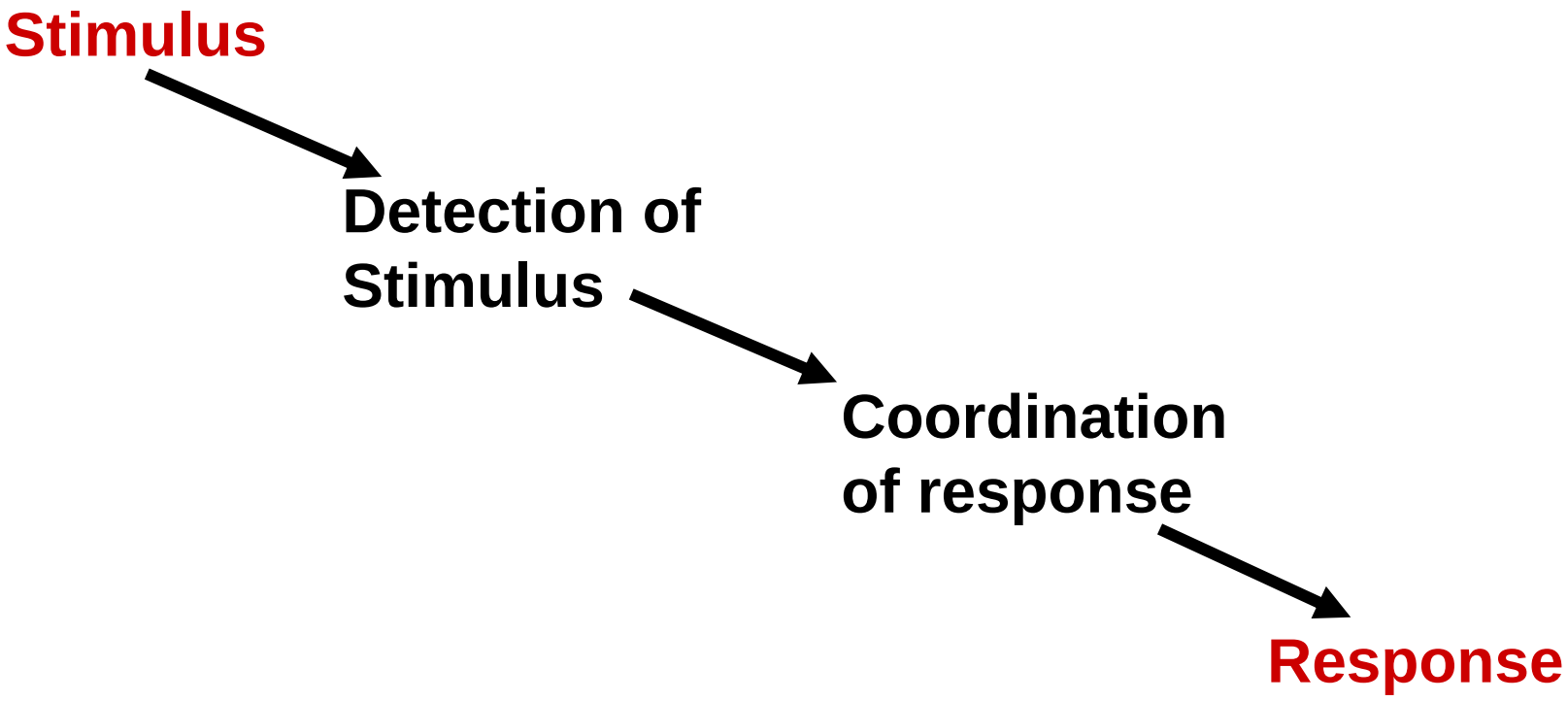
Plant Responses to the Environment

- Explain why plants need to respond to their environment.
- Define the term: *tropism.*
- Explain how plant responses to environmental changes are coordinated by hormones.
- Outline the role of hormones in leaf loss in deciduous plants.
- Evaluate the experimental evidence for the role of auxins in the control of apical dominance and the role of gibberellin in the control of stem elongation.
- Describe how plant hormones are used commercially.

Responding to the Environment



Why do plants need to respond to their environment?

- So the plant can:
  - Reduce stress.
  - Avoid being eaten.
  - Survive long enough to reproduce.

How do plants do this?

- Tropisms.
  - Directional growth responses.
  - Direction of growth determined by the direction of the stimulus.
  - Plants can grow towards or away from various stimuli.

Tropisms

- Phototropism
  - Shoots grow towards light.
- Geotropism
  - Roots grow towards the pull of gravity.
  - Shoots grow away from the pull of gravity.
- Chemotropism
  - Pollen tubes grow towards chemicals in the ovary.
- Thigmotropism
  - Climbing plants grow around walls or other structures.

What controls tropisms?

- Hormones:
  - Chemicals produced by a variety of cells.
  - Transported away from point of production to target cells.
  - Often called growth regulators.
  - Bind to receptors on target cell plasma membrane.
    - Shape specificity

How do hormones move around the plant?

- No blood system.

- Plant hormones are transported by:
  - Active transport from one cell to another.
  - Diffusion
  - Mass flow in Phloem/Xylem vessels.

What effects can plant hormones have?

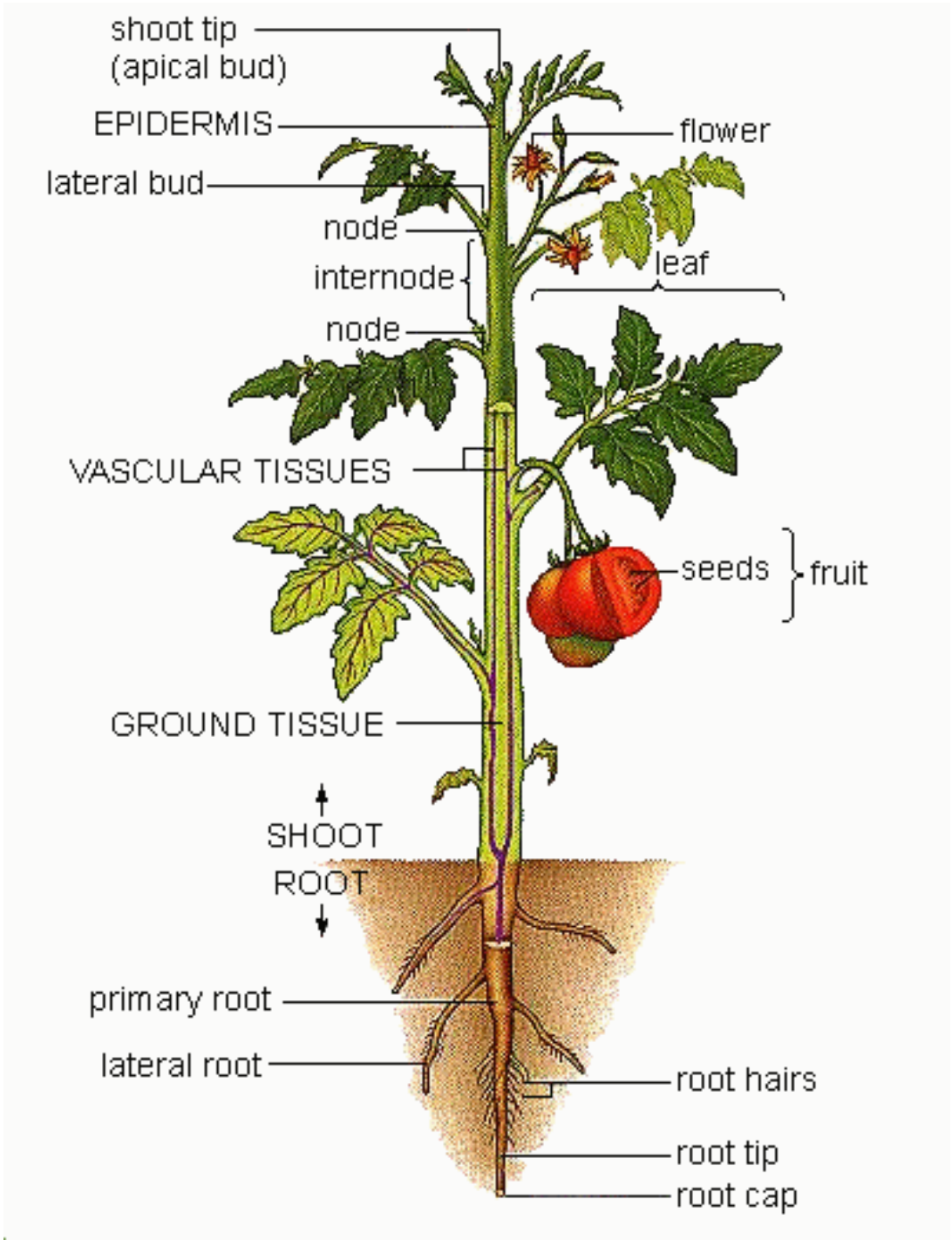
- Hormones can:
  - Amplify the effects of other hormones (Synergy).
  - Cancel out the effects of other hormones (Antagonism).
  - Influence cell division.
  - Influence cell elongation.
  - Influence cell differentiation.

Plant Hormone Effects

Hormone	Effects
Auxins	Promote cell division & elongation, inhibit growth of side shoots, inhibit leaf abscission.
Cytokinins	Promote cell division.
Gibberellins	Promote seed germination and growth of stems (cell elongation).
Abscisic Acid	Inhibits seed germination & growth. Causes stomatal closure.
Ethene	Promotes fruit ripening.

Plant Structure

- Shoots
  - Elevate the plant above the soil
  - Many functions including:
    - photosynthesis
    - reproduction & dispersal
    - food and water conduction
- Roots
  - Anchor the plant in the soil
  - Absorb water and nutrients
  - Conduct water and nutrients
  - Food Storage

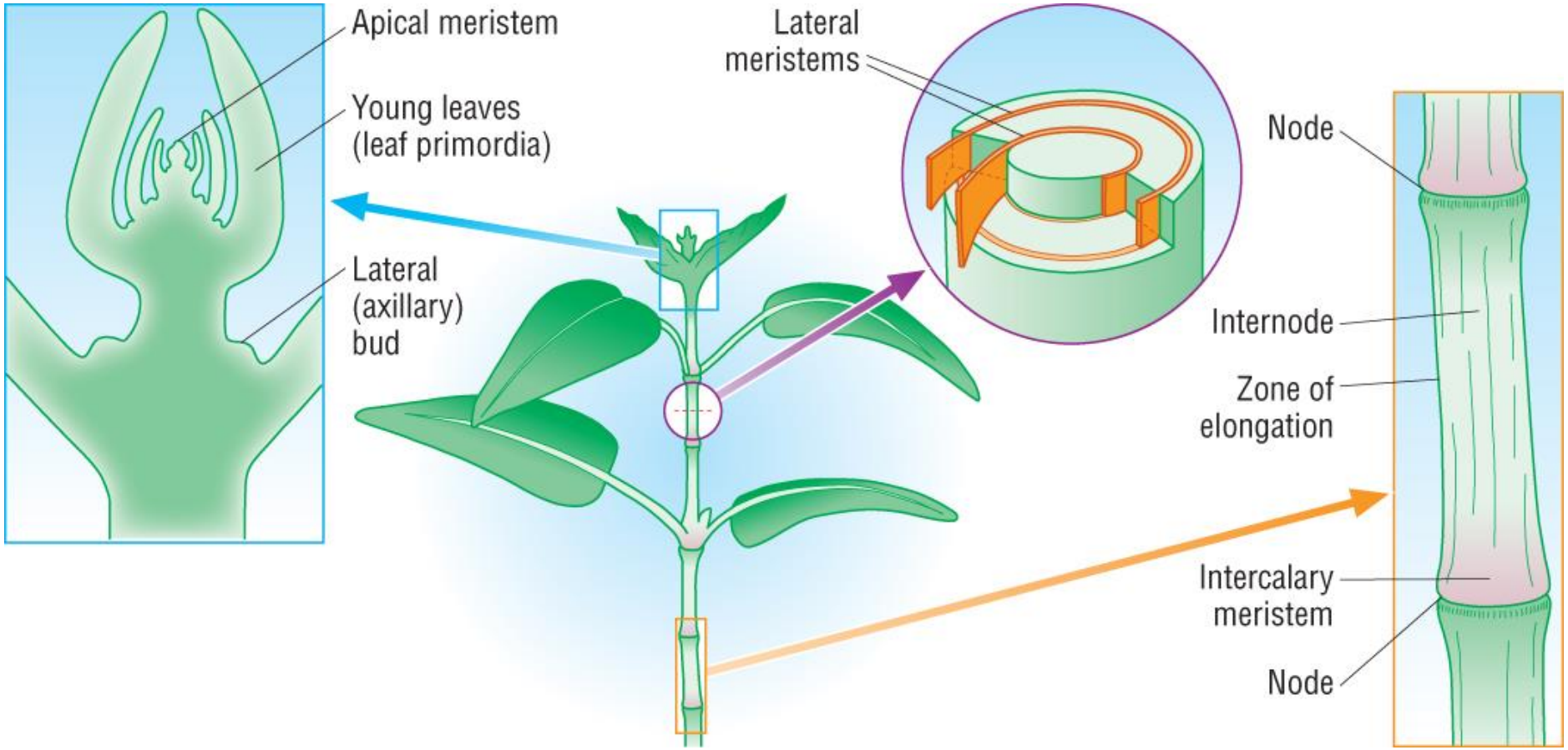


Plant Growth

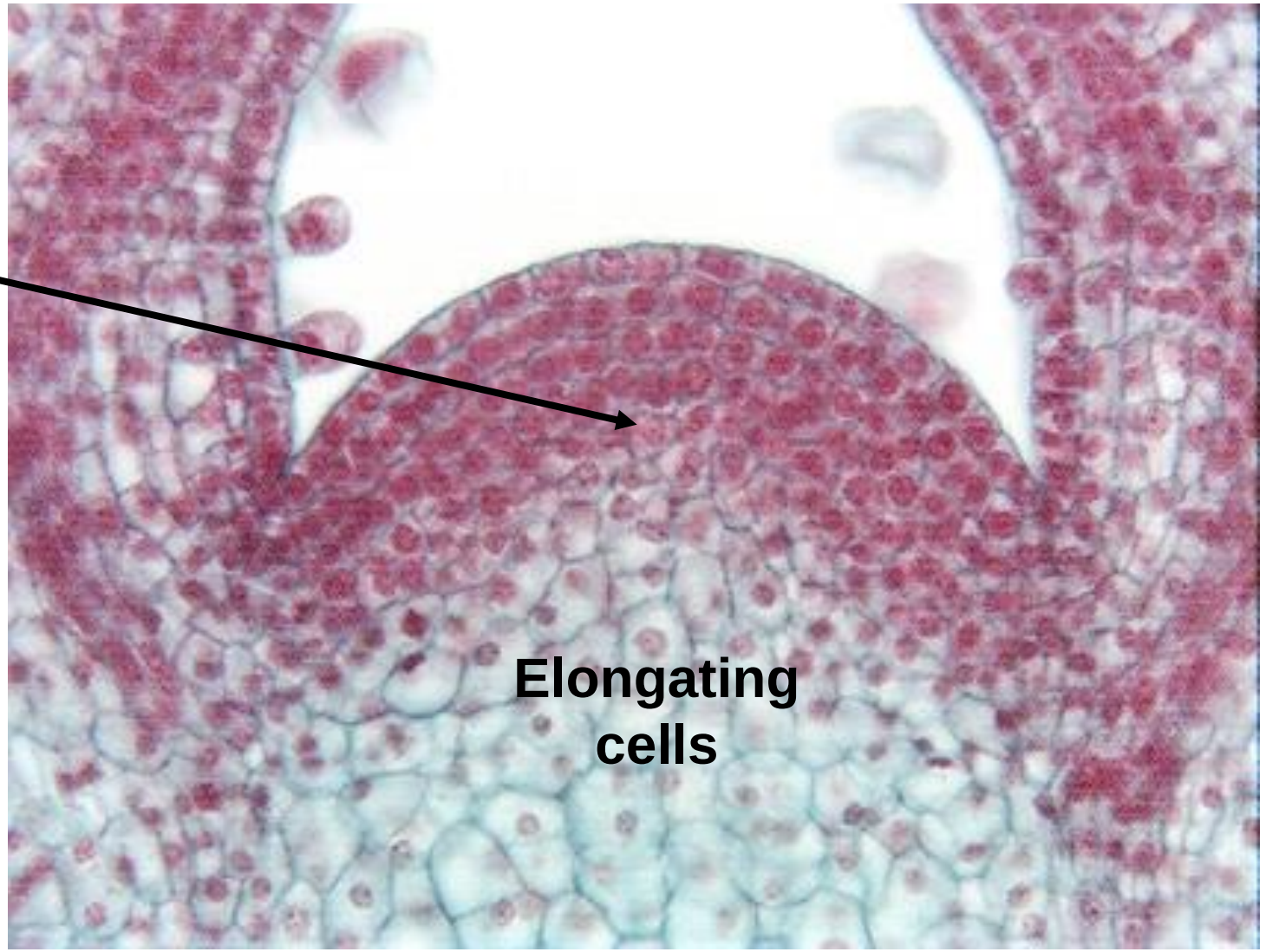
- Only occurs in certain areas of the plant.
  - Meristems.

- 4 different types:
  - Apical meristem
    - Tips (apices) of roots/shoots
  - Lateral bud meristem
    - Buds for producing side shoots
  - Lateral meristem
    - Cylidrical areas around roots/shoots for increasing girth
  - Intercalary meristem
    - Between nodes of shoots for increasing shoot length

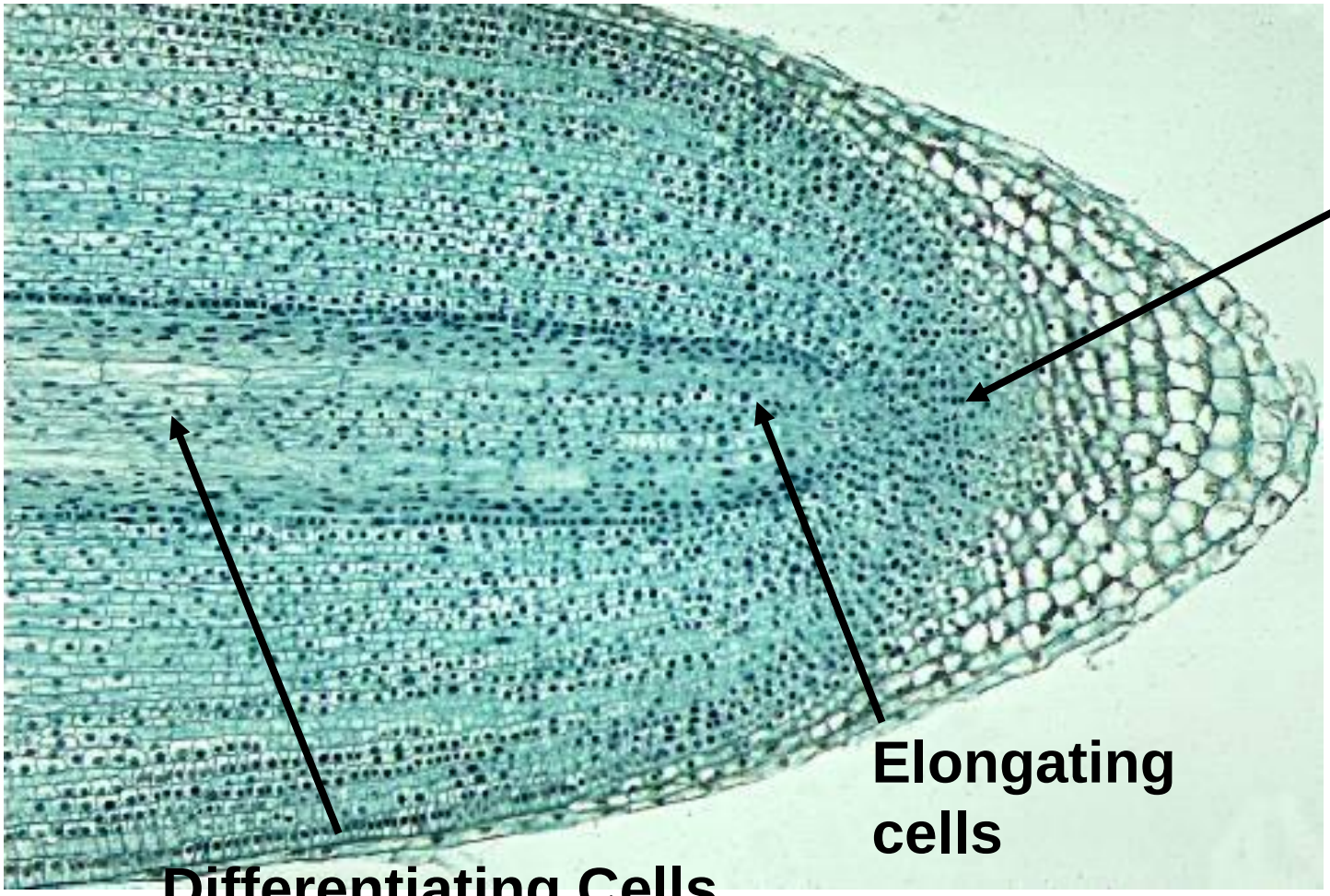
Meristems


Apical meristem
Young leaves
(leaf primordia)
Lateral
(axillary)
bud
Lateral
meristems
Node
Internode
Zone of
elongation
Intercalary
meristem
Node

Shoot Apical Meristem



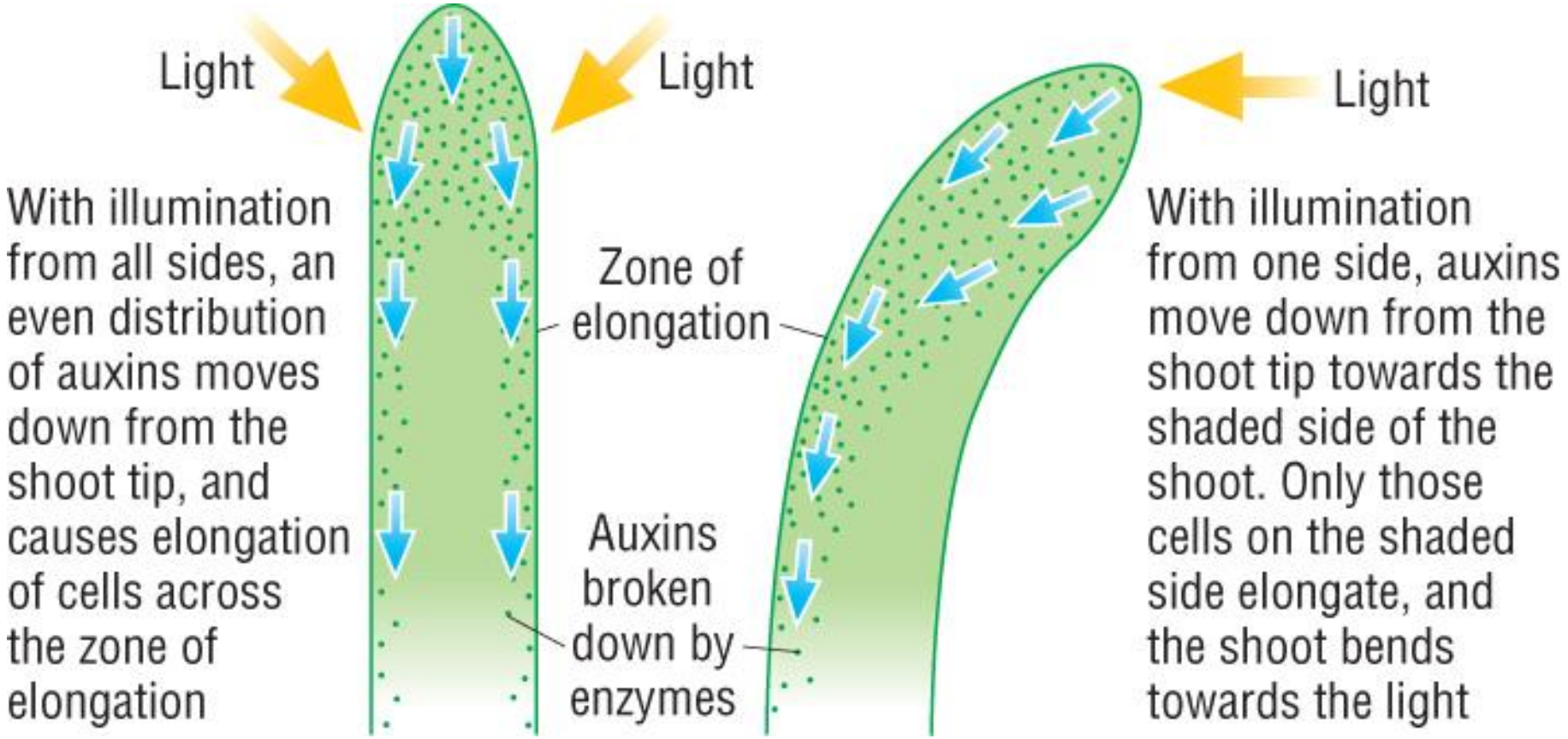
Root Apical Meristem



Auxins

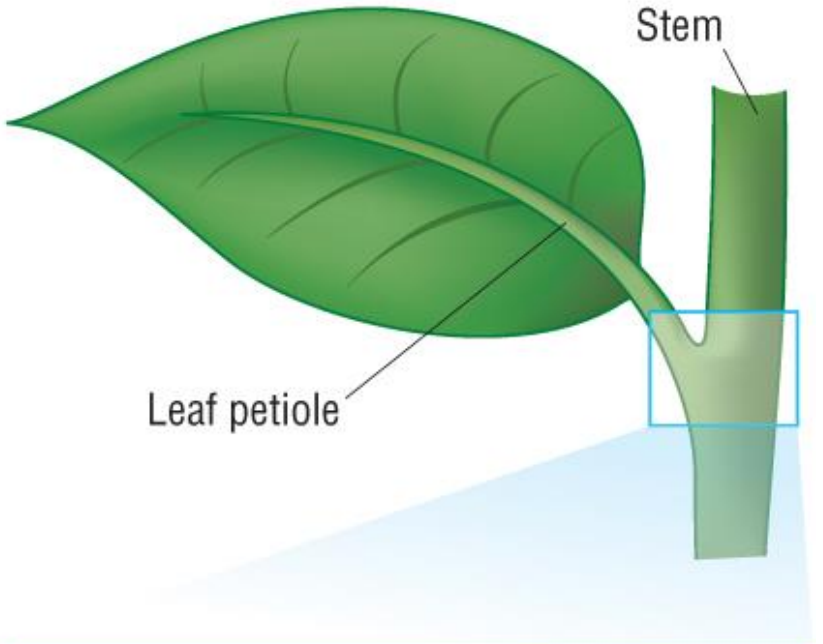
- Eg. Indole-3-Acetic Acid (IAA).
- Stimulate cell elongation.
  - The effect is stronger if gibberellins are also present.
  - Auxins also stimulate cell division if cytokinins are present.
- Produced by apical meristem cells.
- Diffuse or actively transported to zone of elongation, making the shoot/root grow.

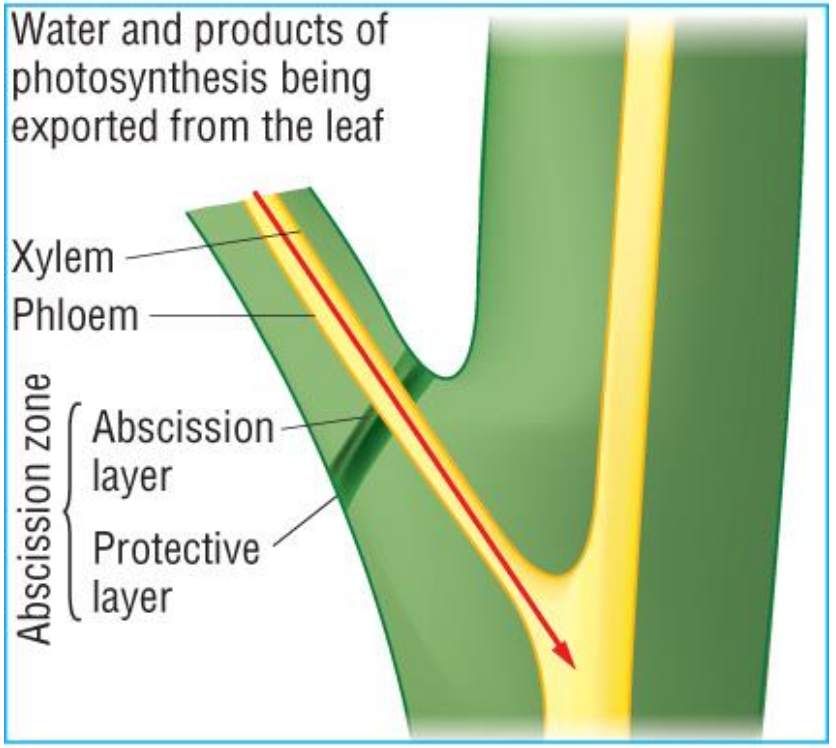
Phototropisms



Leaf abscission

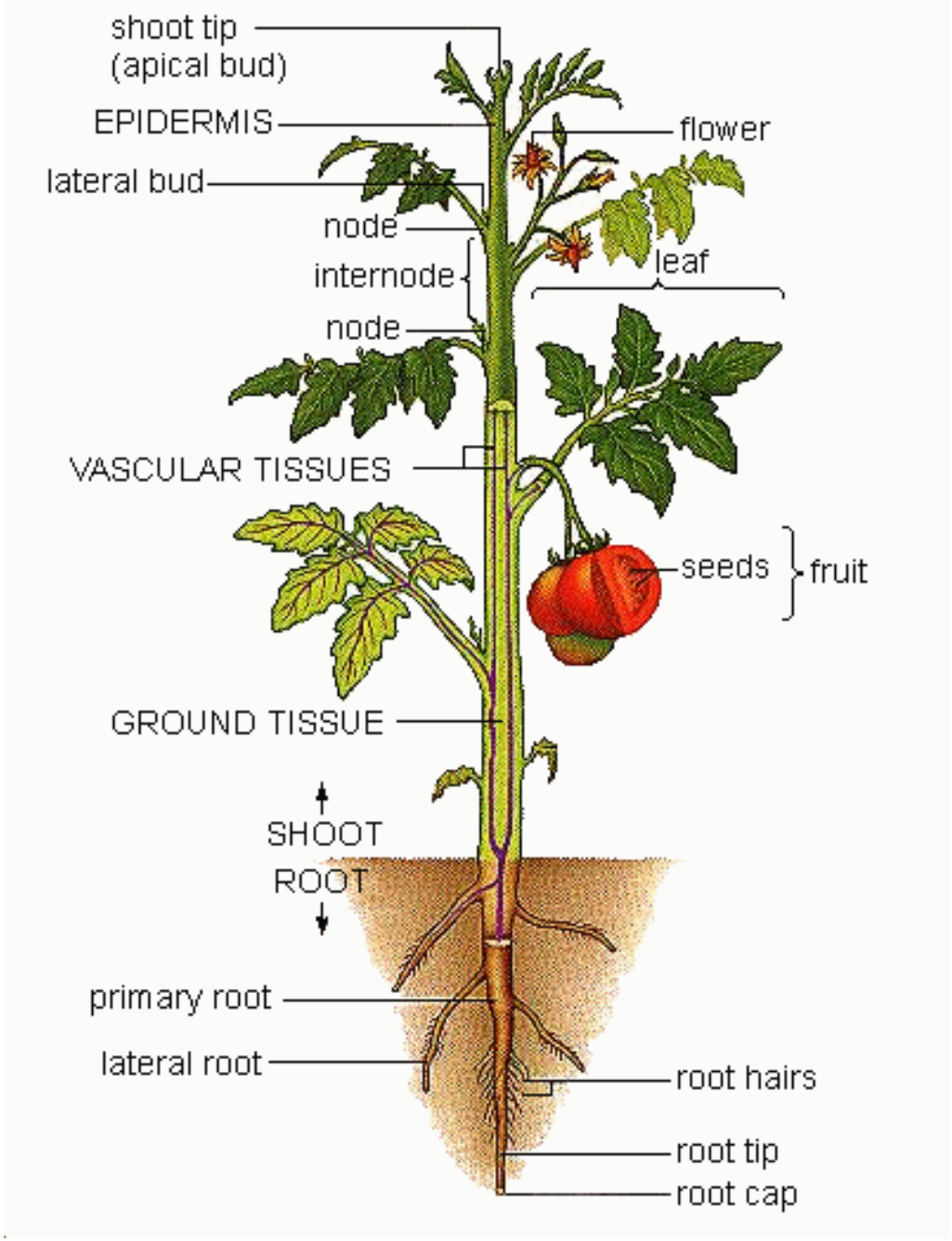
- Auxins inhibit leaf abscission.
- Cytokinins prevent deciduous leaves from senescing.
- If cytokinin levels drop, senescence begins.
- Senescence causes auxin production to drop.
- Low auxin makes cells in the abscission zone more sensitive to ethene.
- Low auxin also causes ethene production to increase.
- Ethene causes production of enzyme cellulase.
- Cellulase digests cell walls in abscission zone.
- Leaf petiole eventually separates from stem.





Apical Dominance

- The growing apical bud at the tip of a shoot inhibits growth of lateral buds further down the shoot.



How does apical dominance occur?

- Observation
  - If we cut the apical bud off of a shoot the dormant lateral buds quickly begin to grow side branches.
- Possible Explanation
  - Auxins produced in the apical meristems travel down the shoot & inhibit growth of lateral buds. When apex is removed, auxin concentration in the shoot falls and lateral buds grow.

To test this hypothesis…

- Researchers applied a paste containing auxins to the cut off apex.
  - Nearby lateral buds did not grow.
- Does this support or refute the hypothesis?
- Could anything else have produced the same effect?

Further evidence…

- Researchers applied a ring of auxin transport inhibitor below an intact shoot apex.
- Lateral buds grew.

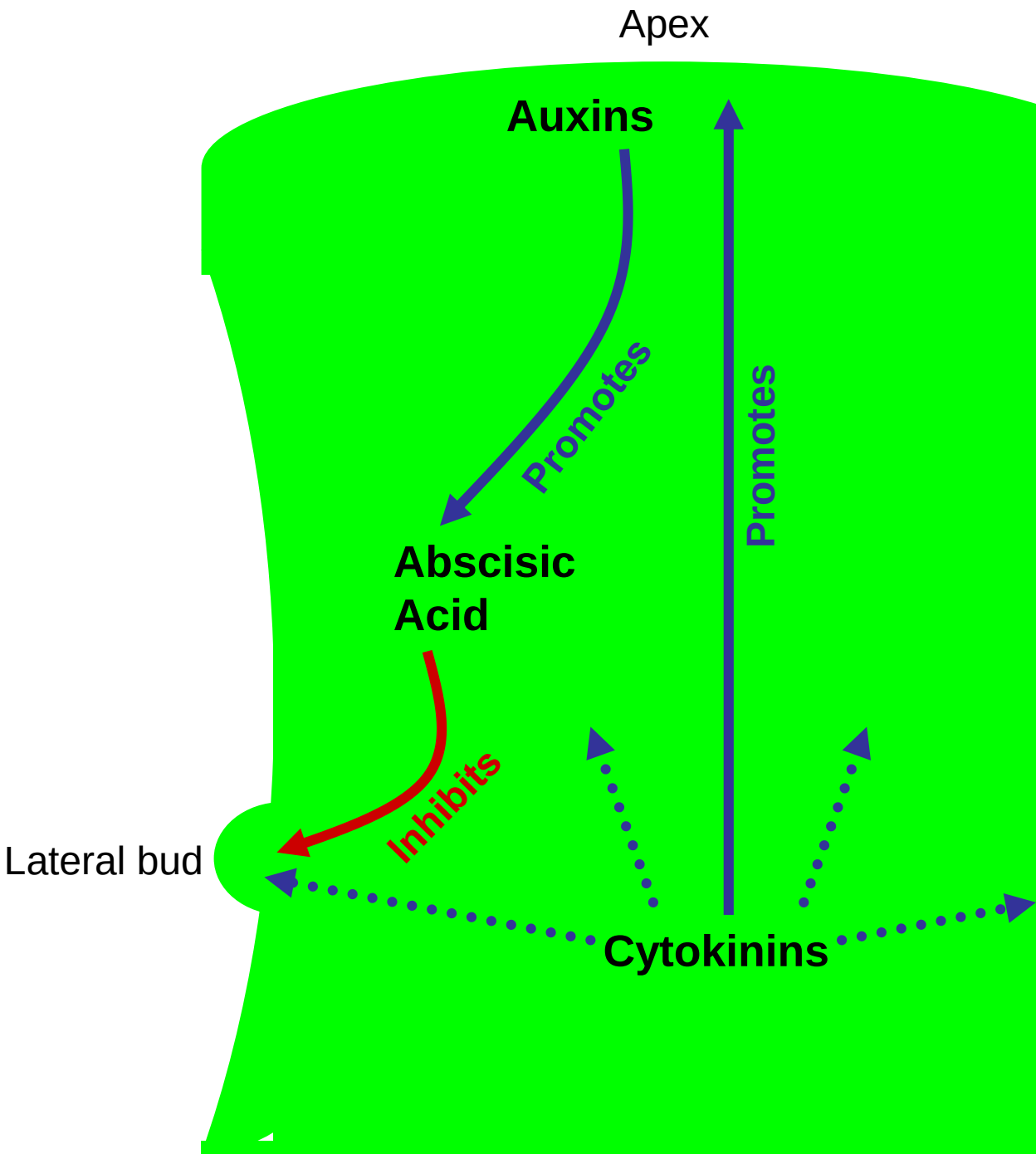
- Hypothesis:
  - Normal auxin concentrations inhibit lateral bud growth but low concentrations promote growth.

Many years later…

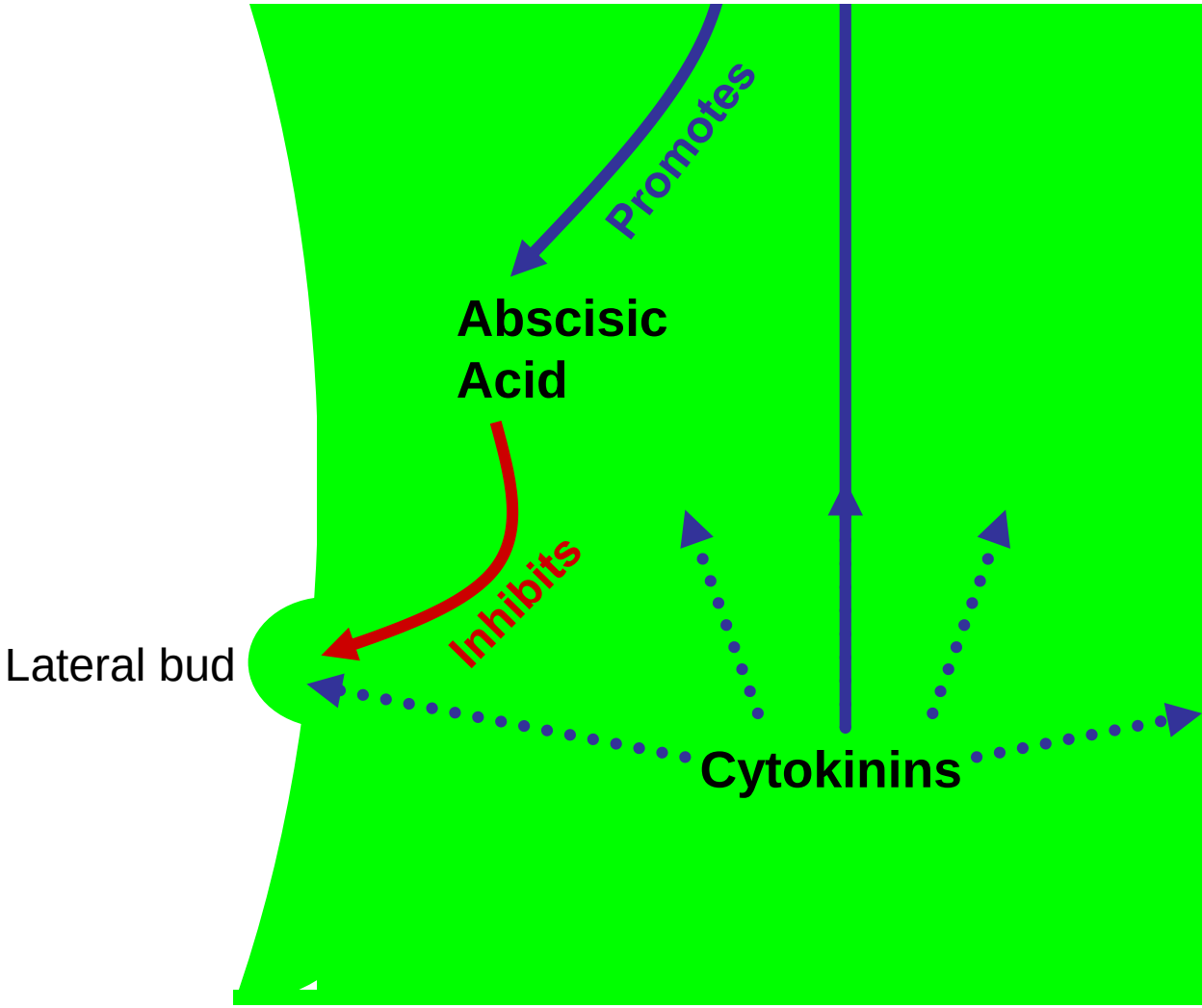
- Scientists disproved a direct causative relationship between auxin concentration and lateral bud growth inhibition.

- We now think two other hormones are involved.

- Auxins promote production of Abscisic Acid, which inhibits bud growth.
- Cytokinins promote bud growth and the apex acts as a sink for Cytokinins.



- Removal of the apex removes the Cytokinin sink and reduces Abscisic Acid production.



Gibberellins & Stem Elongation

- Observation
  - Rice plants infected by a certain fungus grow very tall.
  - A family of compounds (Gibberellins) were found to be produced by the fungus.
- Possible explanation
  - Gibberellins cause tall plants.

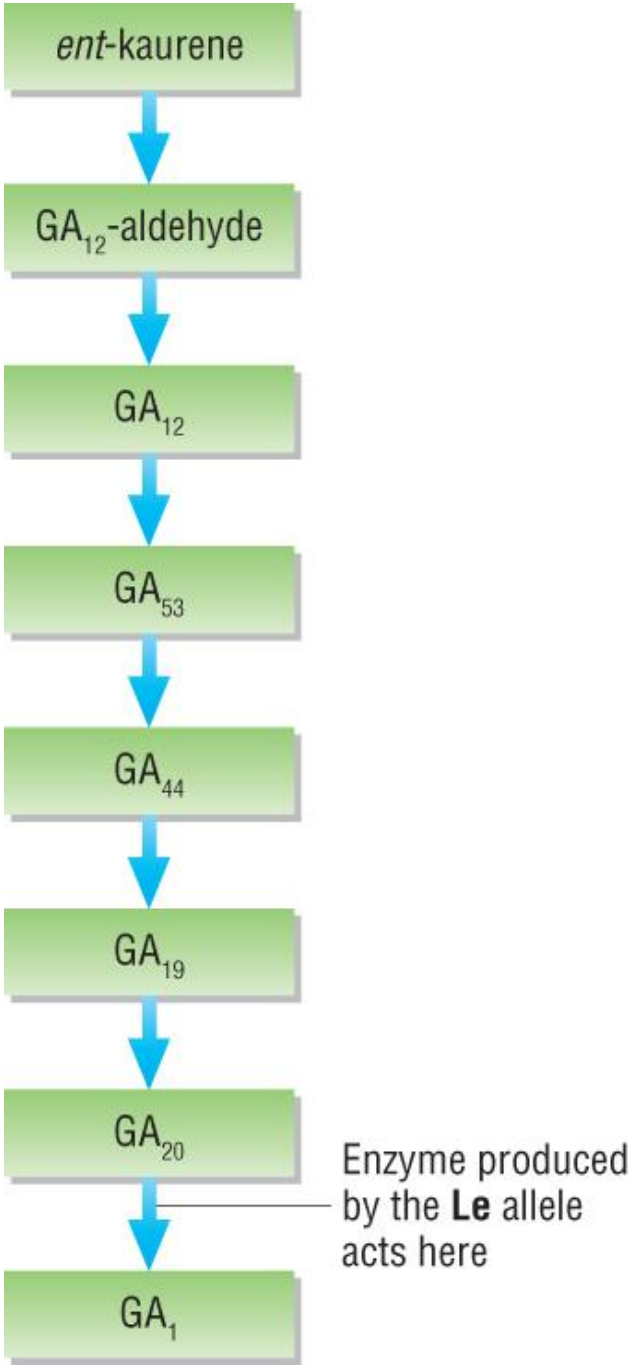
Gibberellins

- Observation
  - One of the Gibberellin compounds (Gibberellic Acid, GA_3) was applied to dwarf varieties of pea plants or cabbages.
  - These plants grew tall.
- Possible explanation
  - GA_3 is responsible for plant stem growth.
- But…
  - Just because GA_3 can cause stem growth does not mean it does so in nature.

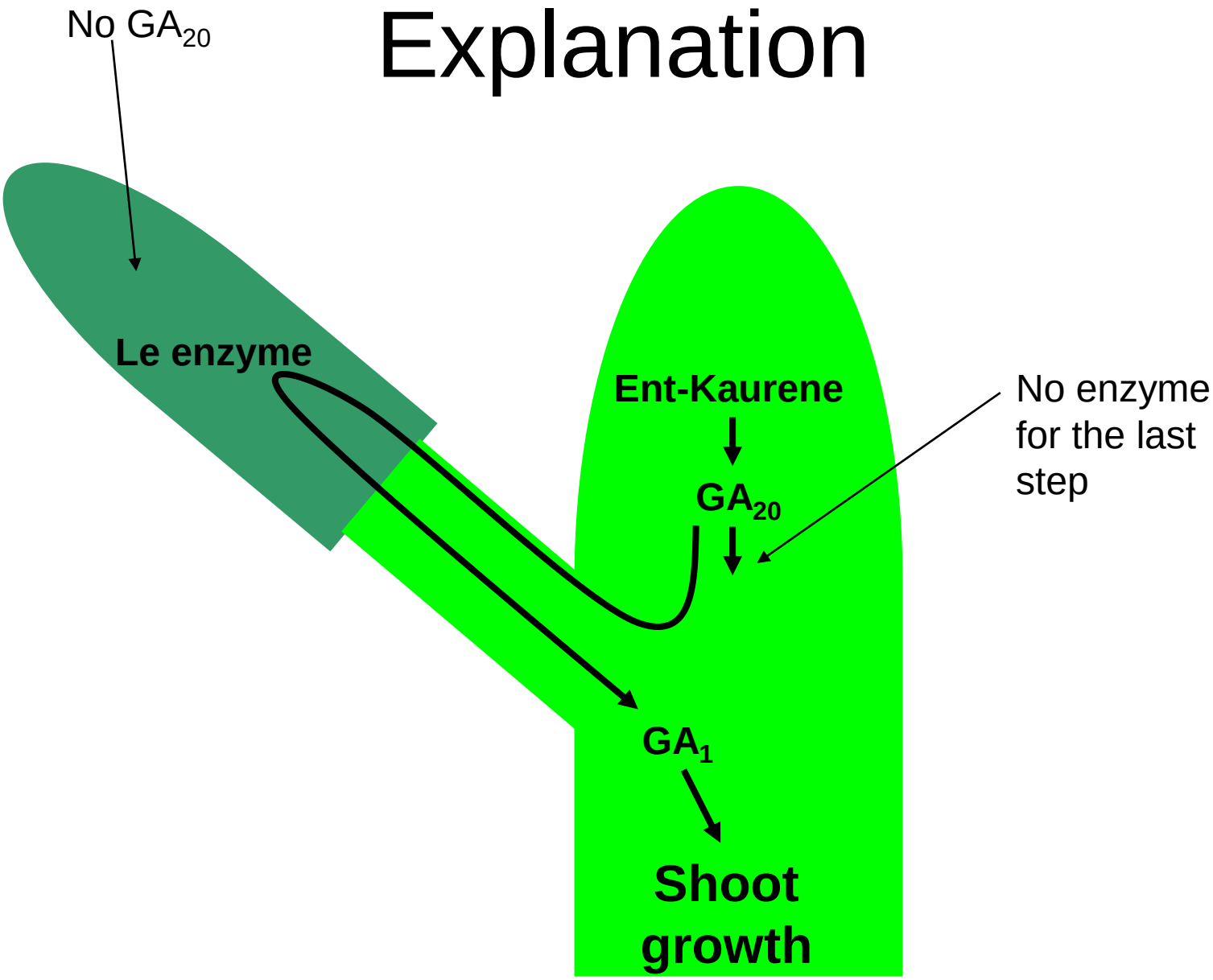
So…

- Method
  - They compared GA_1 concentrations in tall pea plants (homozygous Le) with dwarf pea plants (homozygous le).
- Observation
  - Plants with the higher GA_1 concentrations were taller.
- Possible explanation
  - It's actually GA_1 not GA_3 which causes stem growth.

- Method
  - They chose a plant with a mutation which blocks the first step in this pathway.
    - This produces no gibberellins and is short.
  - They grafted a cutting of this onto a homologous le plant (short).
- Observation
  - The hybrid plant grew tall



Explanation



We now know…

- Gibberellins cause shoot growth by:
  - Stimulating cell elongation and cell division in the internodes
    - Elongation by loosening cell walls and allowing cells to swell.
    - Division by stimulating the cell cycle.

Commercial Uses of Plant Hormones

Auxins

- Prevent leaf/fruit drop & promote flowering
  - Used by the florist industry
- Take cuttings
  - Dipping a cutting in rooting powder (auxins) encourages root growth.
- Produce seedless fruit
  - Treat unpollinated flowers to promote the growth of the ovule to produce fruit
- As a herbicide
  - Auxins promote shoot growth to such an extent that the plant cannot support itself, it buckles & dies.

Gibberellins

- Fruit production
  - Extending the time fruits can be left unpicked
  - Elongating apples to improve shape
  - Elongating grape stalks to allow grapes to grow larger.
- Brewing
  - Speeding up the germination of barley seeds
- Sugar production
  - Elongation of sugar cane internodes
- Plant breeding
  - Speeding up seed production & growth

Cytokinins

- Cytokinins inhibit senescence, & promote bud/shoot growth.
  - Prevent yellowing of lettuce leaves after picking.
  - Help to mass produce plant cuttings
    - Produces a short shoot with lots of side branches which can be separated & sold.

Ethene

- Ethene is a gas at RTP
  - So cannot be sprayed.
  - 2-chloroethylphosphonic acid is used which is absorbed by the plant & releases ethene slowly.
    - Speeds up fruit ripening
    - Speeds up fruit drop
    - Promotes female expression in cucumbers
      - Reduces self pollination
  - Ethene inhibition can also have its uses:
    - Delay fruit ripening – to allow shipping.
    - Extend the shelf life of cut flowers.