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Introduction

Development and Germination

- Development = Growth + Differentiation.
- Mature plant develops from zygote via ordered events forming roots, leaves, branches, flowers, fruits, seeds.
- Development controlled by intrinsic (internal) and extrinsic (external) factors.
- Seed germination activates embryo growth into seedling under favorable conditions.
- Types of germination: Epigeal (cotyledons above soil), Hypogeal (cotyledons below soil).
- Photoblastic seeds require light to germinate.
- Seed viability = capacity to germinate and develop.
- Favorable conditions: water, oxygen, suitable temperature, food, growth regulators, rest period completion.
- Unfavorable conditions cause suspended growth until favorable.

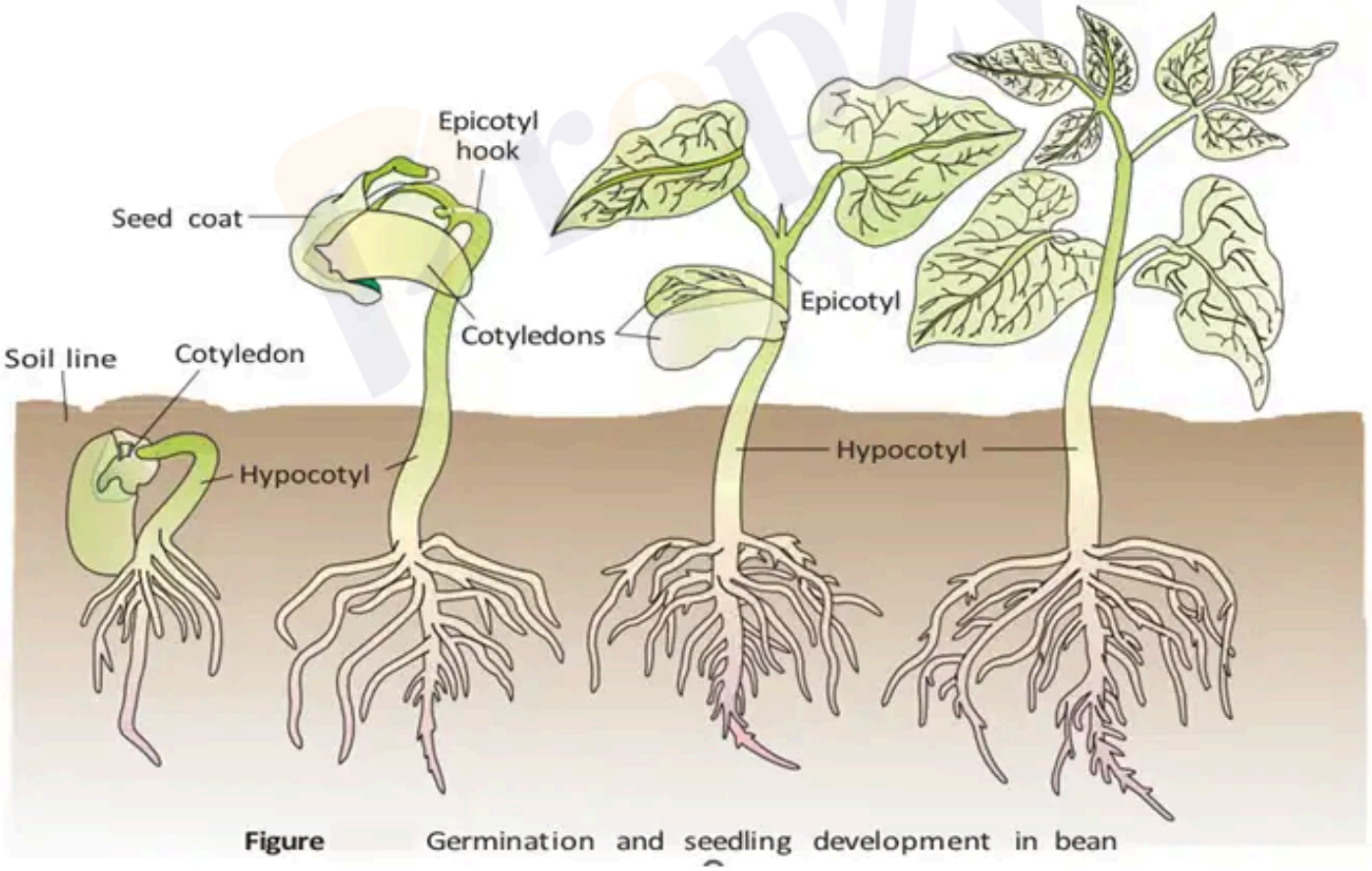


Figure Germination and seedling development in bean

Memory Aids

- Development = Growth + Differentiation.
- Epigeal = cotyledons emerge; Hypogeal = cotyledons stay underground.
- Photoblastic seeds need light.

Quick Checkpoints

- What are the two components of development?
- Difference between epigeal and hypogeal germination?
- What conditions favor seed germination?

Growth

Definition and Types

- Growth = irreversible permanent increase in size of organ, part, or cell.
- Accompanied by metabolic processes using energy.
- Plant growth is indeterminate (continuous) in higher plants via meristems.
- Open form of growth: new cells added by meristem activity.
- Primary growth: elongation by apical and intercalary meristems.
- Secondary growth: increase in girth by lateral meristems (vascular cambium, cork cambium).
- Growth measurable by fresh/dry weight, length, area, volume, cell number.
- Examples: maize root apical meristem produces 17,500+ cells/hour; watermelon cells enlarge 350,000 times.

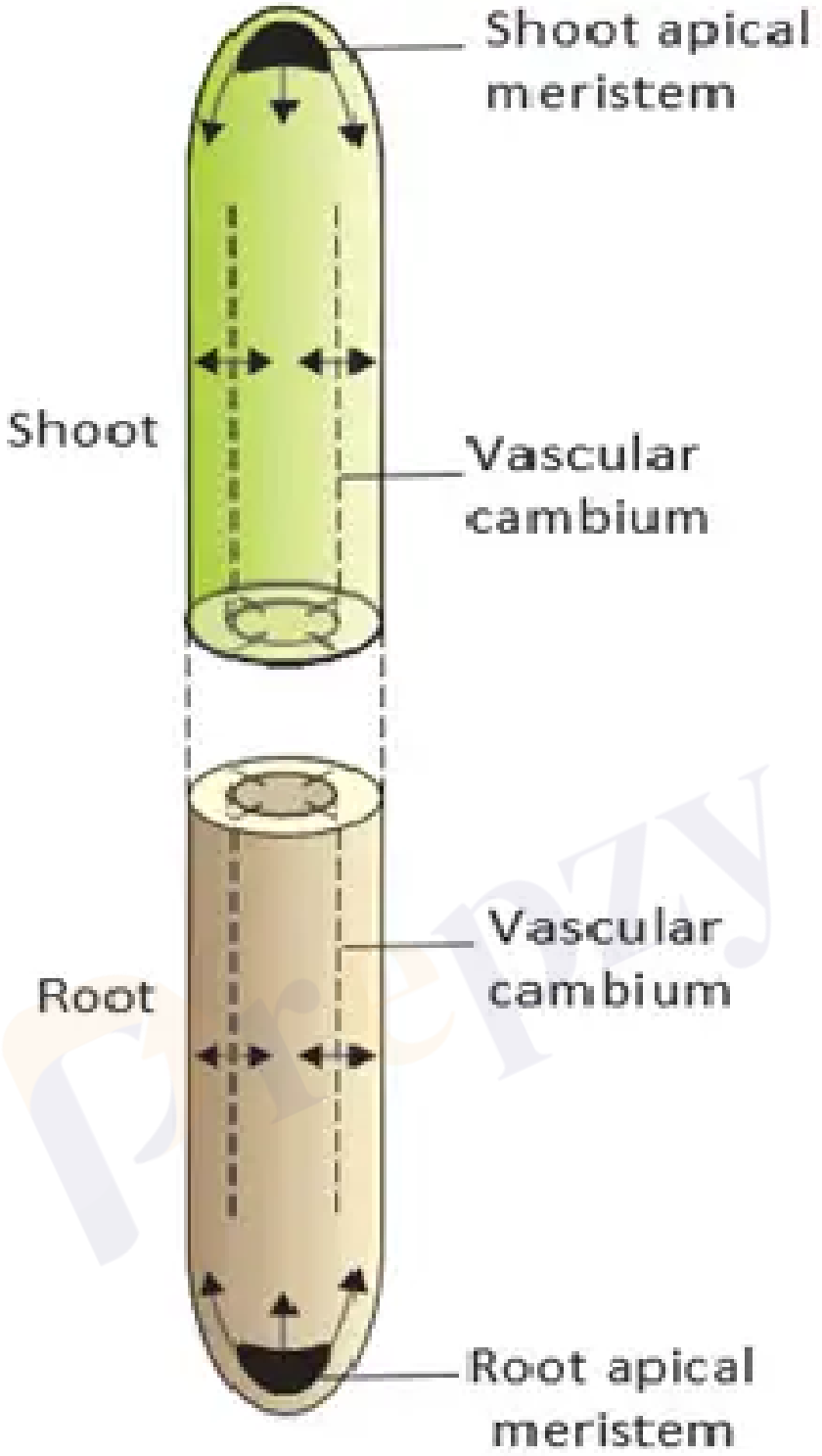


Figure Diagrammatic representation of locations of root apical meristem, shoot aplical meristem and vascular cambium. Arrows exhibit the direction of growth of cells and organ

Memory Aids

- Growth = size increase + metabolism.
- Primary = length; Secondary = girth.
- Meristems drive growth.

Quick Checkpoints

- Define growth in plants.
- What is primary vs secondary growth?
- Role of meristems in growth?

Phases of Growth

Growth Phases

- Meristematic phase: active cell division, high biosynthesis, thin primary walls.
- Elongation phase: cells enlarge, vacuolation increases, new wall deposition.
- Differentiation/maturation phase: cells specialize, wall thickening, protoplasm modification.

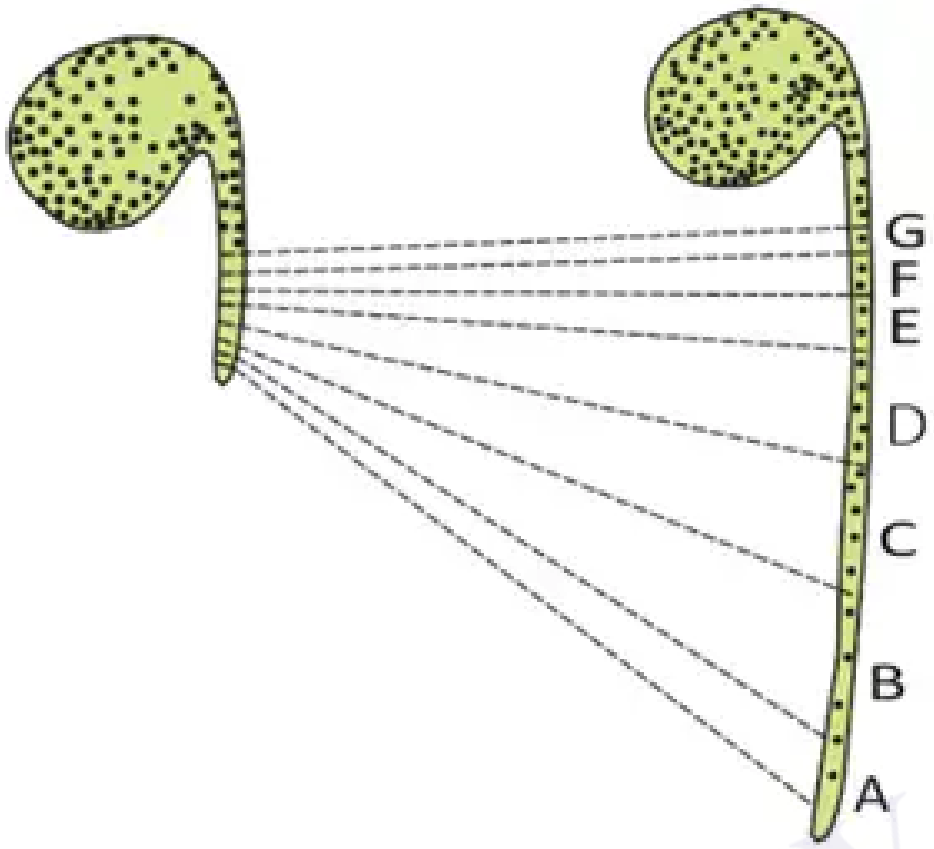


Figure Detection of zones of elongation by the parallel line technique. Zones A, B, C, D immediately behind the apex have elongated most.

Memory Aids

- Meristematic = divide; Elongation = enlarge; Differentiation = specialize.

Quick Checkpoints

- What happens in meristematic phase?
- How do cells change in elongation phase?
- What defines differentiation phase?

Growth Rates

Types and Measurement

- Growth rate = increase in growth per unit time.
- Arithmetic growth: one daughter cell divides, other differentiates; linear increase.
- Geometrical growth: both daughter cells divide; exponential increase; shows lag, log, stationary phases.
- Sigmoid (S-curve) growth typical in natural conditions.
- Growth expressed as absolute growth rate (total growth/time) and relative growth rate (growth per unit initial size/time).

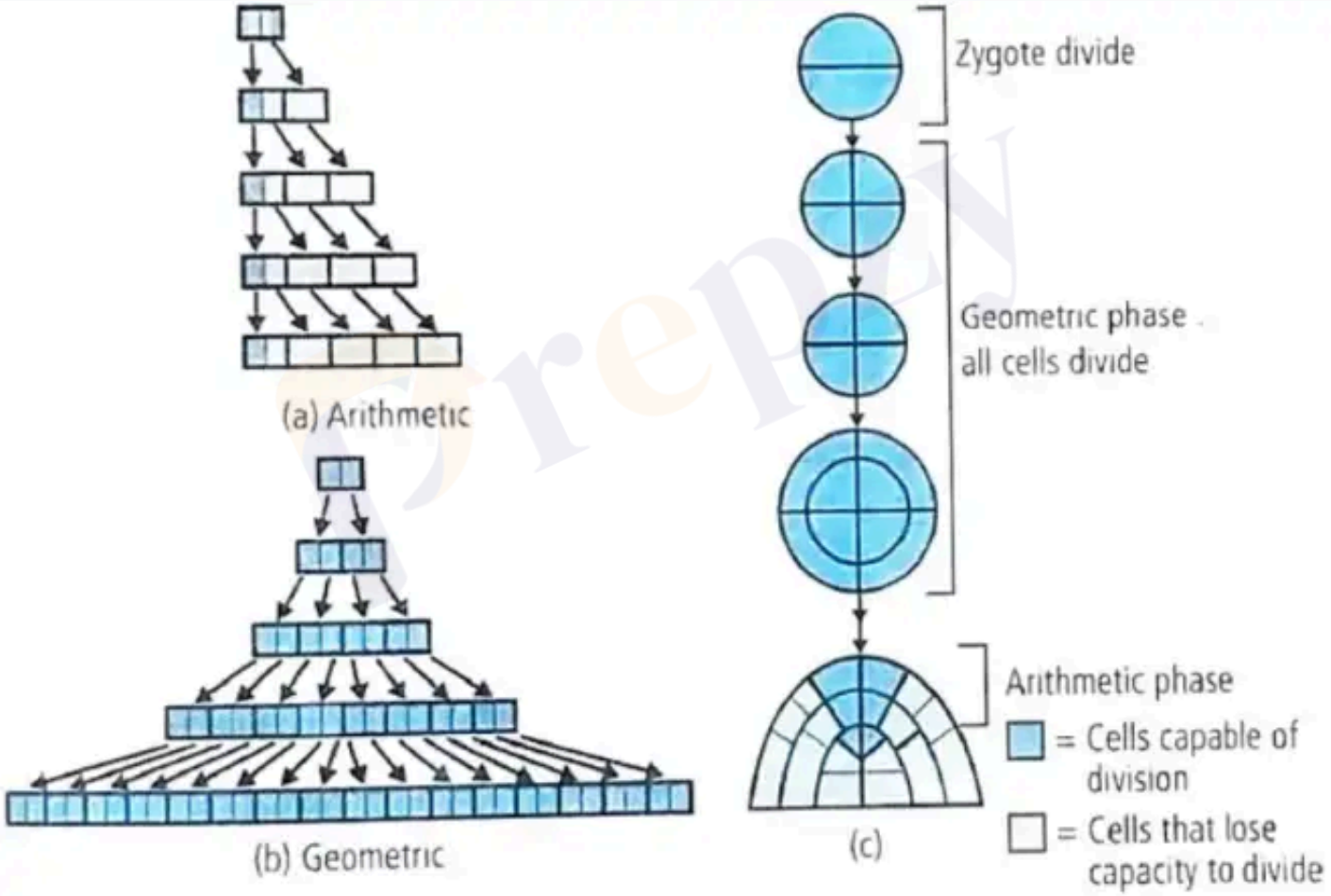


Fig.: Diagrammatic representation of (a) Arithmetic (b) Geometric growth and (c) Stages during embryo development showing geometric and arithmetic phases

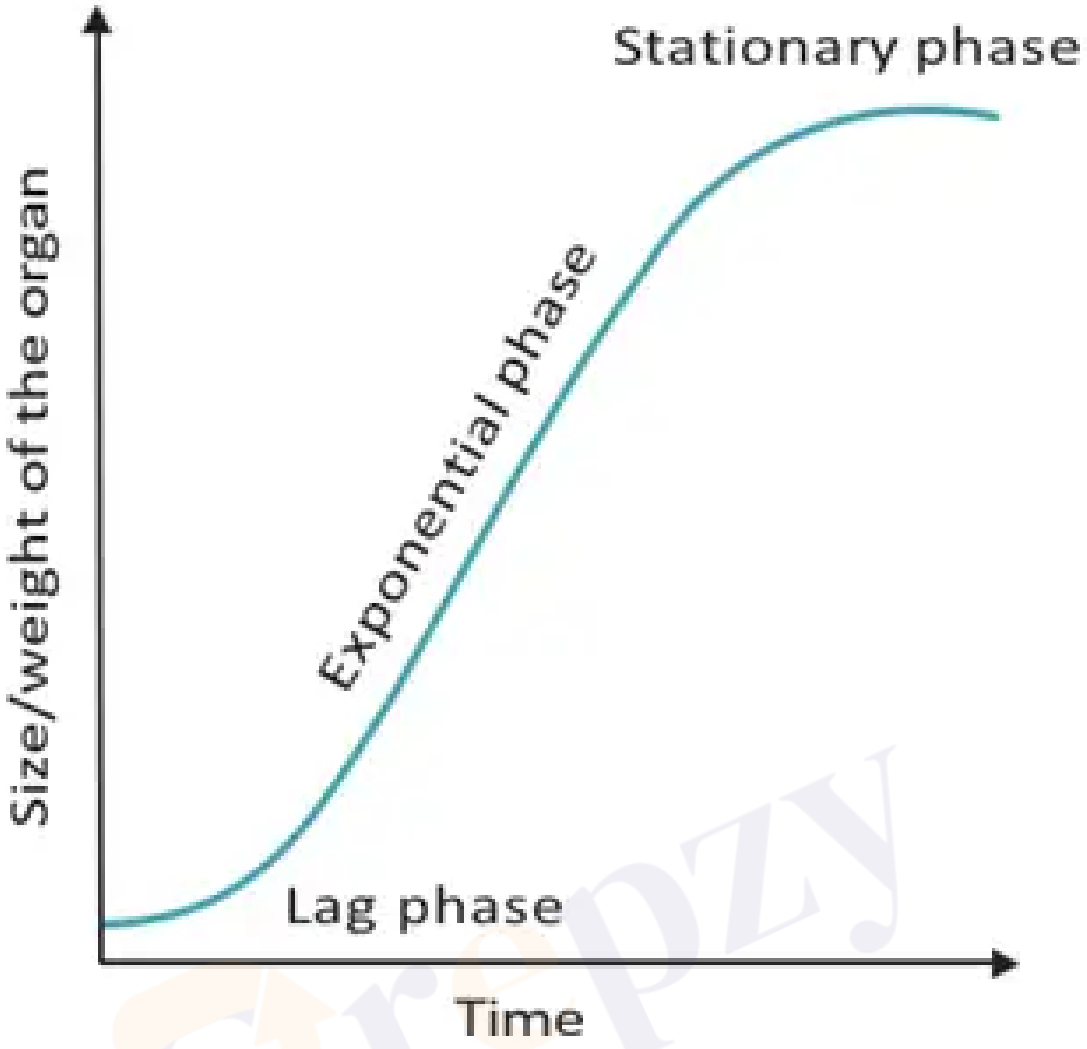


Figure An idealised sigmoid growth curve typical of cells in culture, and many higher plants and plant organs

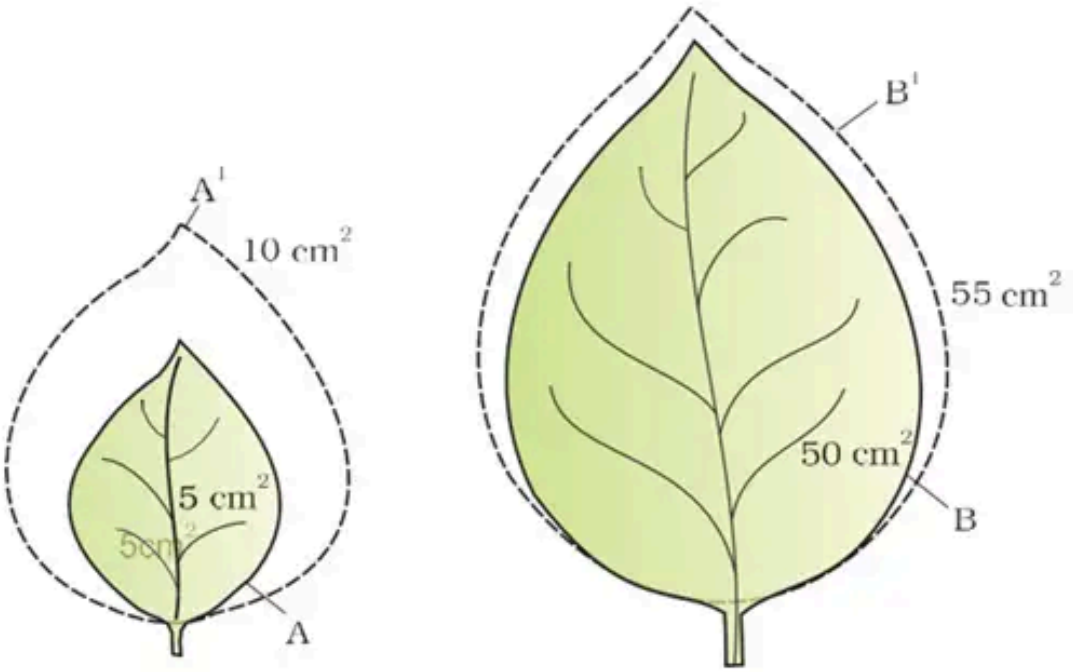


Figure Diagrammatic comparison of absolute and relative growth rates. Both leaves A and B have increased their area by 5 cm^2 in a given time to produce A^1, B^1 leaves.

Memory Aids

- Arithmetic = linear growth; Geometrical = exponential growth.
- Absolute growth rate = total growth/time.
- Relative growth rate = growth per unit initial size/time.
- S-curve = lag, log, stationary phases.

Quick Checkpoints

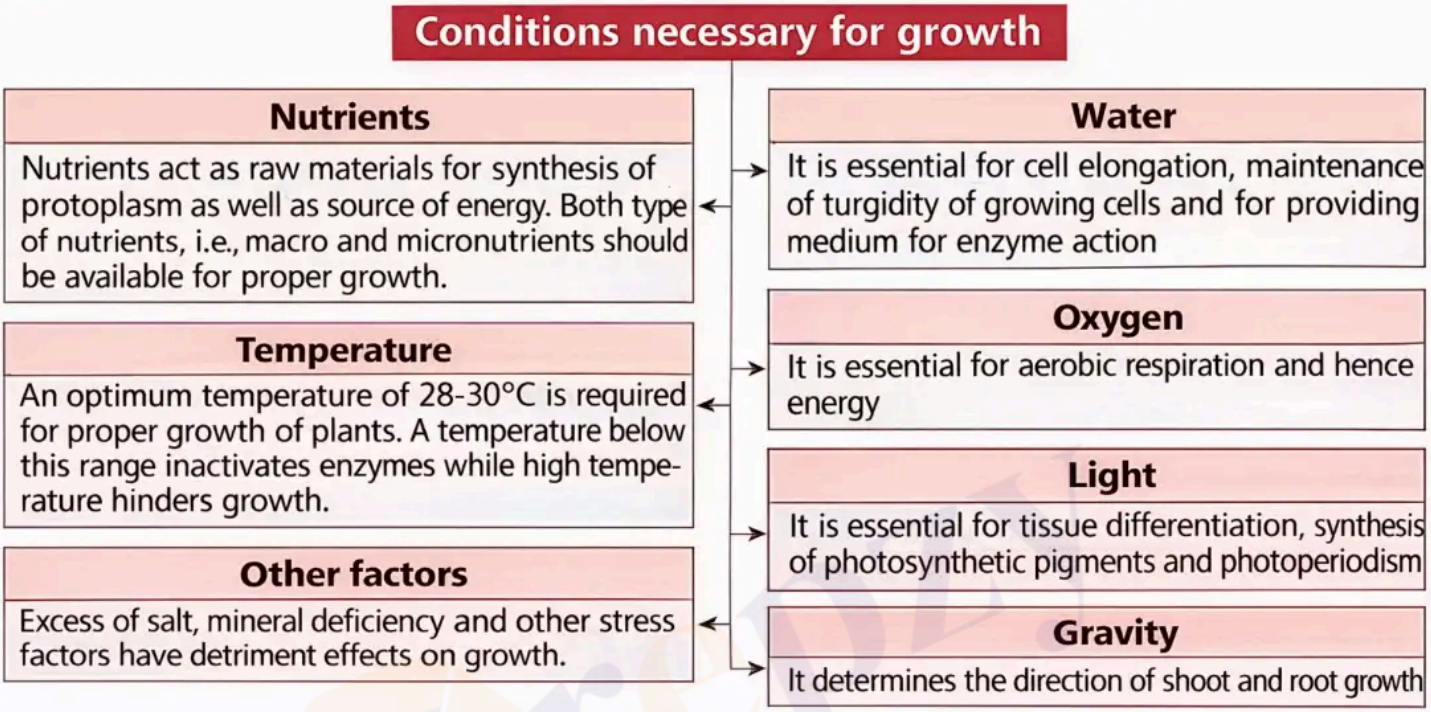
- Difference between arithmetic and geometrical growth?
- What phases are in sigmoid growth curve?
- Define absolute and relative growth rates.

Conditions for Plant Growth

Essential Factors

- Nutrients: macro and micronutrients for cell building and energy.

- Water: maintains cell turgor, enzyme function, growth.
- Temperature: optimal 28-30°C; extremes inhibit growth.
- Oxygen: required for respiration and energy production.
- Light: needed for pigment synthesis and growth regulation.
- Gravity: guides root and shoot orientation.
- Other factors: salt concentration and mineral availability affect growth.



Memory Aids

- Water, nutrients, light, oxygen, temperature, gravity essential.
- Optimal temperature 28-30°C.

Quick Checkpoints

- List key factors for plant growth.
- Why is water important for growth?
- How does gravity affect plant growth?

Differentiation, Dedifferentiation and Redifferentiation

Differentiation

- Permanent qualitative changes in cell structure, chemistry, and physiology.
- Occurs by activation or repression of specific genes.
- Example: Tracheary elements lose protoplasm and develop strong lignocellulosic secondary walls for water conduction.

Dedifferentiation

- Despecialisation of differentiated cells to regain division capacity.
- Dedifferentiated tissues act as meristems (e.g., interfascicular vascular cambium, cork cambium, wound cambium).
- In culture, parenchyma cells dedifferentiate to form callus (mass of dividing cells).

Redifferentiation

- Specialisation of cells derived from dedifferentiated meristems.
- Similar to differentiation by primary meristems.
- Forms secondary tissues like secondary phloem, secondary xylem, cork, and secondary cortex.

Commitment or Determination

- Same apical meristem cells produce different cell types (xylem, phloem, parenchyma, sclerenchyma, fibres, collenchyma).
- Determined by location and specific signals received.
- Example: Cells distal to root apical meristem form root cap; peripheral cells form epidermis, cortex, endodermis, pericycle, vascular tissues.

Memory Aids

- Differentiation = Permanent specialization.
- Dedifferentiation = Reversal to division-capable state.
- Redifferentiation = New specialization after dedifferentiation.
- Commitment = Location-based cell fate decision.

Quick Checkpoints

- What triggers differentiation in cells?
- How does dedifferentiation enable tissue regeneration?
- What tissues form by redifferentiation?
- What determines different cell types from the same meristem?

Development

Concept and Process

- Development is a sequence of changes in structure and function of an organism, organ, tissue, or cell.
- Includes formation, growth, differentiation, maturation, reproduction, senescence, and death.
- Plant stages: seed germination, seedling, juvenile, maturation, flowering, seed formation, senescence.
- Phase conversion (e.g., leaf initiation to expansion) is also development.
- Occurs at cellular level (e.g., chloroplast appearance in sunlight-exposed cells).
- Development ends in senescence and death.
- Controlled by intrinsic factors (genes, growth regulators) and extrinsic factors (light, temperature, water, oxygen, nutrition).
- Development pathways vary with environment and life phases, showing plasticity.
- Plasticity example: heterophylly—different leaf forms in juvenile vs mature plants or air vs water leaves.

Memory Aids

- Development = Formation + Growth + Differentiation + Maturation + Senescence + Death
- Plasticity = Ability to form different structures based on environment or growth phase
- Heterophylly = Different leaf shapes in one plant

Quick Checkpoints

- What stages are included in development?
- How do intrinsic and extrinsic factors influence development?
- Define plasticity in plant development.
- Give examples of heterophylly.

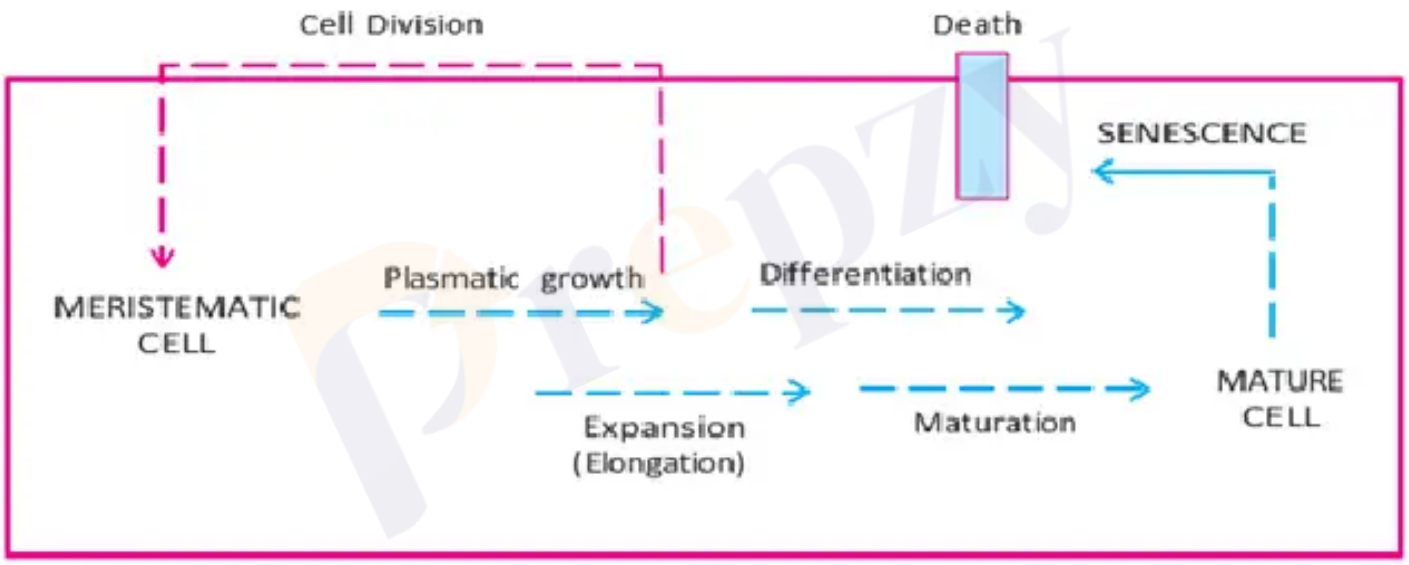


Figure Sequence of the developmental process in a plant cell

Development Sequence in Plant Cell

- Starts with meristematic cell capable of division.
- Cell divides to form new cells.
- Cells grow in size (plasmatic growth).
- Cells differentiate to become specialized.
- Cells expand or elongate.
- Cells mature into fully developed cells.
- Mature cells age (senescence).
- Cells die naturally at cycle end.

Memory Aids

- Meristematic cell → Division → Growth → Differentiation → Expansion → Maturation → Senescence → Death

Quick Checkpoints

- What is the first stage of cell development?
- What happens after cell division?
- Define senescence in cells.

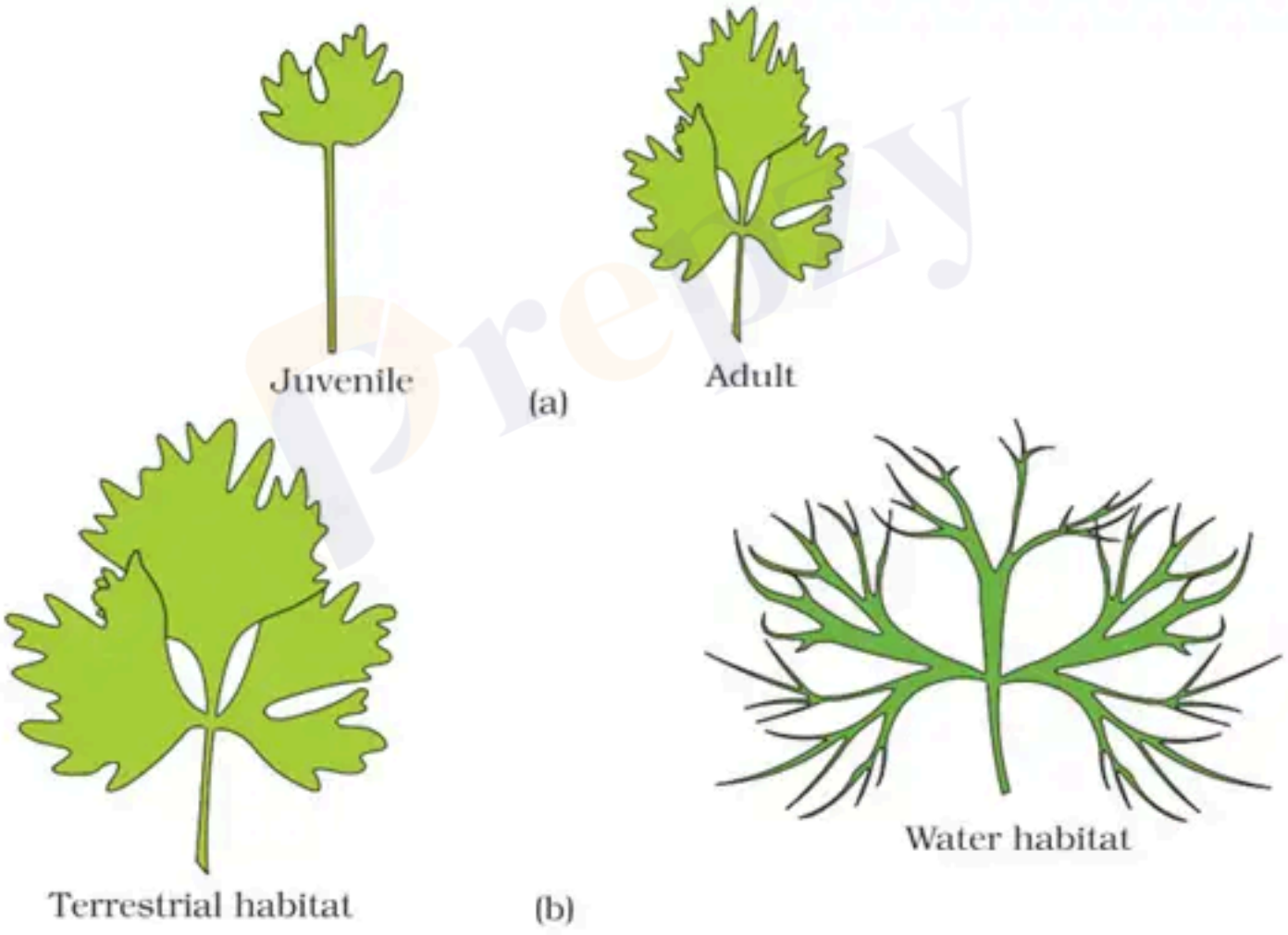


Figure Heterophylly in (a) larkspur and (b) buttercup

Heterophylly Examples

- *Larkspur*: juvenile leaves are simple; adult leaves are complex.
- *Buttercup*: leaf shape varies by habitat—broad flat leaves on land, divided finely branched leaves in water.
- Shows plant adaptation to growth stages and environment.

Memory Aids

- Heterophylly = Different leaf types on one plant
- Environmental heterophylly = Leaf shape changes with habitat

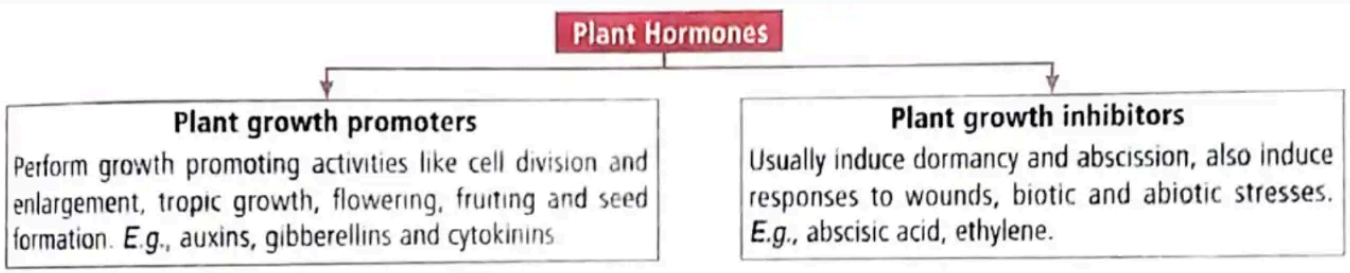
Quick Checkpoints

- What is heterophylly?
- How does *Buttercup* leaf shape change with environment?
- Give an example of heterophylly in *Larkspur*.

Plant Growth Regulators

Overview

- Plant growth regulators (PGRs) are small molecules regulating growth, differentiation, and development in plants.
- Also called plant hormones or phytohormones.
- Produced naturally, active in low concentrations, and translocated to target regions.
- Divided into plant growth promoters and inhibitors based on function.



Memory Aids

- Promoters: Auxins, Gibberellins, Cytokinins.
- Inhibitors: Abscisic Acid, Ethylene.

Quick Checkpoints

- What are phytohormones?
- Difference between growth promoters and inhibitors?

Auxins

Characteristics and Discovery

- Weakly acidic hormones with unsaturated ring structure.
- Natural auxins: Indole-3-acetic acid (IAA), Indole-3-butyric acid (IBA).
- Synthetic auxins: NAA, 2,4-D, MCPA.
- Discovered by Darwin (1880) and E.W. Went (1928) via coleoptile experiments.
- Auxin moves basipetally (tip to base).
- IAA synthesized from tryptophan.
- Bioassays: Avena curvature test, root growth inhibition test.

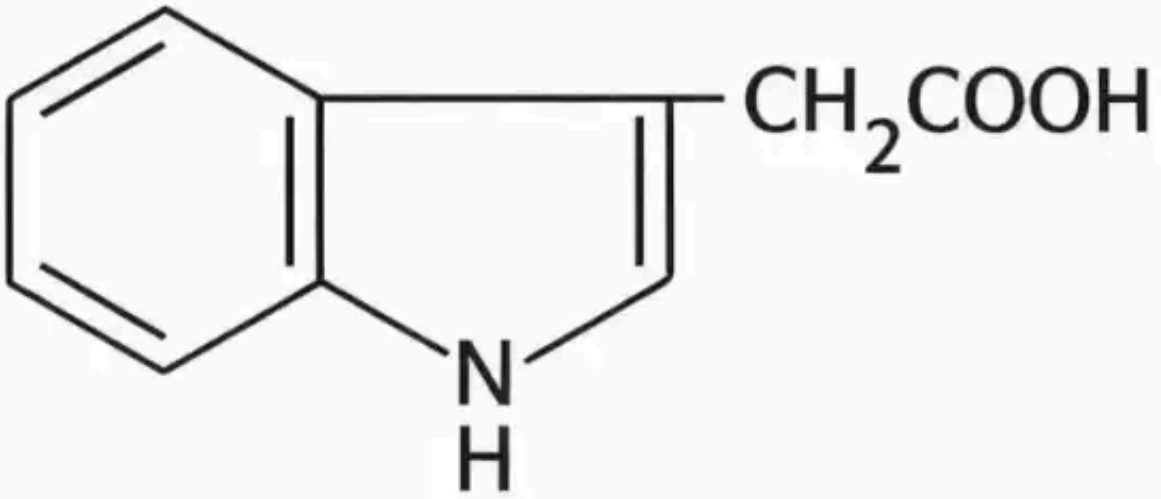


Fig.: Structure of indole acetic acid (IAA)

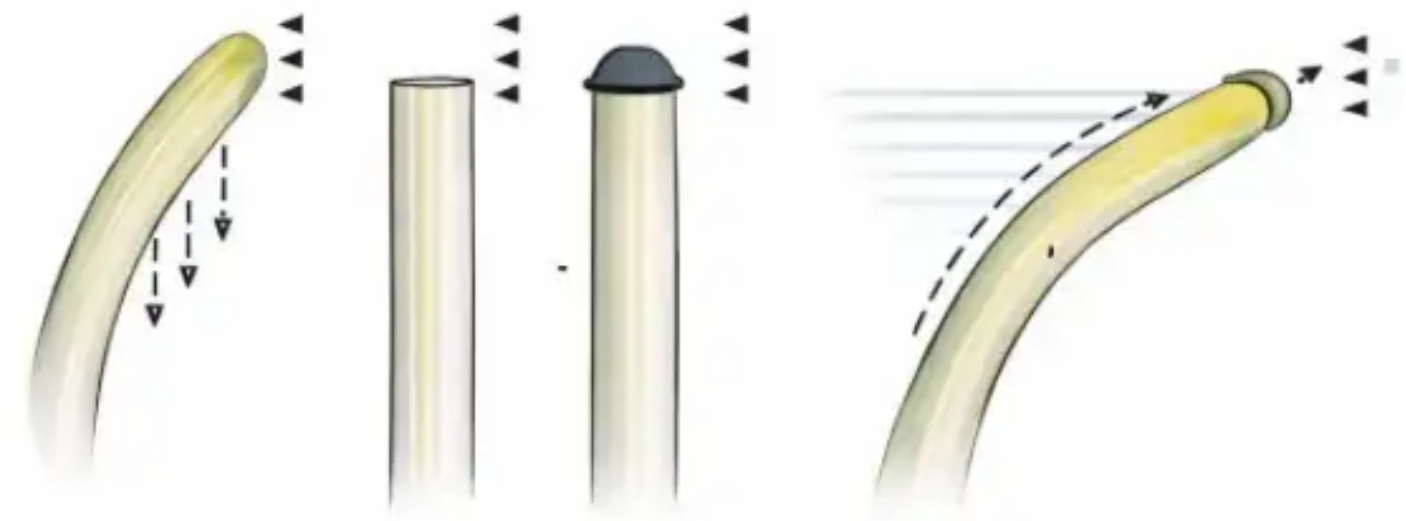


Fig.: Experiment used to demonstrate that tip of the coleoptile is the source of auxin (Arrows indicate direction of IAA)

Memory Aids

- Auxin = "Apex Up" (promotes apical dominance).
- IAA = Indole ring + Acetic acid group.

Quick Checkpoints

- What is the role of auxins in apical dominance?
- How does auxin affect root growth?

Physiological functions

Auxin Effects

- Stimulates cell division in cambium and elongation in shoots.
- Induces early xylem and phloem differentiation.
- Initiates rooting in stem cuttings; inhibits root growth at high concentration.
- Inhibits axillary bud growth; promotes apical dominance.

- Decapitation overcomes apical dominance (used in tea plantations, hedge making).
- Promotes flowering in pineapples and early fruit formation.
- Retards senescence and early abscission; promotes abscission in mature organs.
- Induces parthenocarpy (e.g., tomato) and feminizing effect in some plants.
- Synthetic auxins (2,4-D, 2,4,5-T) act as selective herbicides.
- Differential auxin distribution causes phototropism and geotropism.
- Stimulates respiration and metabolism by mobilizing resources.

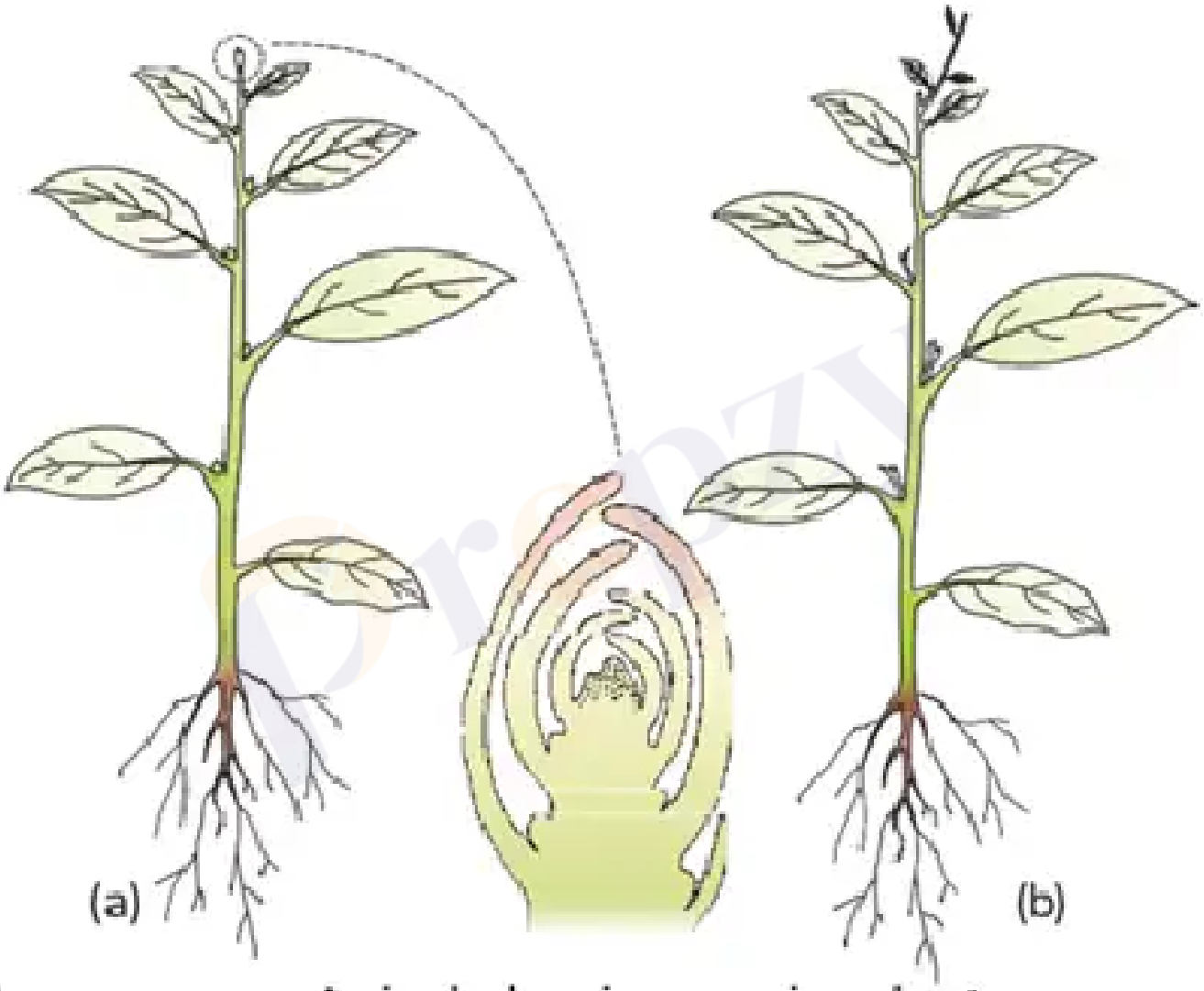


Figure Apical dominance in plants :
(a) A plant with apical bud intact
(b) A plant with apical bud removed
Note the growth of lateral buds into branches after decapitation.

Memory Aids

- Auxin promotes "Apex Dominance" and rooting.
- 2,4-D = selective dicot weed killer.

Quick Checkpoints

- How does auxin regulate apical dominance?
- What is the effect of auxin on senescence?

Gibberellins

Characteristics and Discovery

- Weakly acidic hormones with gibberellin ring structure.
- Discovered by Kurosawa (1926) from *Gibberella fujikuroi* fungus.
- GA_3 is the most studied gibberellin.
- Produced in apical shoot buds, young leaves, root tips, developing seeds.
- Synthesized from mevalonic acid (acetyl Co-A derivative).
- Transported by diffusion and conducting channels.
- Bioassays: Barley endosperm test, dwarf pea test.

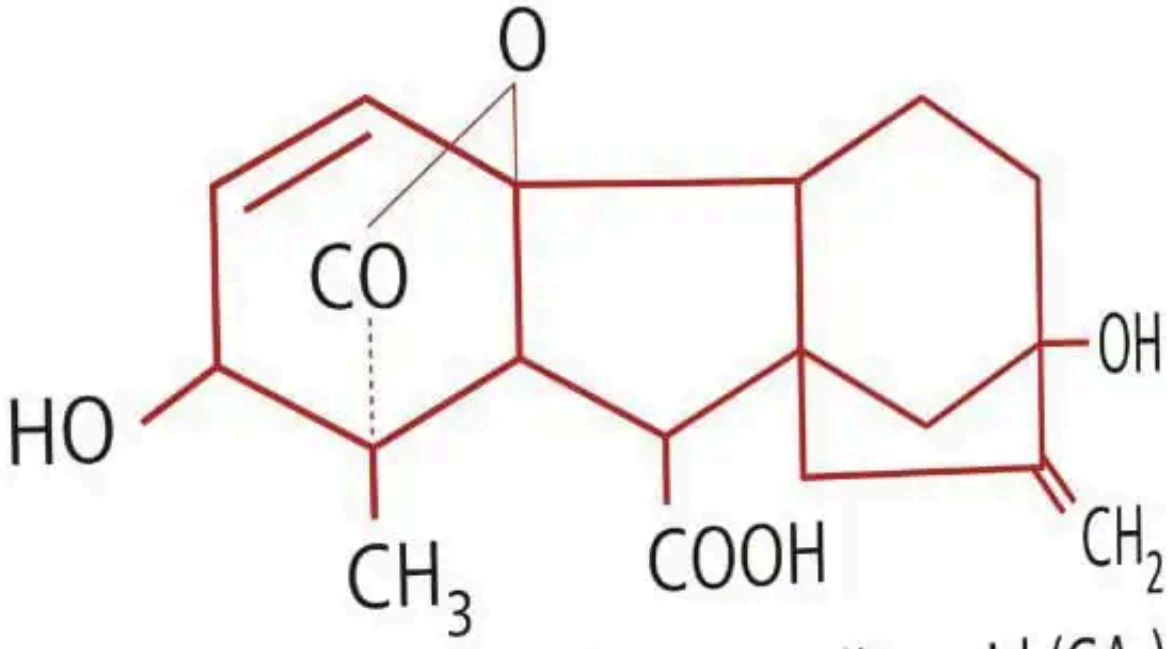


Fig.: Structure of gibberellic acid (GA_3)

Memory Aids

- GA = "Grow Axis" (promotes stem elongation).
- GA_3 overcomes dwarfism and dormancy.

Quick Checkpoints

- How does GA_3 affect seed germination?
- What is bolting in plants?

Physiological functions

Gibberellin Effects

- Enhances seed germination by increasing α-amylase synthesis, overcoming dormancy.
- Induces seed germination even in dark (photoblastic seeds).

- Causes bolting (rapid internode elongation) in rosette plants.
- Overcomes genetic dwarfism (e.g., maize, pea).
- Promotes maleness in female plants.
- Delays senescence, extending fruit market period.
- Used in malting industry to speed up process.
- Improves fruit shape and stalk length (e.g., grapes, apples).
- Increases sugarcane stem length and yield.
- Hastens maturity and seed production in juvenile conifers.

Memory Aids

- GA = "Germination Activator".
- Bolting = GA-induced stem elongation.

Quick Checkpoints

- What role does gibberellin play in dormancy?
- How does GA affect fruit development?

Cytokinins

Characteristics and Discovery

- Basic hormones derived from aminopurine or phenyl urea promoting cytokinesis.
- Discovered by F. Skoog et al. observing callus proliferation with yeast extract and DNA.
- Kinetin (synthetic) discovered from degraded herring sperm DNA.
- Natural cytokinin: Zeatin from unripe maize grains and coconut milk.
- Found in regions of rapid cell division: root apices, shoot buds, young fruits.
- Bioassays: Tobacco pith culture, leaf senescence retardation, radish cotyledon expansion.

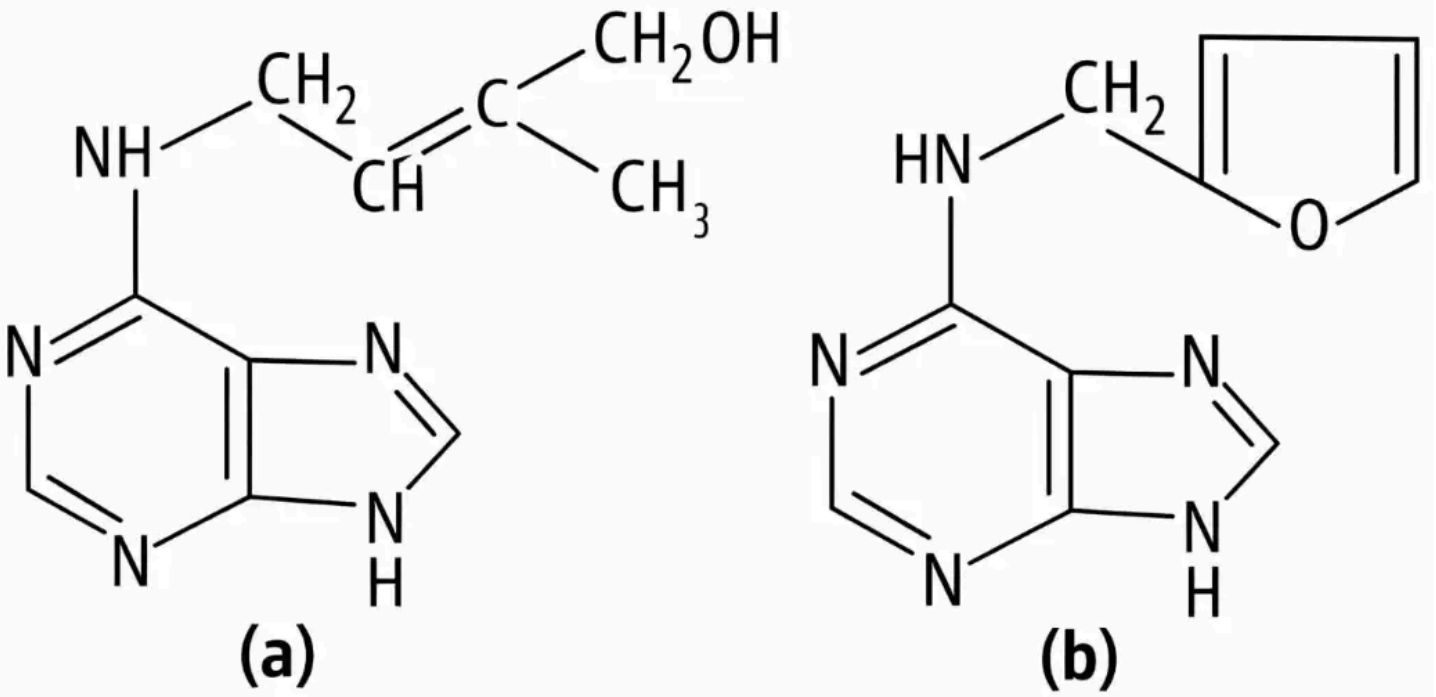


Fig.: Structure of (a) Zeatin (b) Kinetin

Memory Aids

- Cytokinins = "Cell Kick-starters" (promote division).
- Zeatin and Kinetin are key cytokinins.

Quick Checkpoints

- Where are cytokinins mainly found?
- How do cytokinins affect apical dominance?

Physiological functions

Cytokinin Effects

- Enhances cell division and morphogenesis.
- Increases seedling width and promotes new leaves and chloroplast formation.
- Stimulates lateral and adventitious shoot growth.
- Overcomes apical dominance.

- Induces femaleness in male plants.
- Retards senescence (Richmond-Lang effect) and abscission.
- Increases mobilization of food materials.
- Prolongs life of cut shoots and flowers; keeps vegetables fresh.

Memory Aids

- Cytokinins = "Cell division and delay senescence".

Quick Checkpoints

- What is the role of cytokinins in senescence?
- How do cytokinins influence shoot growth?

Ethylene

Characteristics and Discovery

- Only gaseous phytohormone.
- Stimulates transverse growth; inhibits longitudinal growth.
- Synthesized from methionine.
- Discovered by H.H. Cousins (1910) and identified as ethylene by R. Gane (1934).
- Produced in minimal amounts throughout plant; peaks during fruit ripening and senescence.
- Bioassays: Triple response in etiolated pea, gas chromatographic assay.

Memory Aids

- Ethylene = "E for Ethephon and Ripening".

Quick Checkpoints

- What is the triple response caused by ethylene?
- How does ethylene affect fruit ripening?

Physiological functions

Ethylene Effects

- Causes swelling and horizontal growth; forms apical hook in dicot seedlings.
- Promotes senescence and abscission of leaves and flowers.
- Increases respiration rate during fruit ripening (respiratory climacteric).
- Overcomes seed and bud dormancy; initiates germination and sprouting.
- Increases female flowers and fruit set in cucumber.
- Used to synchronize flowering and fruit set in pineapple and mango.
- Promotes internode elongation in deep water rice to keep shoots above water.
- Stimulates root growth and root hair formation.
- Commercially used as ethephon for fruit ripening and abscission.
- Induces adventitious root formation in waterlogged roots.

Memory Aids

- Ethylene = "Gas hormone for ripening and abscission".

Quick Checkpoints

- What role does ethylene play in seed dormancy?
- How is ethylene used in agriculture?

Abscisic Acid

Characteristics and Discovery

- Mildly acidic growth inhibitor, also called stress hormone.
- Production increases under drought, waterlogging, and stress.
- Discovered by Addicott et al. (1963) from cotton bolls.
- Found abundantly in chloroplasts; synthesized from mevalonic acid or xanthophyll.
- Bioassays: Rice seedling growth inhibition, α-amylase synthesis inhibition in barley endosperm.

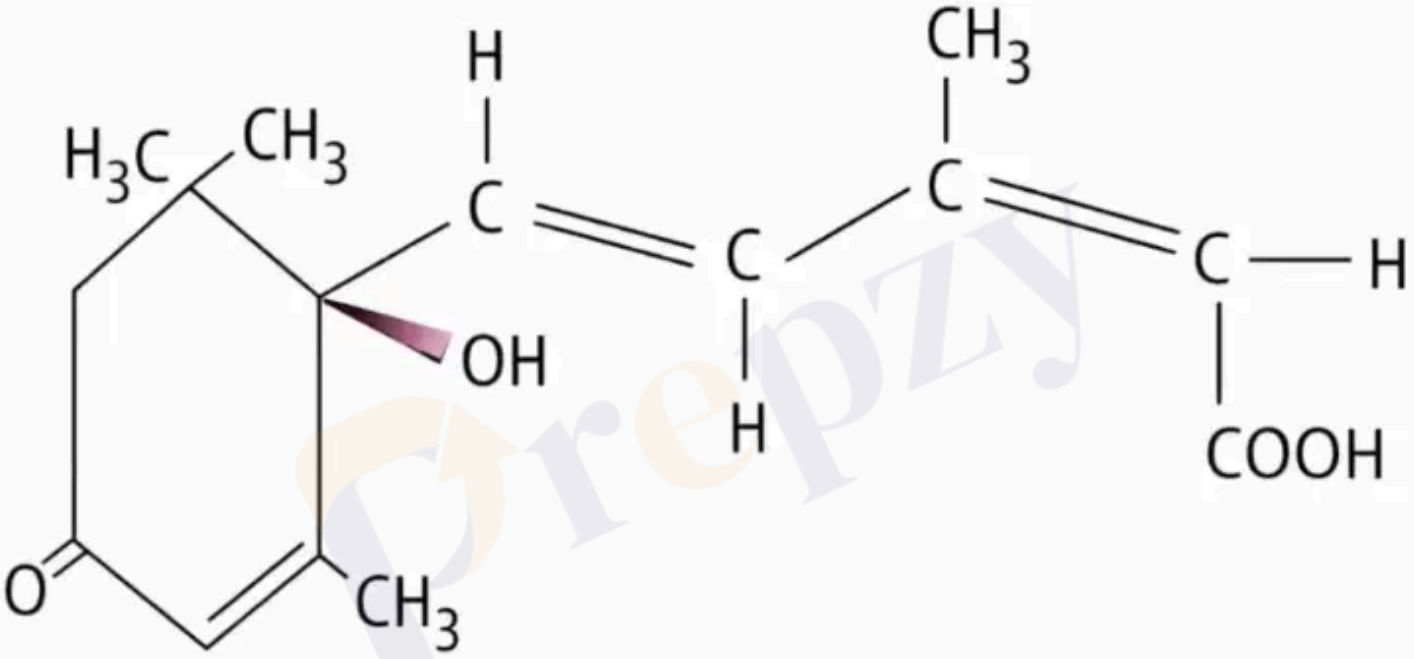


Fig.: Structure of abscisic acid

Memory Aids

- ABA = "Abscission and Dormancy Agent".
- Stress hormone that closes stomata.

Quick Checkpoints

- How does ABA induce dormancy?

- What is ABA's role in stomatal regulation?

Physiological functions

Abscisic Acid Effects

- Induces abscission of plant parts.
- Limits seed germination; induces dormancy in seeds and buds.
- Inhibits flowering in long-day plants; stimulates in some short-day plants.
- Causes partial stomatal closure under drought (antitranspirant).
- Important in seed development, maturation, and desiccation tolerance.
- Promotes leaf senescence; antagonizes gibberellin effects.
- Regulates growth synergistically or antagonistically with other hormones.
- Auxins, gibberellins, cytokinins act synergistically; ABA antagonizes them.
- Auxins, cytokinins, ethylene feminize plants; gibberellins promote maleness.
- Cytokinins and auxins prevent senescence; ABA and ethylene induce it.
- Cytokinins open stomata; ABA closes stomata.
- ABA induces dormancy; gibberellins overcome dormancy.
- Auxins, gibberellins, cytokinins promote cambial activity and fruit development; ABA inhibits.

Memory Aids

- ABA = "Antagonist to growth promoters".
- Induces dormancy and senescence.

Quick Checkpoints

- How does ABA interact with gibberellins?
- What hormones regulate dormancy and senescence?