UNIT 5: PLANT RESPONSES TO THE ENVIRONMENT (INTERNAL AND EXTERNAL)

1. INTRODUCTION

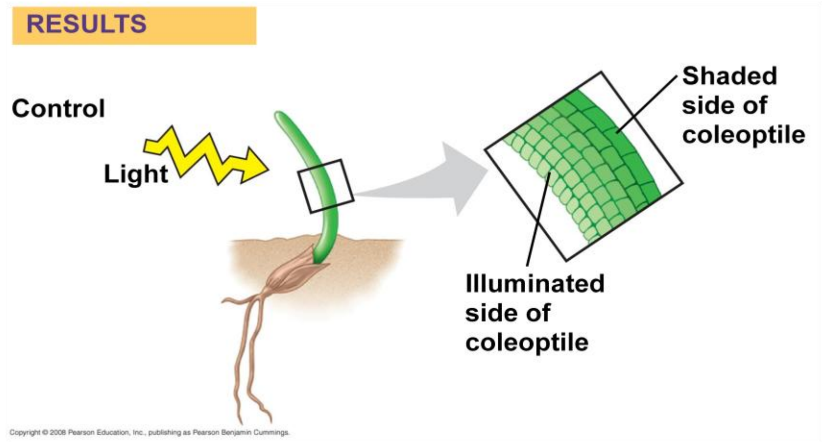
- Plants, being rooted to the ground, must respond to environmental changes that come their way.
- For example, the bending of a seedling toward light begins with sensing the direction, quantity, and color of the light.
- Plants have cellular receptors that detect changes in their environment
- For a stimulus to elicit a response, certain cells must have appropriate receptors.
- A potato left growing in darkness produces shoots that look unhealthy and lacks elongated roots
- These are morphological adaptations for growing in darkness, collectively called etiolation
- After exposure to light, a potato undergoes changes called de-etiolation, in which shoots and roots grow normally

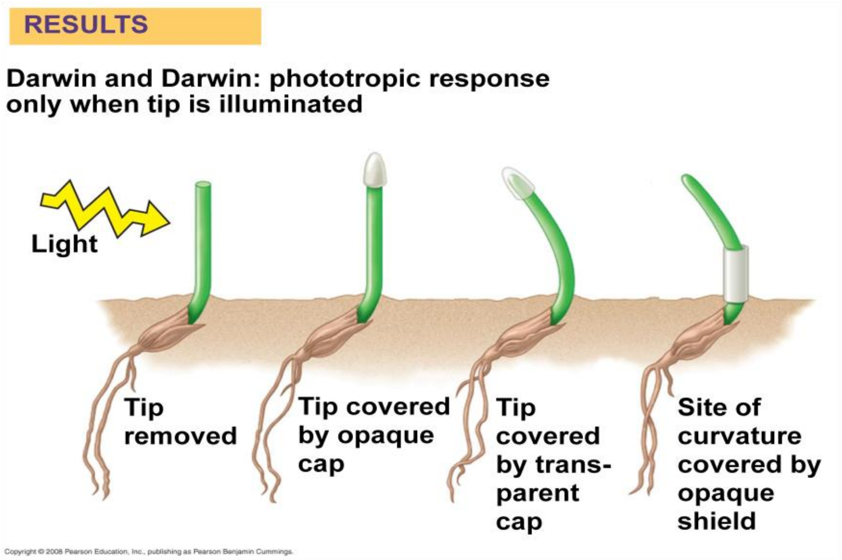
(a) Before exposure to light (b) After a week's exposure to natural daylight

2. TROPISMS AND PLANT HORMONES

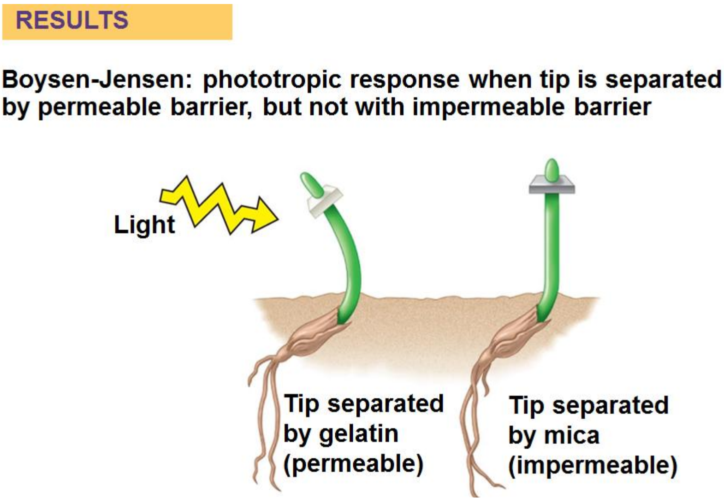
- Any response resulting in curvature of organs toward or away from a stimulus is called a tropism
- Tropisms are often caused by hormones.
- Hormones are chemical signals that coordinate different parts of an organism.
- Phototropism is a plant's response to light. Roots are negative phototropic (grow away from light) and shoots are positive phototropic (grow towards light)

- In the late 1800s, Charles Darwin and his son Francis conducted experiments on **phototropism.**
- They observed that a grass seedling could **bend toward light** only if the tip of the **coleoptile** was present
- They postulated that a **signal was transmitted from the tip to the elongating region**

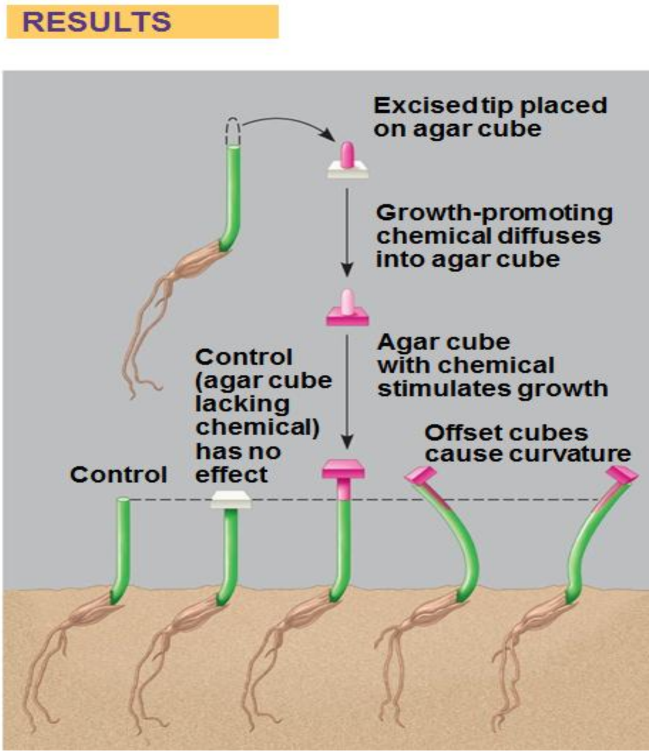




- In 1913, Peter Boysen-Jensen demonstrated that the signal was a mobile chemical substance.



- In 1926, Frits Went extracted the chemical messenger for phototropism, **auxin**, by modifying earlier experiments.



3. PLANT HORMONES

- In general, hormones control plant growth and development by affecting the division, elongation, and differentiation of cells
- Plant hormones are produced in very low concentration, but a minute amount can greatly affect growth and development of a plant organ.
- The following are plant hormones: Auxins, Cytokinins, Gibberellins, Brassinosteroids, Abscisic Acid, Ethylene.

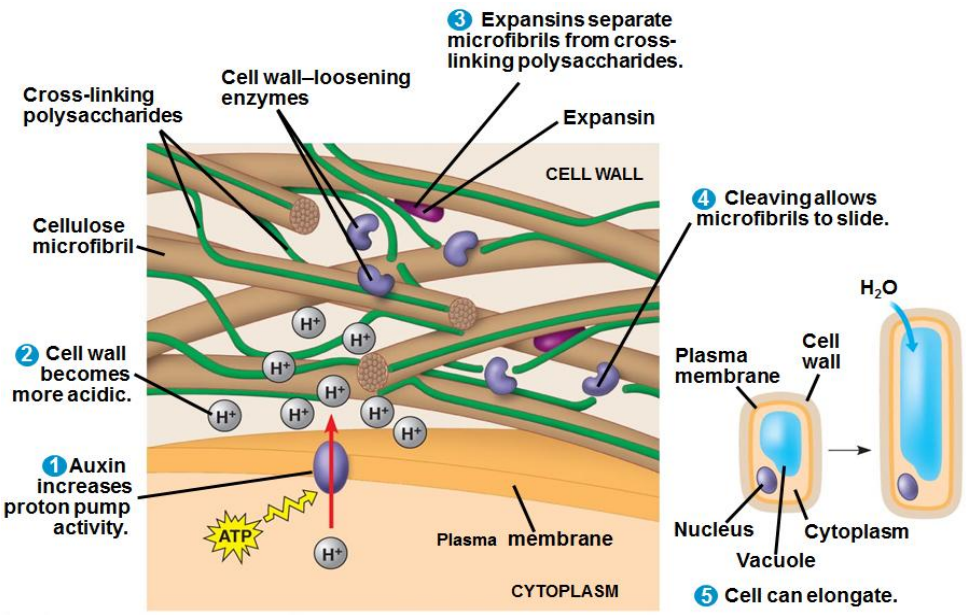
(1) AUXINS

- The term auxin refers to any chemical that promotes elongation of coleoptiles
- Indoleacetic acid (IAA) is a common auxin in plants; in this lecture the term auxin refers specifically to IAA.
- Auxin transporter proteins move the hormone from the basal end of one cell into the apical end of the neighboring cell.

The role of auxins in cell elongation

- According to the *acid growth hypothesis*, auxin stimulates proton pumps in the plasma membrane.
- The proton pumps lower the pH in the cell wall, activating expansins, enzymes that loosen the wall's fabric.
- With the cellulose loosened, the cell can elongate

Cell elongation in response to auxins: the acid growth hypothesis



Lateral and Adventitious Root Formation

- **Auxin is involved in root formation and branching.**

Auxins as Herbicides

- An overdose of synthetic auxins can kill eudicots

Other Effects of Auxin

Auxin affects secondary growth by inducing cell division in the vascular cambium and influencing differentiation of secondary xylem.

(2) CYTOKININS

- Cytokinins are so named because they stimulate cytokinesis (cell division).
- Cytokinins are produced in actively growing tissues such as roots, embryos, and fruits
- Cytokinins work together with auxin to control cell division and differentiation.

Control of Apical Dominance

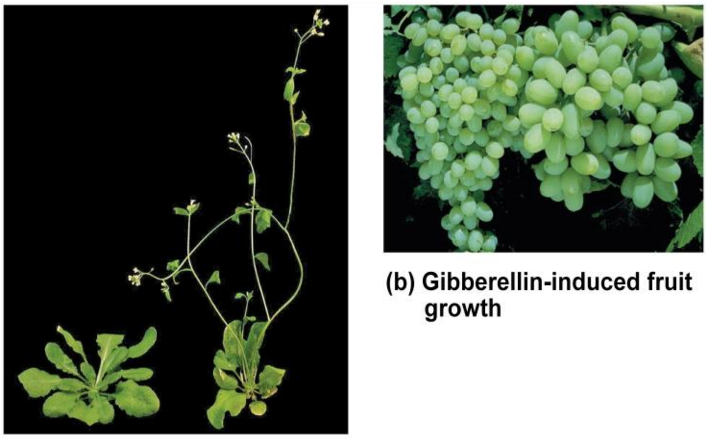
- Cytokinins, auxin, and other factors interact in the control of apical dominance, a **terminal bud's ability to suppress development of auxiliary buds**
- If the terminal bud is removed, plants become **bushier - PRUNING**

Anti-Aging Effects

- **Cytokinins** retard the aging of some plant organs by
- **inhibiting protein breakdown**,
- **stimulating RNA and protein synthesis**,
- and **mobilizing nutrients from surrounding tissues.**

(3) GIBBERELLINS

- Gibberellins have a variety of effects, such as stem elongation, fruit growth, and seed germination
- **Stem Elongation**
  - Gibberellins stimulate growth of leaves and stems
  - In stems, they stimulate cell elongation and cell division
- Fruit Growth
  - In many plants, both auxin and gibberellins must be present for fruit to set
  - Gibberellins are used in spraying of Thompson seedless grapes


(a) Gibberellin-induced stem growth

(b) Gibberellin-induced fruit growth

(4) <u>Brassinosteroids</u>

- Brassinosteroids are chemically similar to the sex hormones of animals.
- They induce cell elongation and division in stem segments.

(5) ABSICIC ACID

- Abscisic acid (ABA) slows growth
- Two of the many effects of ABA:
  - Seed dormancy
  - Drought tolerance

<u>Seed Dormancy</u>

- Seed dormancy ensures that the seed will germinate only in optimal conditions
- In some seeds, dormancy is broken when ABA is removed by heavy rain, light, or prolonged cold.

<u>Drought Tolerance</u>

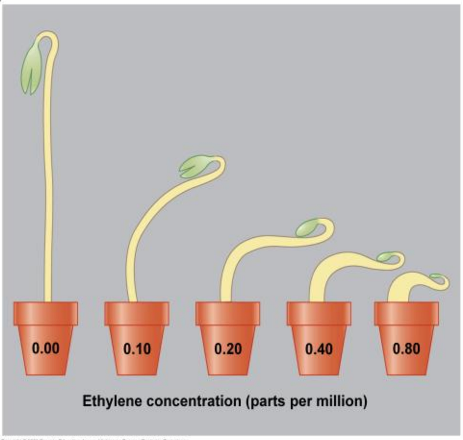
- ABA is the primary internal signal that enables plants to **withstand drought**

(6) ETHYLENE

- Plants produce ethylene in response to stresses such as drought, flooding, mechanical pressure, injury, and infection

- The effects of ethylene include response to
  - mechanical stress,
  - senescence,
  - leaf abscission, and
  - fruit ripening

Fig. 39-13



Senescence

- Senescence is the programmed death of plant cells or organs.
- A burst of ethylene is associated with apoptosis, the programmed destruction of cells, organs, or whole plants

Leaf Abscission

- A change in the balance of auxin and ethylene controls leaf abscission, the process that occurs in **autumn when a leaf falls.**

Fruit Ripening

- A burst of ethylene production in a fruit **triggers the ripening process.**

4. RESPONSES TO LIGHT

- Light cues many key events in plant growth and development.
- Effects of light on plant morphology are called photomorphogenesis.
- There are two major classes of light receptors: blue-light photoreceptors and phytochromes.
- Various blue-light photoreceptors control:

– hypocotyl elongation,

– stomatal opening, and

– phototropism

Phytochromes as Photoreceptors

- Phytochromes are **pigments that regulate many of a plant's responses to light** throughout its life
- These responses include **seed germination and shade avoidance**

Phytochromes and Seed Germination

- Many seeds remain dormant until light conditions change.
- **Red light increased germination**, while **far-red light inhibited germination.**
- The photoreceptor responsible for the opposing effects of red and far-red light is a **phytochrome.**

Biological Clocks and Circadian Rhythms

- Many plant **processes oscillate** during the day
- Many **legumes lower their leaves in the evening and raise them in the morning**, even when kept under constant light or dark conditions.
- **Circadian rhythms** are cycles that are about **24 hours** long and are governed by an internal "clock".

5. Photoperiodism and Responses to Seasons

- **Photoperiod**, the **relative lengths of night and day**, is the environmental stimulus plants use most often to detect the **time of year**.
- **Photoperiodism** is a physiological response to photoperiod.
- Some processes, including flowering in many species, require a certain photoperiod
- Plants that flower when a light period is shorter than a critical length are called **short-day plants.**
- Plants that flower when a light period is longer than a certain number of hours are called **long-day plants.**

- Flowering in **day-neutral plants** is **controlled by plant maturity**, not photoperiod.

6. PLANTS RESPOND TO A WIDE VARIETY OF STIMULI OTHER THAN LIGHT

- Because of immobility, plants must adjust to a range of environmental circumstances.

1. **Gravity**: Response to gravity is known as **gravitropism**

Roots show **positive gravitropism**; **shoots** show **negative gravitropism**

Environmental stressors:

- Environmental stresses have a potentially adverse effect on survival, growth, and reproduction
- Stresses can be abiotic (nonliving) or biotic (living)
- Abiotic stresses include drought, flooding, salt stress, heat stress, and cold stress
- During **drought**, plants reduce transpiration by closing stomata, slowing leaf growth, and reducing exposed surface area
- Growth of shallow roots is inhibited, while deeper roots continue to grow.
- **Excessive heat** can denature a plant's enzymes
- Heat-shock proteins help protect other proteins from heat stress

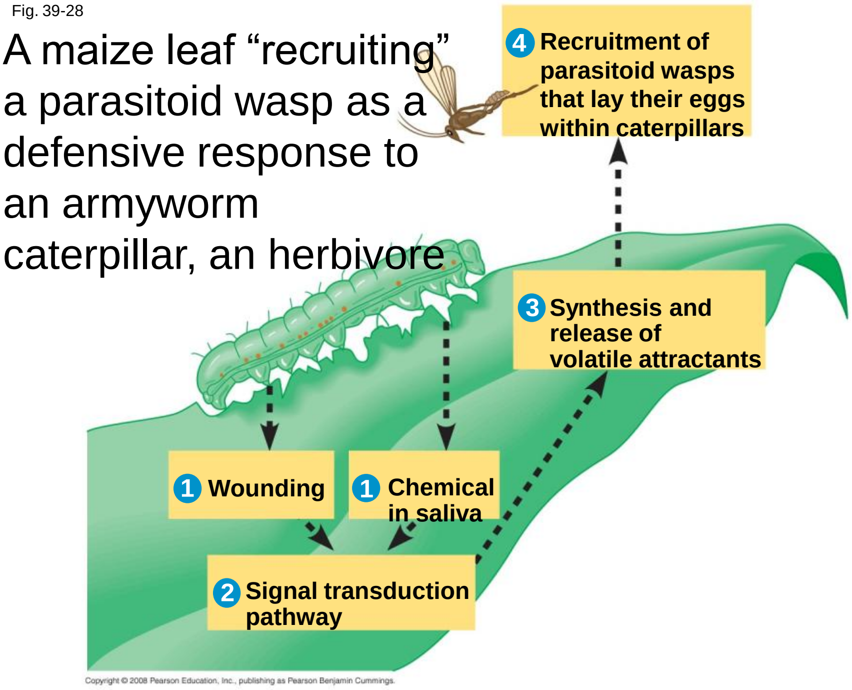
7. PLANTS RESPOND TO ATTACKS BY HERBIVORES AND PATHOGENS

- Plants use defense systems to:
  - deter herbivory,
  - prevent infection, and
  - combat pathogens

Defences against herbivores

- Herbivory, animals eating plants, is a stress that plants face in any ecosystem,
- Plants counter excessive herbivory with physical defenses such as **thorns and chemical defenses** such as **distasteful or toxic compounds**

- Some plants even **“recruit” predatory animals** that help defend against specific herbivores.



Defences against pathogens

- A plant’s first line of defense against infection is the epidermis and periderm.
- If a pathogen penetrates the dermal tissue, the second line of defense is a chemical attack that kills the pathogen and prevents its spread.
- This second defense system is enhanced by the inherited ability to recognize certain pathogens.
- A **virulent** pathogen is one that a plant has little specific defense against.
- An **avirulent** pathogen is one that may harm but does not kill the host plant.