Plant Sensory Systems

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(Freeman Ch38)

Plant Sensory Systems, Signals, and Responses

- Plants process information
- Environmental stimuli affect ability to grow and reproduce…
  - wavelength of light, photoperiod, time of day
  - gravity, mechanical stimulation (touch or wind)
  - disease-causing agents and herbivores

When sensory cells receive a stimulus, they _____ the signal and respond by producing hormones that carry information to target cells elsewhere in the body.

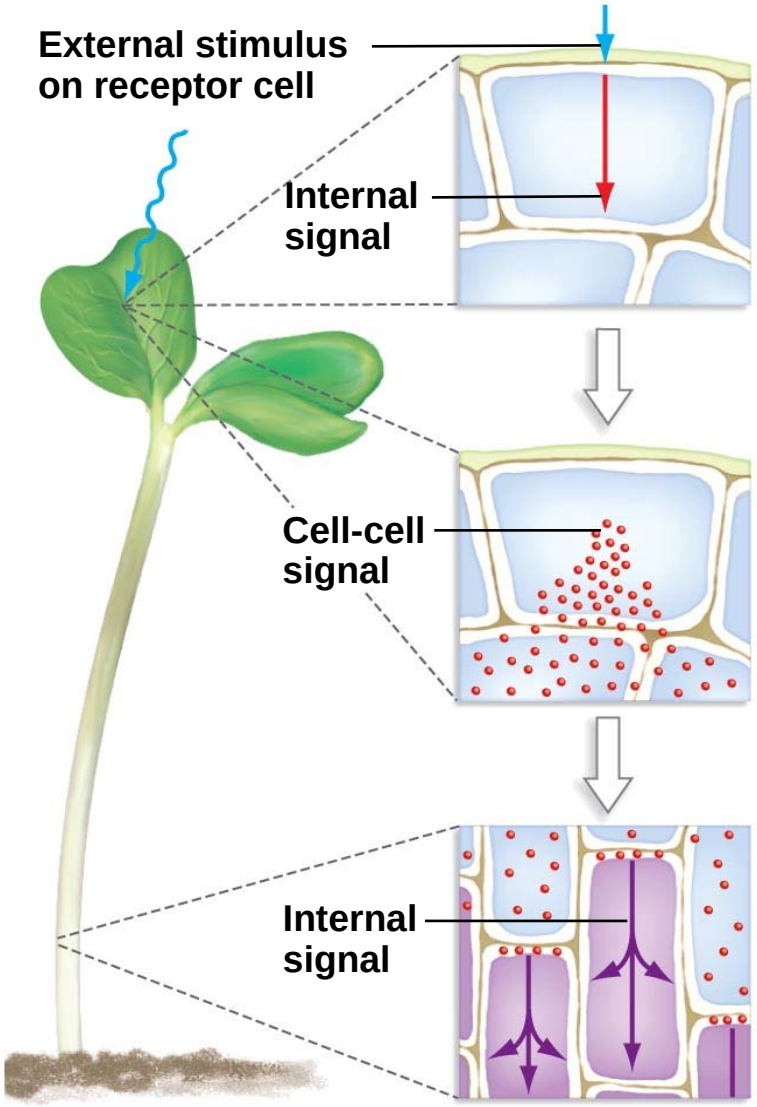
Hormones produce a response by acting on target cells.

Information Processing

- Monitor aspects of environment that affect fitness (survive & reproduce)

- Three steps:
- (1) a receptor cell receives an external signal
- (2) the receptor cell sends a signal to cells in another part of the plant
- (3) responder cells receive the signal and change activity appropriately.

STEPS IN INFORMATION PROCESSING



1. Receptor cell perceives external stimulus and transduces the information to an internal signal.

2. A hormone (cell-cell signal) released by the receptor cell travels throughout the body.

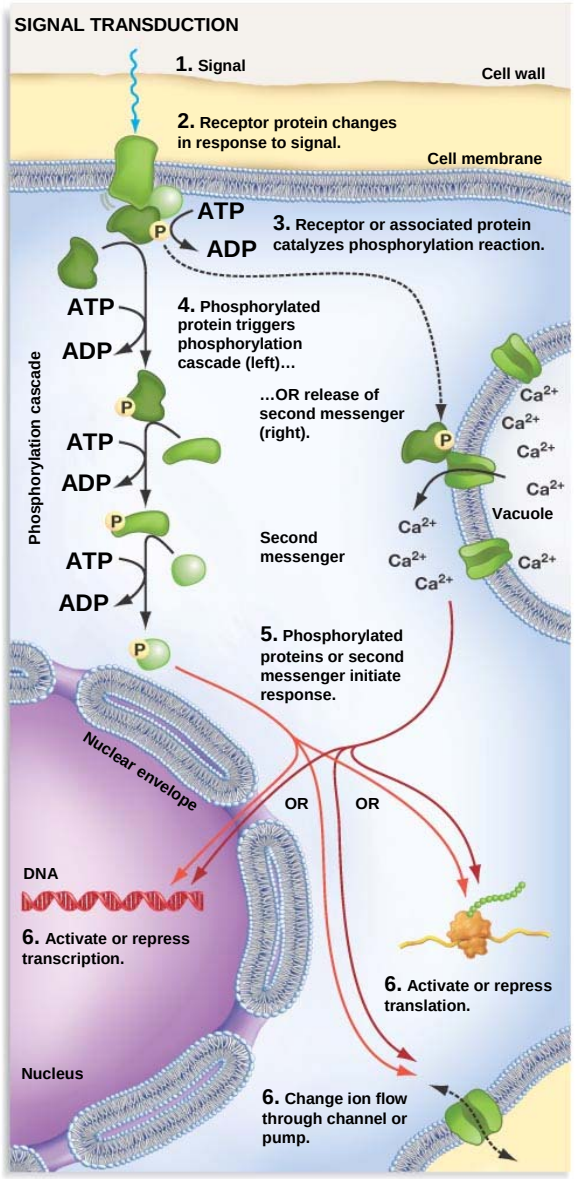
3. Receptor cells receive the hormonal (cell-cell) signal, transduce it to an internal signal, and change activity.

Signal Transduction

- Signals from environment received by specialized protein (for that function).

- Receptor proteins change shape in response to a stimulus. This causes the information to change form—from an external signal to an intracellular signal.

- This process is called _____.


SIGNAL TRANSDUCTION
1. Signal
Cell wall
2. Receptor protein changes in response to signal.
Cell membrane
ATP
ADP
3. Receptor or associated protein catalyzes phosphorylation reaction.
4. Phosphorylated protein triggers phosphorylation cascade (left)…
…OR release of second messenger (right).
Phosphorylation cascade
Second messenger
Ca2+
Vacuole
5. Phosphorylated proteins or second messenger initiate response.
Nuclear envelope
OR
OR
DNA
6. Activate or repress transcription.
6. Activate or repress translation.
Nucleus
6. Change ion flow through channel or pump.

- Two basic signal transduction pathways:

- **Phosphorylation cascades** are triggered when the receptor protein's shape leads to the transfer of a phosphate group from ATP to the receptor or a nearby protein.

- **Second messengers** are produced when hormone binding results in the release of an intracellular signal (usually Ca^{2+} in plants) from storage areas.

Signal transduction in a receptor cell often results in the release of a _____ that carries information to responder cells.

Blue Light: The Phototropic Response

- Plants sense and respond to specific, narrow range of wavelengths
- Any directed movement by an organism toward light is called

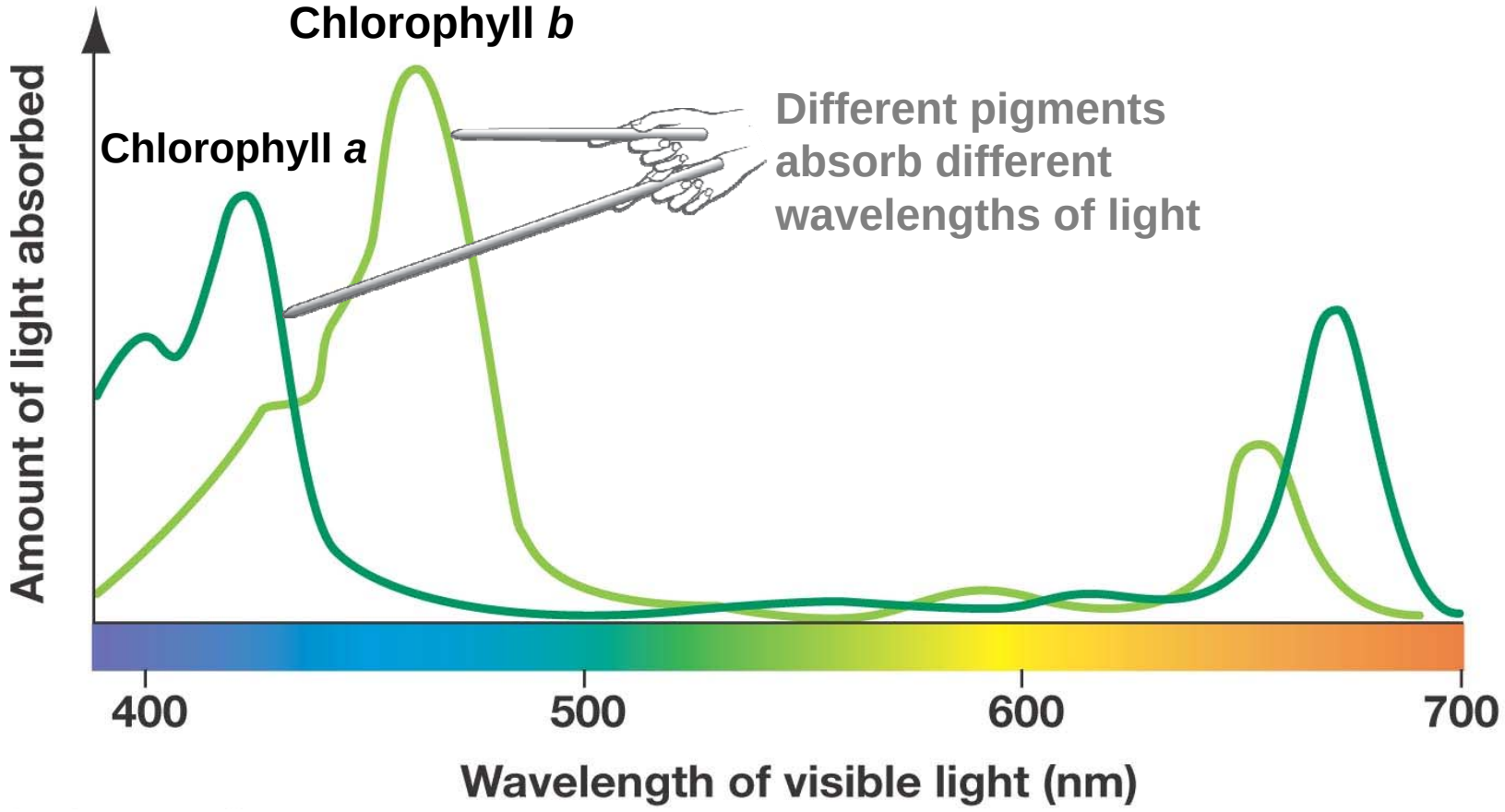
_____

- Plants exhibit a phototropic response only to blue wavelengths

- Why blue light?

Photosynthesis

Chlorophyll *a* and *b* Absorb Most Strongly in the Blue (and Red) Parts of the Visible Spectrum



Shoots Bend Specifically toward Blue Light

(b) Shoots bend specifically toward blue light.

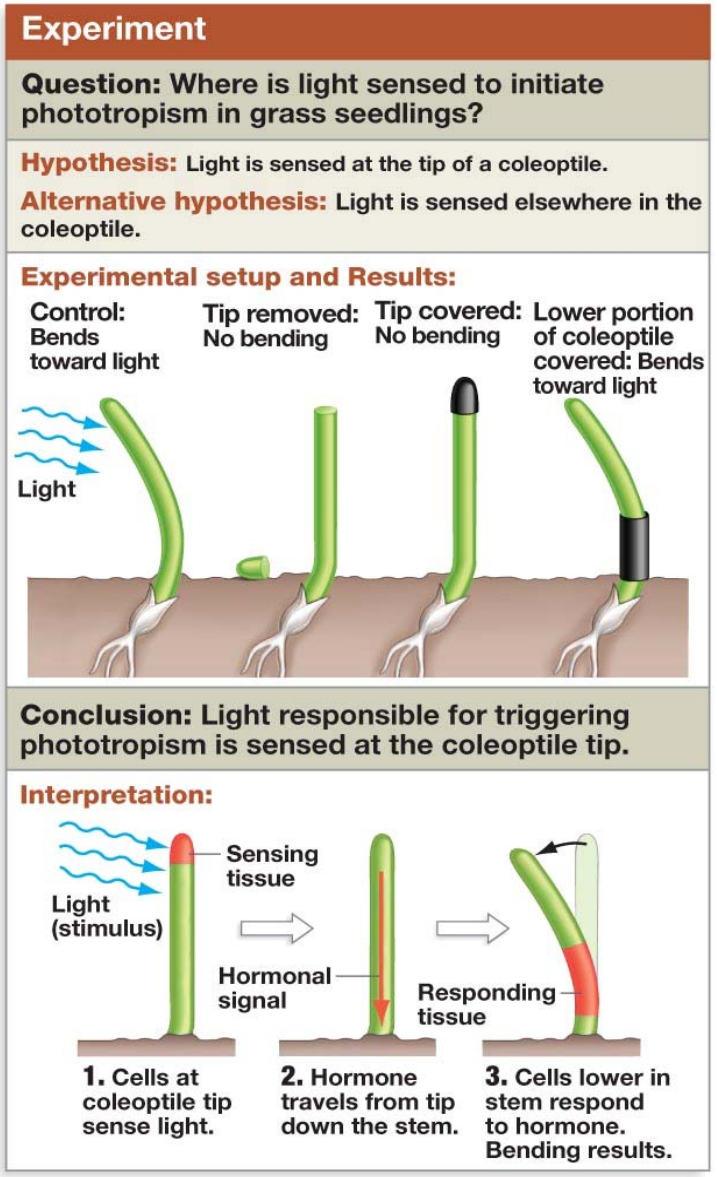
Auxin: Phototropic Hormone

- The sensory and response cells in phototropism are not the same. Blue light is sensed at the tip of a **coleoptile** (protected shoot) and info is then transmitted to lower cells.

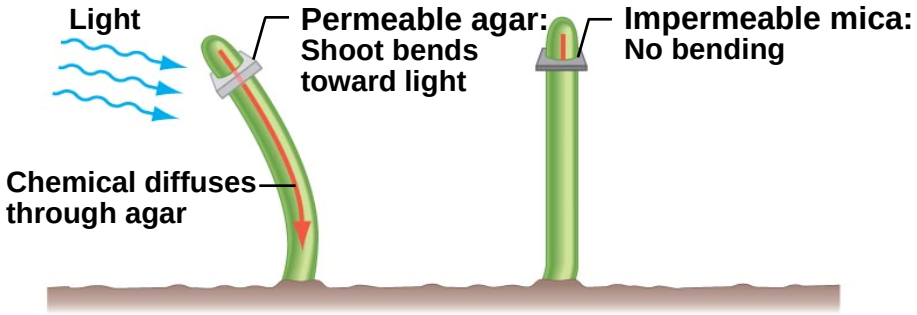
- Auxin (a hormone) is produced at the tip of the coleoptile, is transported to the area of bending, and acts as a signal…

- **Auxin** promotes cell _____ in the shoot.

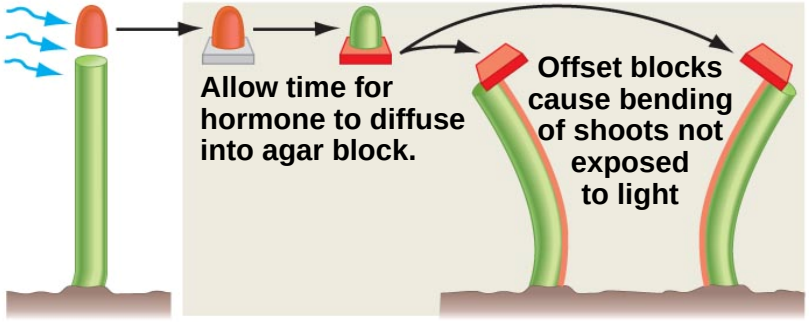
The Sensory and Response Cells Involved in Phototropism Are the Same



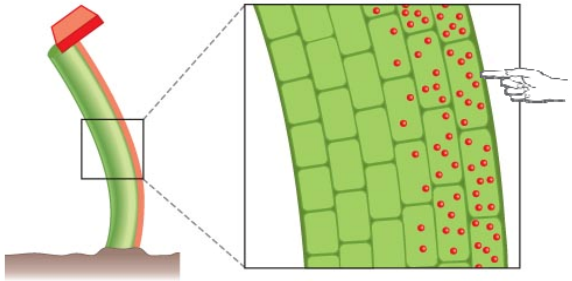
(a) The phototropic signal is a chemical.



(b) The hormone can cause bending in darkness.



(c) The hormone causes bending by elongating cells.



Auxin moves from the light and then down

Photoperiodism & Flowering

- Flowering in response to changes in day length—triggered by red/far-red light.

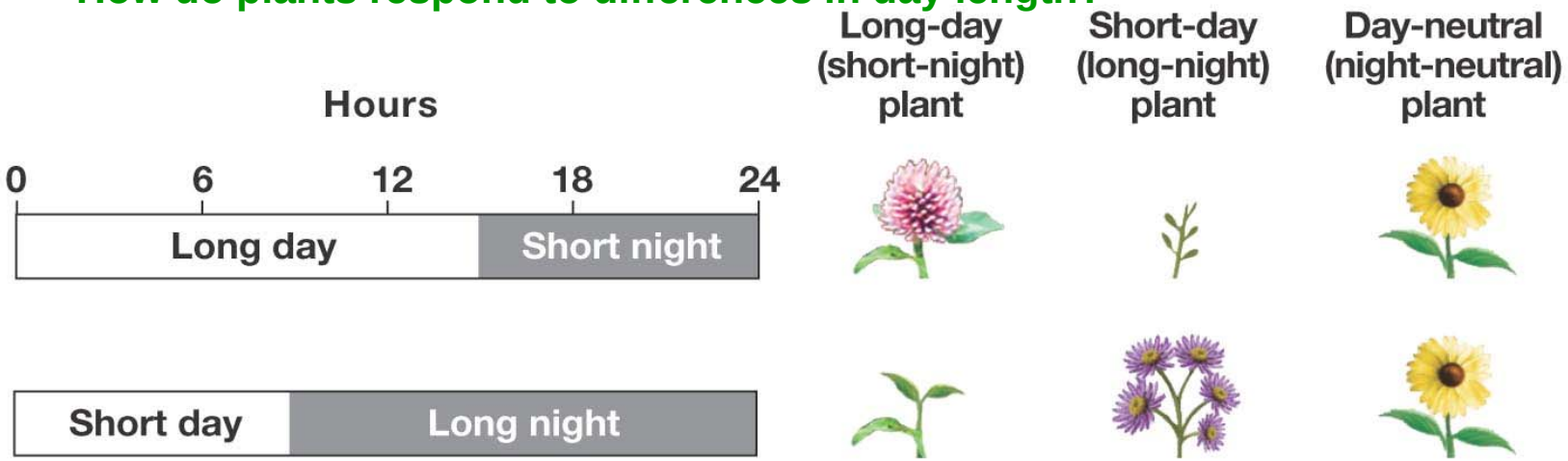
- **Photoperiodism** is any response by an organism that is based on _____, the relative lengths of day and night.

- In plants, the ability to measure photoperiod is important because it allows the plant to respond to seasonal changes in climate and the correlated availability of resources and pollinators.

Different Species Respond to Photoperiod in Different Ways

(a)

How do plants respond to differences in day length?



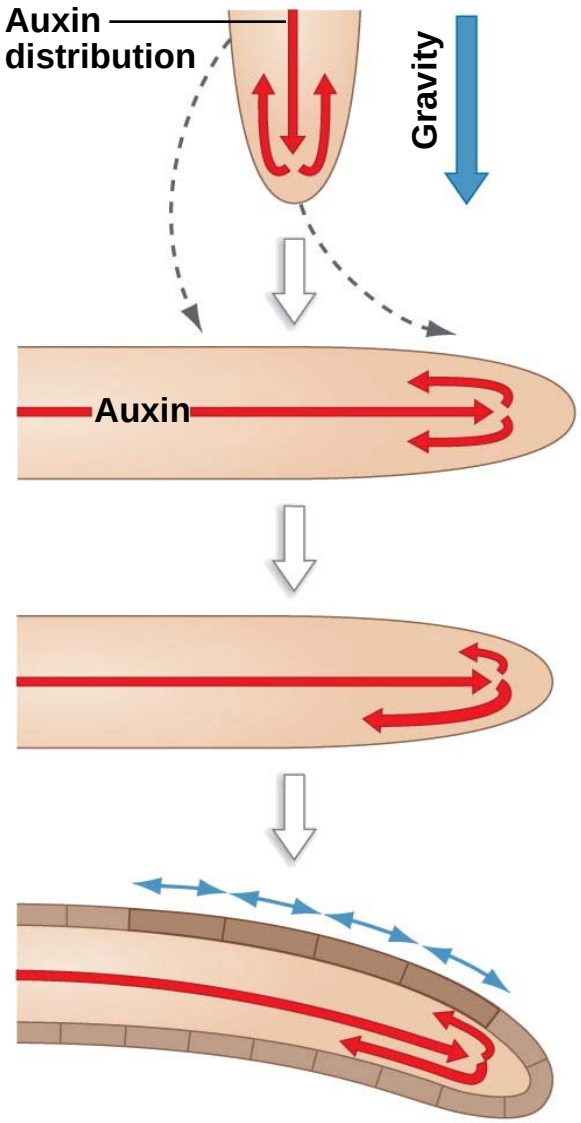
Gravity: The Gravitropic Response

_____ is the ability of plants to move in response to gravity. Roots grow down and shoots grow up or out.

Auxin as the Gravitropic Signal

- Root cap cells that sense changes in the direction of gravitational pull respond by changing the distribution of auxin in the root tip.

AUXIN AS THE GRAVITROPIC SIGNAL



1. Normal distribution of auxin in vertical root prior to disturbance.

2. Root tip moved into horizontal position.

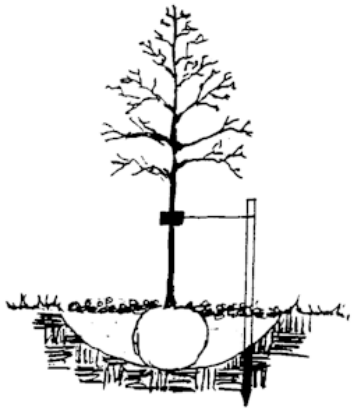
3. Gravity-sensing cells actively redistribute the auxin–more goes to bottom side.

4. Asymmetric auxin distribution inhibits cell growth on lower side and stimulates growth on upper side, leading to bending.

The Auxin Redistribution Hypothesis for Gravitropism

How Do Plants Respond to Wind and Touch?

- Plants get shorter and stockier in response to wind and touch.
- **Thigmotropism** is plant movement in response to touch.
- Recall *Phenotypic Plasticity*



Youth, Maturity, and Aging: The Growth Responses

- Controlling growth in response to changes in age or environmental conditions (one of the most basic aspects of information processing in plants).

- Hormones play a key role in regulating _____.

Auxin and Apical Dominance

- **Apical dominance:** most of a stem's growth occurs at the shoot apical meristem.

- Apical dominance occurs because a _____ auxin from the tips of growing shoots to the tissues below signals the direction of growth.

- If the signal stops, it means that apical growth has been interrupted. In response, **lateral buds** sprout at the angles between leaves and the stem and begin to take over for the main shoot.

Auxin's Overall Role

- Auxin: controls growth via phototropism, gravitropism, and apical dominance.
- Auxin has other important effects as well:
- Fruit development is influenced by auxin produced by seeds within the fruit.
- Falling auxin concentrations are involved in _____ (the shedding of leaves and fruits) associated with _____ aging).

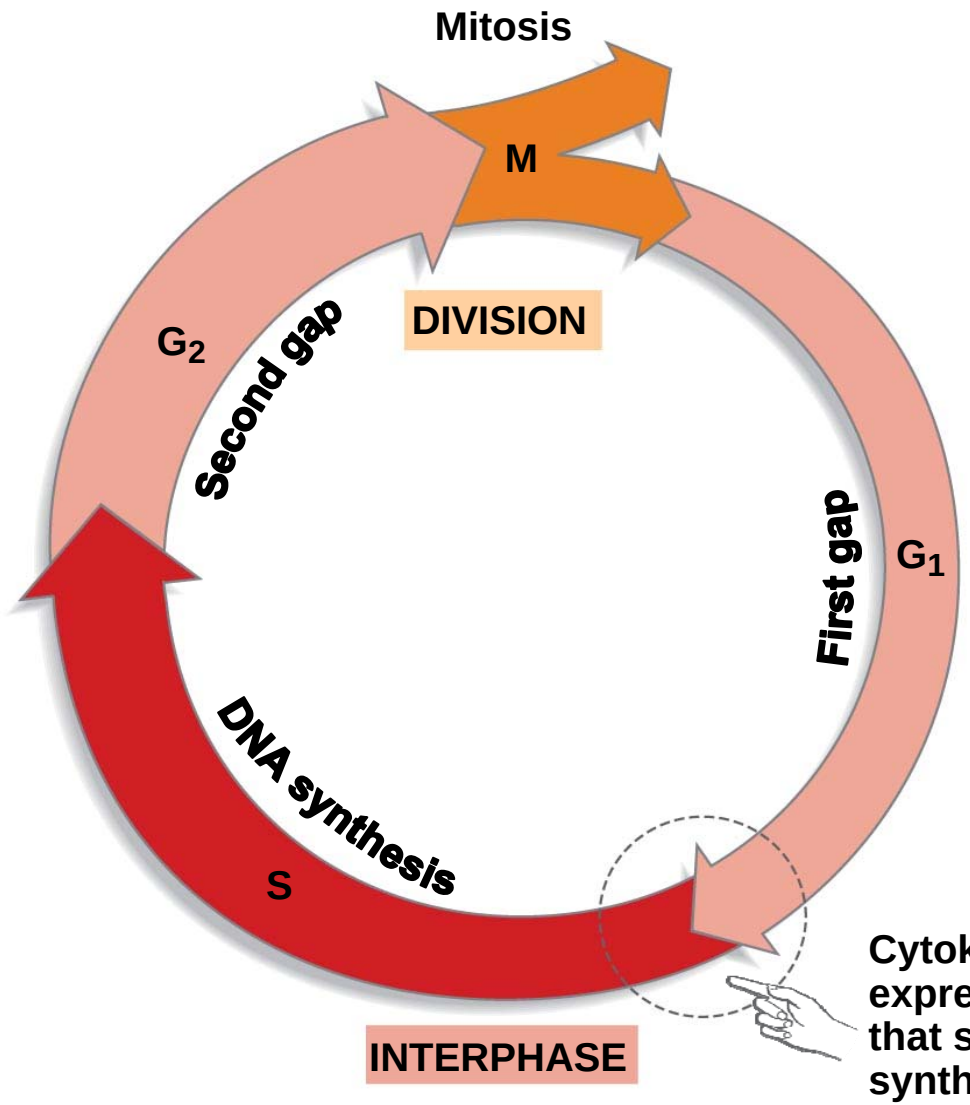
Cytokinins & Cell Division

- **Cytokinins** are a group of plant hormones that promote cell division.

- Cytokinins are synthesized in root tips, young fruits, seeds, growing buds, and other developing organs.

- Cytokinins regulate growth by _____ the _____ that keep the cell cycle going. In the absence of cytokinins, cells arrest at the G_1 checkpoint in the cell cycle and cease growth.

Cytokinins Affect the Cell Cycle



Cytokinins promote expression of genes that start S phase (DNA synthesis). Without cytokinins, cells remain in G_1 and do not divide

Gibberellins and ABA: Growth and Dormancy

- Two types of hormones are responsible for initiating and terminating growth in plants in response to changes in environmental conditions:
- **gibberellins** _____ growth,
  abscisic acid (ABA) _____ growth.

Gibberellins Stimulate Shoot Elongation

- **Gibberellic acid (GA)** is a gibberellin that appears to promote cell elongation and to increase rates of cell division in roots.

Gibberellins and ABA Interact during and Germination

- Many plants produce seeds that have to undergo a period of drying or a period of cold, wet conditions before they are able to germinate in response to warm, wet conditions.

- In many plants, ABA is the signal that inhibits seed germination, and gibberellins are the signal that triggers embryonic development.

Video 34.3 Germination of soybean plants

- During seed germination, gibberellins activate production of α-**amylase**, a digestive enzyme that breaks the bonds between sugar units of starch. This releases sugars to the growing embryo.

ABA Closes Guard Cells in Stomata

- In most plants, stomata open in response to blue light, allowing gas exchange during photosynthesis. When stomata are open, water can be lost; if the roots cannot replace water lost at the leaves, then the stomata close.

- ABA from _____ is transported to leaves, resulting in the _____
  Therefore, this signal overrides that from the blue-light receptors.

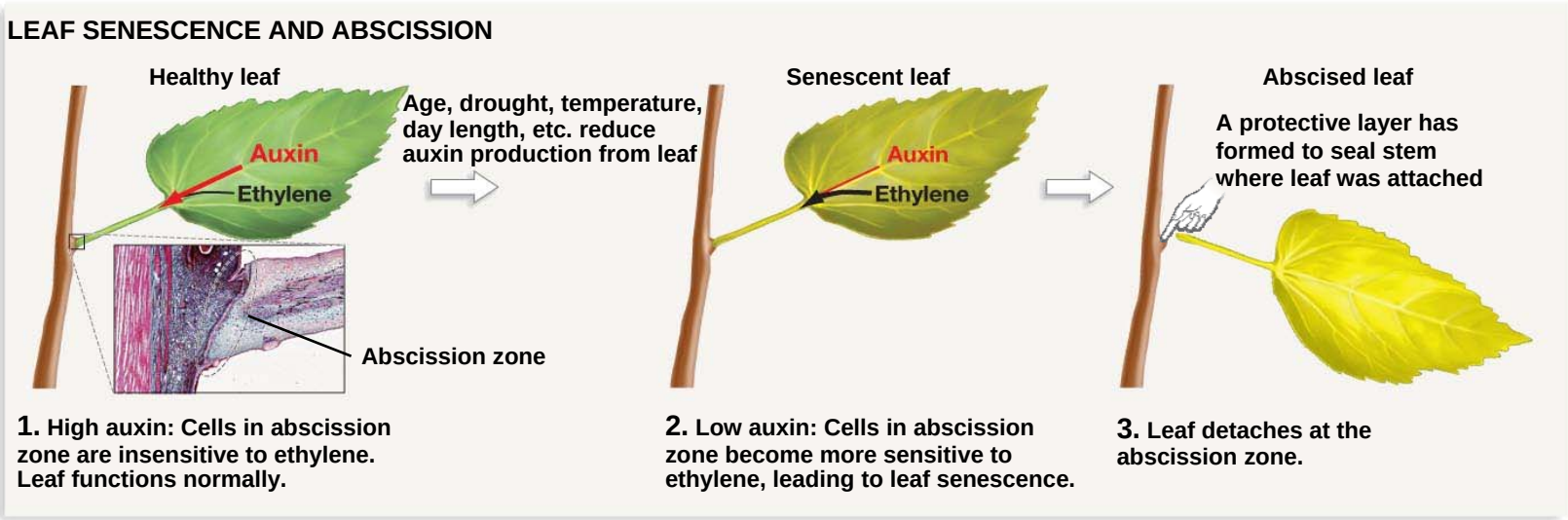
_____ and Senescence

- Senescence = regulated aging process.

- The gaseous hormone **ethylene** is strongly associated with three aspects of senescence in plants:
  - 1) _____
  - 2) flower fading
  - 3) abscission.

The **abscission zone** is a region of the leaf petiole that becomes more sensitive to ethylene as auxin levels drop. As a result, it degrades first and the leaf breaks off at this point.

Leaves Drop in Response to Signals from Auxin and Ethylene



Overview
Plant Growth Regulators

(1) A single hormone often affects many different target tissues. This means there can be an array of responses to the same cell-cell signal.

(2) In most cases, several hormones affect the same response.

Hormones do not work independently—they _____ with each other.

How Do Plants Sense and Respond to Pathogens?

- If a pathogen invades a plant, the plant mounts a defense called the **hypersensitive response (HR)**. HR causes the rapid and localized death of cells surrounding the site of infection,

- Other Responses too…

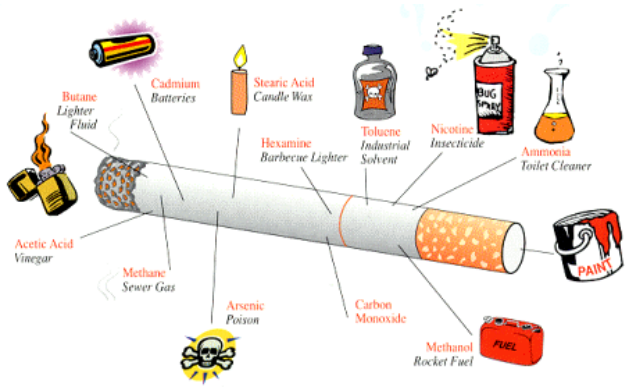
Video 39.1
Lepidopteran larvae feeding on leaves

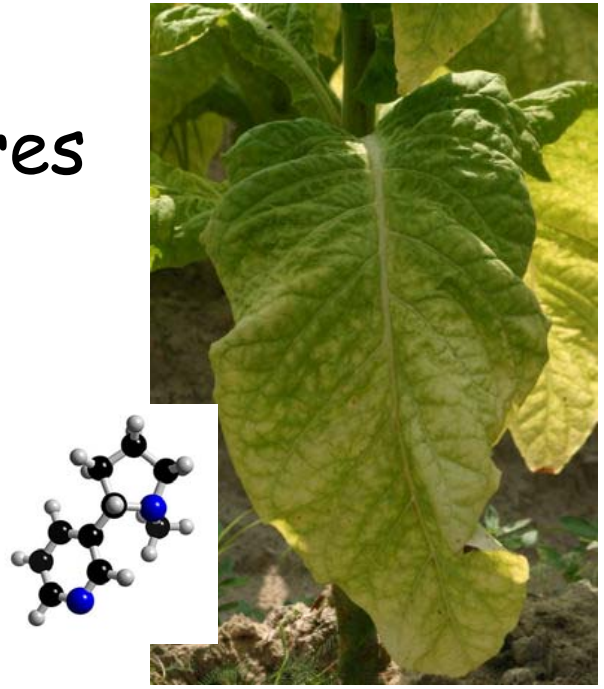
Herbivory

= toxins

(Primary metabolites involved in homeostasis and typical cellular function)

- Tobacco makes nicotine
  - Harmful to many herbivores





Secondary Metabolites

- Hormones/Pheromones
  - Mimic juvenile hormone; stop molt to adult
  - Attract your herbivore's insect prey!
  - Warn other plants to mobilize their defensive cascades

- Poisons
  - Disrupt nervous system of herbivore
    - nicotine
  - Disrupt digestive system of herbivore
    - proteinase inhibitors

How Do Plants Sense and Respond to Herbivore Attack?

- Many plant seeds and storage organs contain _____, proteins that block the enzymes found in the mouths and stomachs of animals that digest proteins.

- When a herbivore ingests a large dose of a proteinase inhibitor, it gets sick. As a result, herbivores learn to detect and avoid plant tissues containing high concentrations of these proteins.

Pheromones Released from Plant Wounds Recruit Help from Wasps

- A _____ is an organism that is free living as an adult but parasitic as a larva. Because parasitoids (for example, a wasp egg laid in a caterpillar's body) kill their host, parasitoid attacks limit the amount of damage that herbivores do to plants.
- **Pheromones** are chemical messengers synthesized by an individual and released into the environment that elicit a response from a different individual.
- Plants produce wasp attractant pheromones in response to attack by caterpillars.

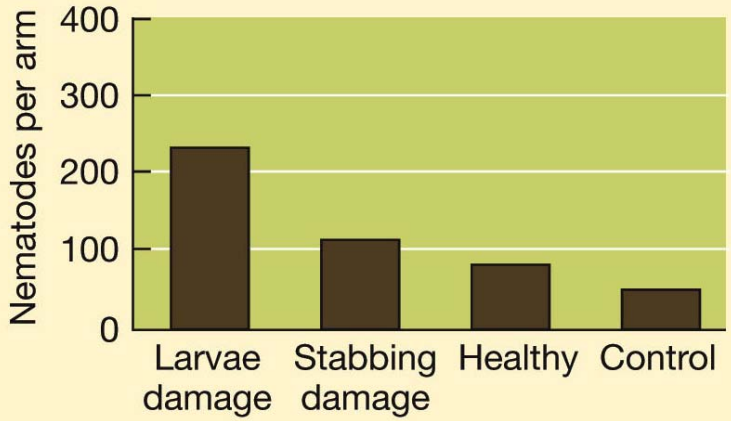
Parasitoid

wasp

EXPERIMENT

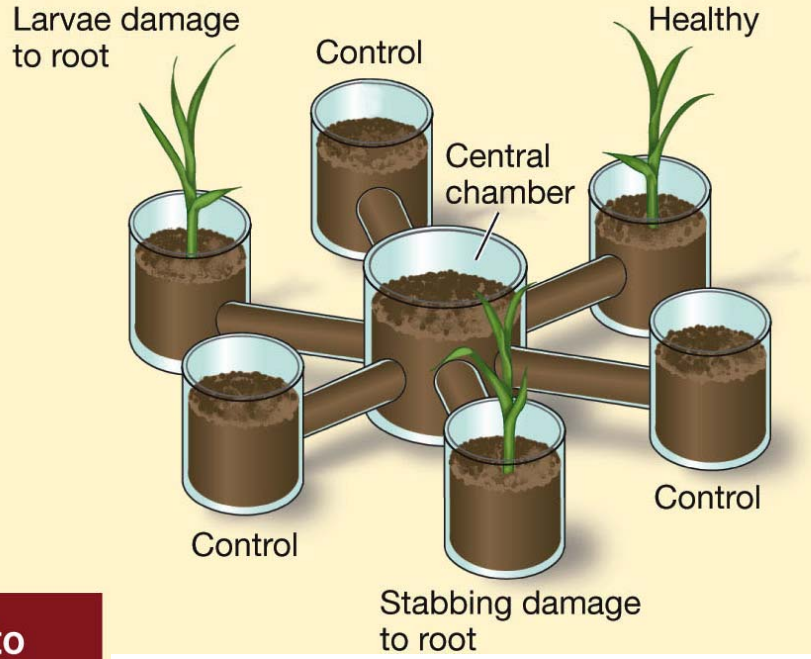
HYPOTHESIS: Corn roots attacked by beetle larvae attract nematodes that will attack the larvae.

Attract the herbivore's prey!



RESULTS

Nematodes moved into each of the arms, but by far the most moved into the arm leading to the larvae-damaged plant.



CONCLUSION: The nematodes were attracted to the roots that had been attacked by the beetle larvae.

Secondary Metabolites

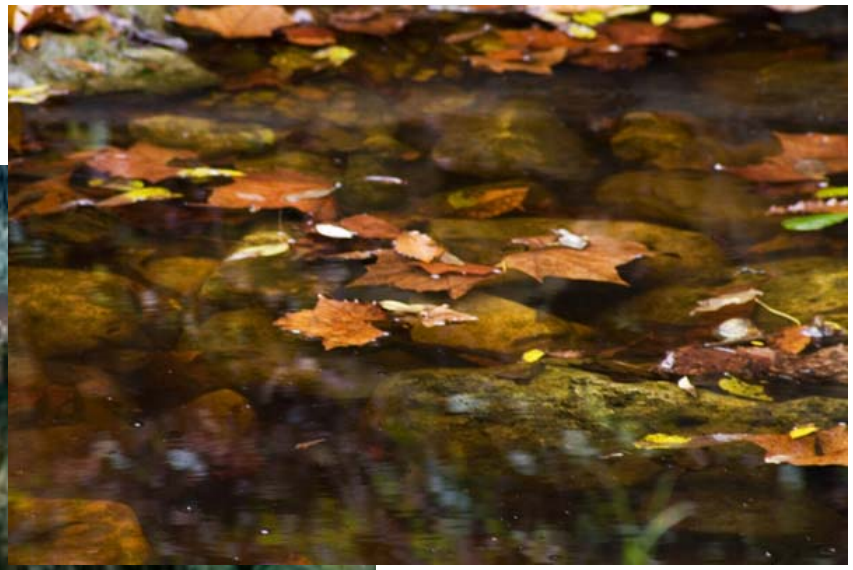
TABLE 39.1

Secondary Plant Metabolites Used in Defense

CLASS	TYPE	ROLE	EXAMPLE
Nitrogen-containing	Alkaloids	Affect herbivore nervous system	Nicotine in tobacco
	Glycosides	Release cyanide or sulfur compounds	Dhurrin in sorghum
	Nonprotein amino acids	Disrupt herbivore protein structure	Canavanine in jack bean
Phenolics	Flavonoids	Phytoalexins	Capsidol in peppers
	Quinones	Inhibit competing plants	Juglone in walnut
	Tannins	Deter herbivores and microbes	Many woods, such as oak
Terpenes	Monoterpenes	Insecticides	Pyrethroids in chrysanthemums
	Sesquiterpenes	Phytoalexins; deter herbivores	Gossypol in cotton
	Steroids	Mimic insect hormones and disrupt insect life cycles	α-Ecdysone in ferns
	Polyterpenes	Feeding deterrent?	Latex in rubber tree

Tannins

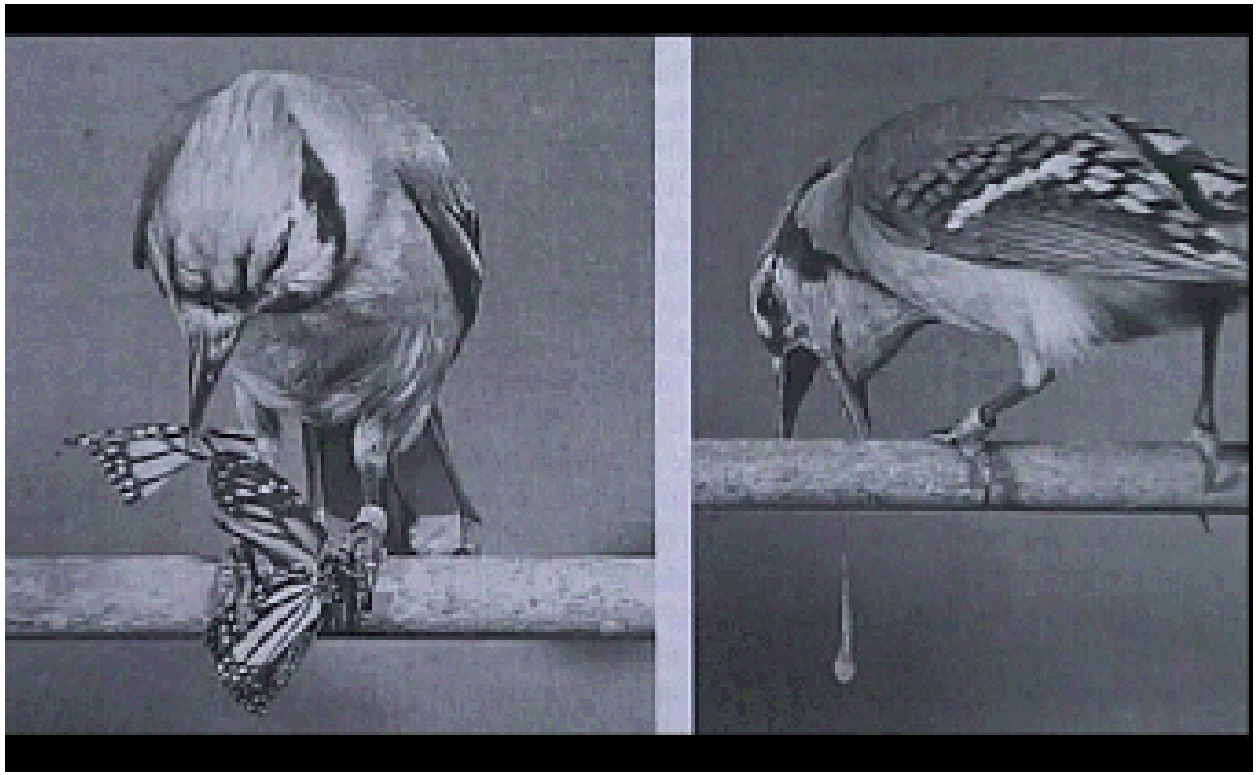
grapes/wine



oak leaves

Milkweeds

Secrete a poisonous latex



Swallowtail butterflies incorporate milkweed toxins into their own tissues for defense (via bird learning)

Milkweeds

Secrete a poisonous latex

Some herbivores 'learn' to disable the defense (cut the latex supply lines, then eat the leaf!)

Another example of an

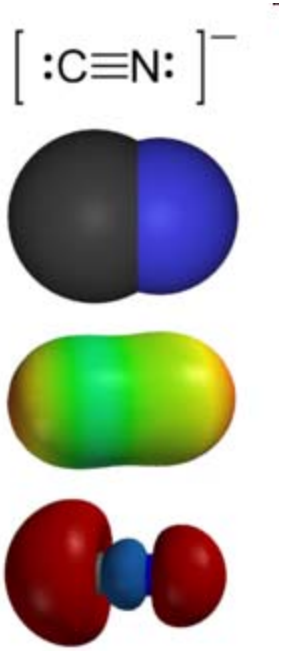
Cyanide (CN)

Cyanide is a very rapidly acting toxin (used by communes for suicide!).

In plants, CN is combined with sugar as a cyanogenic glycoside.

Precursors, stored in vacuoles , get together in cytosol if plant is damaged by wilting, crushing, or chewing.

More than 1000 plant species have cyanide in some form.



Aspirin!

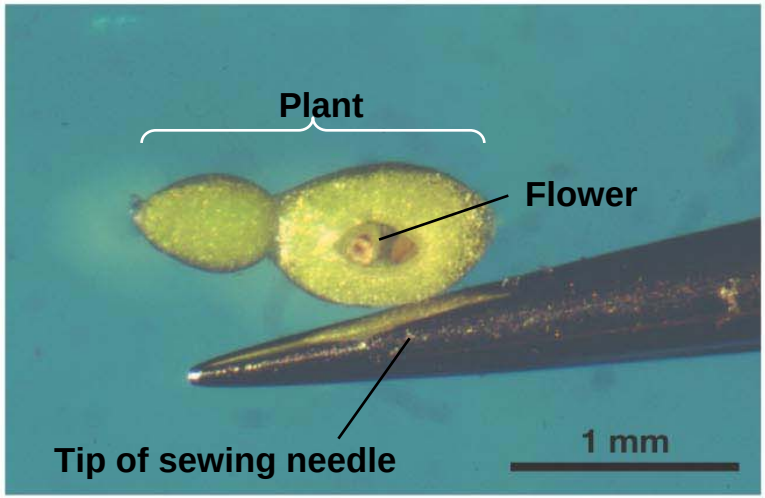
- Salicylic Acid common in plants
  - Well-studied in Willows (*Salix*)
  - Used to combat many pathogens
    - (e.g., viruses)

- Methyl salicylate, a related compound
  - aka 'oil of wintergreen'
  - Volatilizes to signal other plants (~pheromone) to defend selves


SPRING

The _____ of Plant Reproductive Structures Is Highly Variable

(a) Small reproductive structures ⟷ Large reproductive structures



(b) Small seeds ⟷ Large seeds

Plant Reproduction

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spring 2009
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(Freeman Ch40)

DECIDED TO SKIP B/C MUCH OF THIS MATERIAL COVERED ALREADY

Video 34.1 Time-lapse of bud burst in plants