- A blue **and** red light response in ferns



A mutant plant deficient in the red light response except for this single cell, which has been transformed with a fluorescently tagged copy of the intact gene

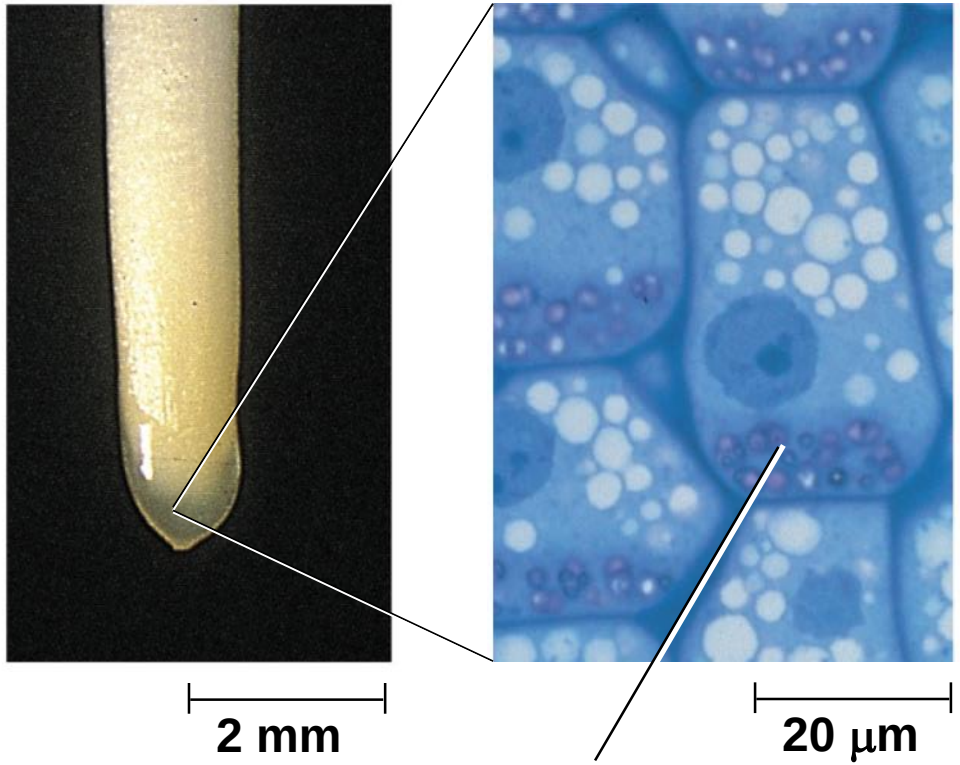
Responses to Gravity





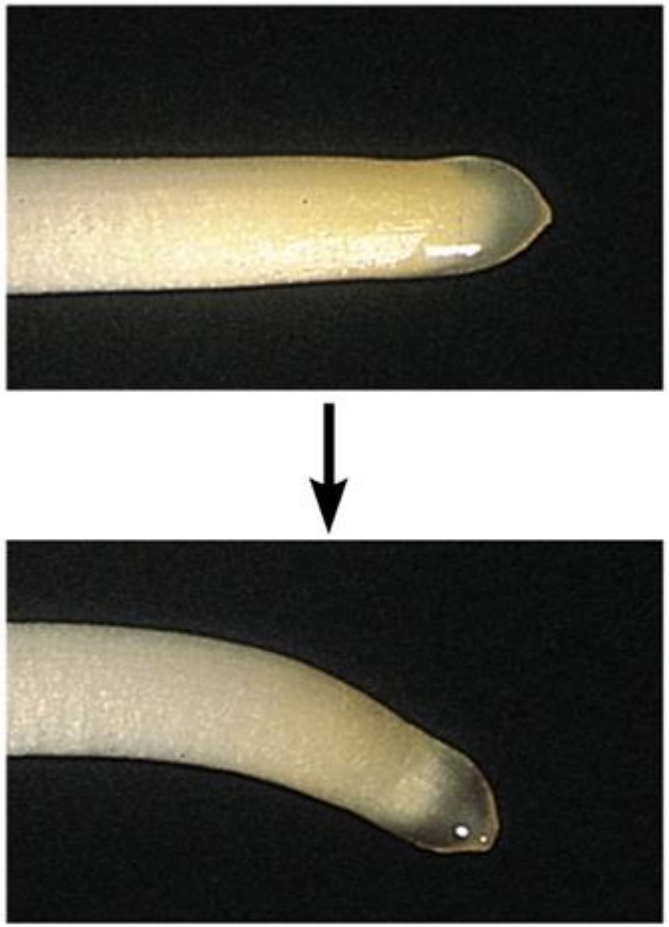
Response to gravity is known as **gravitropism**
Roots show positive gravitropism
Shoots show negative gravitropism

Responses to Gravity

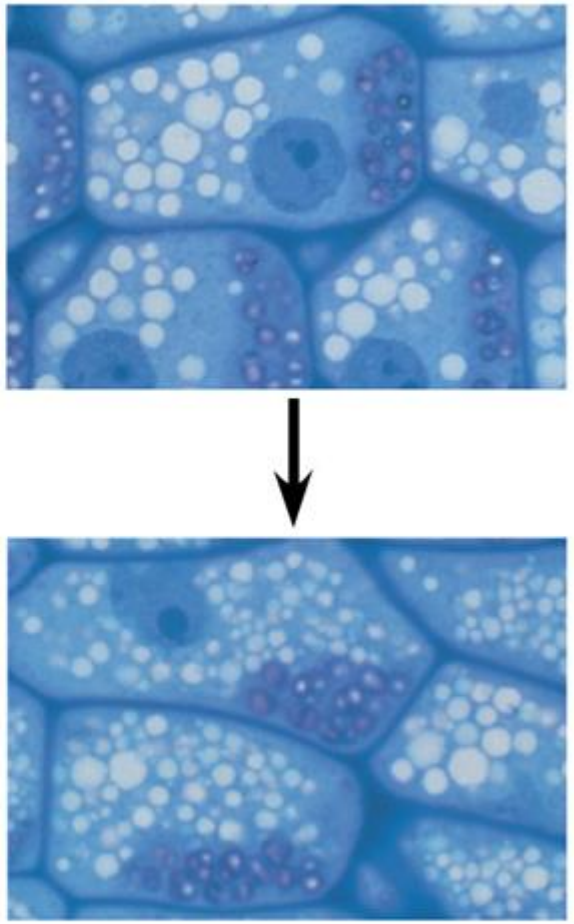


Statoliths:
starch filled organelles in
the root tip columella cells

Responses to Gravity

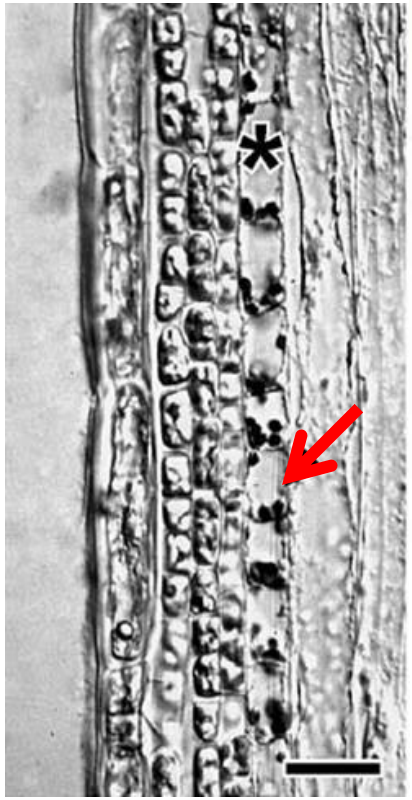


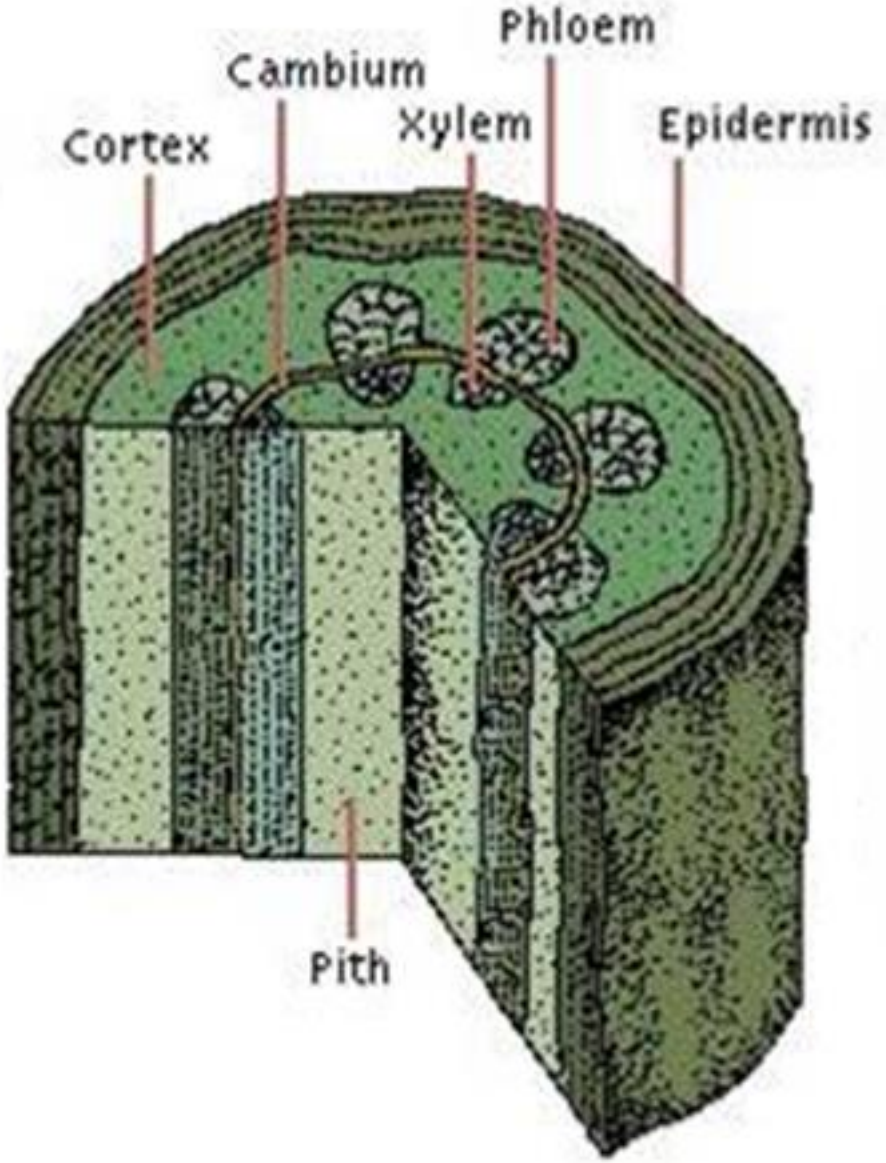
Primary root of maize bending gravitropically



Statoliths settling to the lowest sides of root cap cells

Responses to Gravity





Statoliths:
starch filled organelles in the shoot endodermis

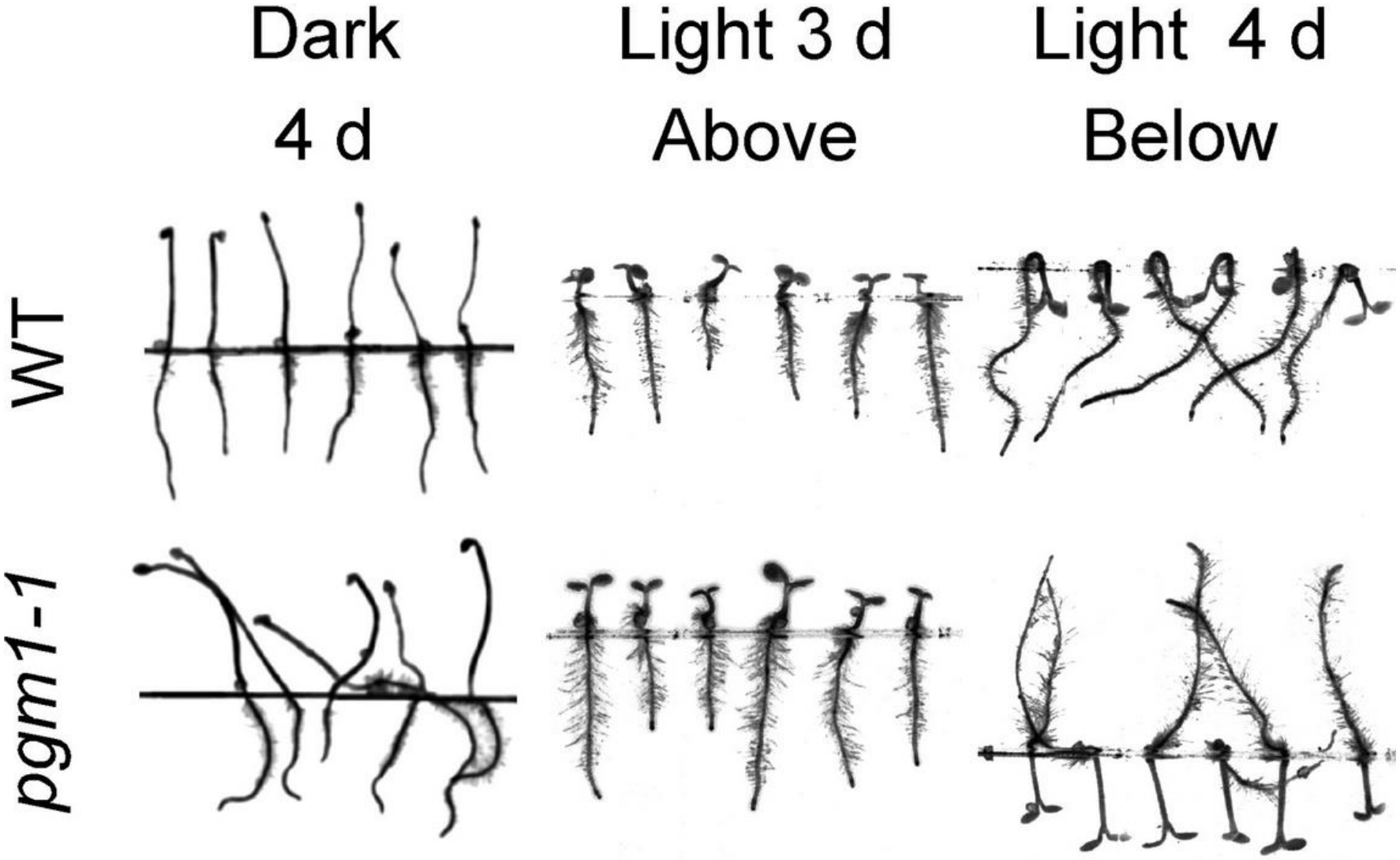
Responses to Gravity

Response to gravity is known as **gravitropism**
Roots show positive gravitropism
Shoots show negative gravitropism

Responses to Gravity

Experiments with light and gravity in Arabidopsis

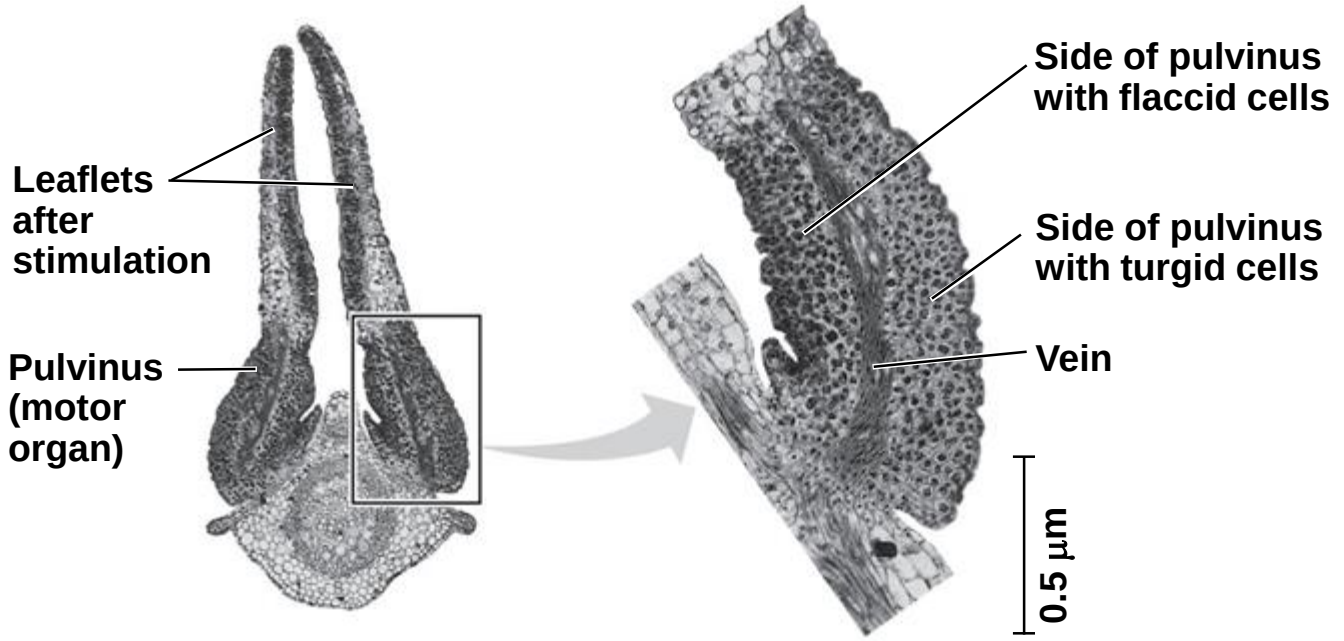
The pgm1 mutant is unable to make starch and so is compromised in gravity perception



Touch responses

Unstimulated state

Stimulated state



Cross section of a leaflet pair in the stimulated state

Touch responses

Touch responses

Regularly touching Arabidopsis plants changes its growth rate and form

Touch responses

Video: Sun Dew Trapping Prey

What do Plants Respond to?

- Light
- Temperature
- Gravity
- Touch
- Damage
- Infection/Herbivory
- Symbionts
- Water drought/flood
- Air e.g. CO_2 and O_2
- Circadian clock
- Endogenous hormones
- Developmental program
- Nutrient levels
- Cell turgour
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