Chapter 13: Plant Growth and Development

Exercises — Exercises

Q1 Define growth, differentiation, development, dedifferentiation, redifferentiation, determinate growth, meristem and growth rate.

SOLUTION

Growth: An irreversible, permanent increase in size of an organ, its parts, or an individual cell. It is accompanied by metabolic processes (anabolic and catabolic) that occur at the expense of energy.

Differentiation: The process by which cells derived from meristems (root apical, shoot apical, cambium) undergo structural and functional changes to mature and perform specific functions. During differentiation, cells may lose their protoplasm and develop specialised cell walls (e.g., tracheary elements).

Development: The sum of all changes an organism undergoes during its life cycle from seed germination to senescence. It is the sum of growth and differentiation, controlled by intrinsic (genetic, PGRs) and extrinsic (light, temperature, water) factors.

Dedifferentiation: The phenomenon by which living, differentiated cells that have lost the capacity to divide regain the ability to divide under certain conditions. Example: formation of interfascicular cambium and cork cambium from fully differentiated parenchyma cells.

Redifferentiation: The process by which cells produced by dedifferentiated meristems once again lose the capacity to divide and mature to perform specific functions. Example: cells produced by cork cambium that form cork (phellem).

Determinate growth: Growth that ceases after a genetically predetermined period, resulting in a fixed final size. Seen in leaves, flowers, and fruits, which have limited dimensions and stop growing after reaching a certain size.

Meristem: A group of cells in plants that retain the capacity to divide and self-perpetuate. They are the sites of active cell division. Types include root apical meristem, shoot apical meristem (primary growth) and lateral meristems — vascular cambium and cork cambium (secondary growth).

Growth rate: The increased growth per unit time. It can be expressed mathematically as arithmetic growth rate (Lt = L0 + rt) or geometric/exponential growth rate (W1 = W0e^rt). It can be absolute (total growth per unit time) or

relative (growth per unit time per unit initial size).

Answer: Growth = irreversible size increase; Differentiation = structural/functional maturation of cells; Development = sum of growth + differentiation over the life cycle; Dedifferentiation = regaining division capacity by mature cells; Redifferentiation = re-loss of division capacity and re-maturation; Determinate growth = growth that stops at a fixed size; Meristem = dividing cell group sustaining plant growth; Growth rate = growth per unit time (arithmetic or geometric).

Q2 Why is not any one parameter good enough to demonstrate growth throughout the life of a flowering plant?

SOLUTION

Growth in flowering plants manifests in many different ways depending on the organ, tissue, or stage of development. No single parameter can capture all these varied expressions of growth.

Different parameters are appropriate for different situations:
- In a maize root apical meristem, growth is best expressed as increase in cell number (over 17,500 new cells per hour).
- In a watermelon, cells may increase in size by up to 3,50,000 times, so increase in cell size (volume) is the relevant parameter.
- Growth of a pollen tube is measured by its length.
- Growth of a dorsiventral leaf is measured by increase in surface area.
- For overall plant growth, dry weight or fresh weight may be used.

Thus, at the cellular level, growth may mean increase in number, volume, length, area, or mass. Relying on a single parameter would give an incomplete or misleading picture of growth across the different organs and phases of a plant's life. A combination of parameters is needed to fully demonstrate growth throughout the life of a flowering plant.

Answer: No single parameter suffices because growth manifests differently in different organs and stages — as cell number (root meristem), cell volume (watermelon), length (pollen tube), or surface area (leaf). A combination of parameters is needed for a complete picture.

Q3 Describe briefly: (a) Arithmetic growth (b) Geometric growth (c) Sigmoid growth curve (d) Absolute and relative growth rates

SOLUTION

(a) Arithmetic Growth:

In arithmetic growth, following mitotic cell division, only one daughter cell continues to divide while the other differentiates and matures. The result is a constant, linear rate of increase in size. A root elongating at a constant rate is the simplest example. When length is plotted against time, a straight (linear) curve is obtained. Mathematically expressed as: Lt = L0 + rt, where Lt = length at time t, L0 = length at time zero, r = growth rate per unit time.

(b) Geometric Growth:

In geometric growth, both daughter cells produced by mitotic division retain the ability to divide and continue to do so. This leads to exponential increase in growth — initial growth is slow (lag phase), followed by a rapid increase at an exponential rate (log or exponential phase). With limited nutrients, growth slows to a stationary phase. Mathematically: W1 = W0e^rt, where W1 = final size, W0 = initial size, r = relative growth rate, t = time, e = base of natural logarithms. Here r is the efficiency index.

(c) Sigmoid Growth Curve:

When the parameter of growth is plotted against time during geometric growth, a typical S-shaped (sigmoid) curve is obtained. It has three phases: (i) lag phase — initial slow growth; (ii) log (exponential) phase — rapid, accelerating growth; (iii) stationary phase — growth slows as nutrients become limiting. This sigmoid or S-curve is characteristic of all living organisms growing in a natural environment and is typical for all cells, tissues and organs of a plant.

(d) Absolute and Relative Growth Rates:

Absolute growth rate: The total growth (increase in size/weight/area) per unit time. It compares the total amount of growth over a given period, irrespective of the initial size.

Relative growth rate: The growth per unit time expressed on a common basis — per unit of the initial parameter (e.g., per unit initial area or weight). It accounts for the initial size of the organ.

Example: If leaves A (2 cm2) and B (20 cm2) both increase by 5 cm2 in the same time, they have the same absolute growth rate (5 cm2/unit time), but leaf A has a much higher relative growth rate (5/2 = 2.5 vs 5/20 = 0.25), meaning A grew

proportionally faster.

Answer: (a) Arithmetic growth: one daughter cell divides, the other differentiates; linear increase; Lt = L0 + rt. (b) Geometric growth: both daughter cells divide; exponential increase; W1 = W0e^rt. (c) Sigmoid curve: S-shaped plot of growth vs time showing lag, log, and stationary phases — characteristic of living organisms. (d) Absolute growth rate = total growth per unit time; relative growth rate = growth per unit time per unit initial size.

Q4 List five main groups of natural plant growth regulators. Write a note on discovery, physiological functions and agricultural/horticultural applications of any one of them.

SOLUTION

Five main groups of natural plant growth regulators (PGRs):

1. Auxins
2. Gibberellins
3. Cytokinins
4. Abscisic acid (ABA)
5. Ethylene

Note on Gibberellins:

Discovery:

Gibberellins were discovered in connection with the 'bakanae' (foolish seedling) disease of rice seedlings caused by the fungal pathogen Gibberella fujikuroi. E. Kurosawa (1926) reported that sterile filtrates of this fungus, when applied to rice seedlings, produced symptoms of the disease (abnormal elongation). The active substances were later identified and named gibberellic acid (GA3). More than 100 gibberellins have since been reported from fungi and higher plants, denoted as GA1, GA2, GA3, etc. All GAs are acidic.

Physiological Functions:

- Cause increase in the length of axis (stem elongation).
- Promote bolting (rapid internode elongation just before flowering) in rosette plants such as beet and cabbage.
- Delay senescence, allowing fruits to remain on the tree longer.
- Stimulate seed germination.
- Hasten maturity in juvenile conifers, leading to early seed production.

- In most situations, gibberellins act as antagonists to abscisic acid (ABA).

Agricultural/Horticultural Applications:
- Spraying sugarcane with gibberellins increases stem length, increasing yield by up to 20 tonnes per acre.
- Used to increase the length of grape stalks, improving bunch quality.
- Applied to apples to improve fruit elongation and shape.
- GA3 is used to speed up the malting process in the brewing industry.
- Spraying juvenile conifers with GAs hastens maturity and enables early seed production.
- Used to delay senescence of fruits, thereby extending their market period.

Answer: Five groups: auxins, gibberellins, cytokinins, abscisic acid, ethylene. Gibberellins: discovered via bakanae disease of rice (Kurosawa, 1926); promote stem elongation, bolting, delay senescence, hasten germination; used in sugarcane (20 t/acre yield boost), grapes, apples, brewing industry.

Q5 Why is abscisic acid also known as stress hormone?

SOLUTION

Abscisic acid (ABA) is called the stress hormone because it plays a central role in mediating plant responses to various abiotic and biotic stresses:

1. Stomatal closure: ABA stimulates the closure of stomata, which reduces water loss through transpiration during conditions of water stress (drought). This is its most well-known stress response.

2. Stress tolerance: ABA increases the tolerance of plants to various kinds of stresses — drought, salinity, cold, and other adverse conditions — by triggering appropriate physiological responses.

3. Seed dormancy: ABA induces and maintains seed dormancy, helping seeds withstand desiccation and other unfavourable environmental conditions until favourable conditions return.

4. General growth inhibition: ABA acts as a general plant growth inhibitor and inhibitor of plant metabolism, slowing down processes when conditions are not suitable for growth.

Because its primary role involves protecting the plant from various stresses (especially water stress via stomatal regulation) rather than promoting growth,

ABA is aptly called the stress hormone.

Answer: ABA is called the stress hormone because it stimulates stomatal closure to reduce water loss under drought, increases tolerance to abiotic stresses (drought, salinity, cold), induces seed dormancy to survive unfavourable conditions, and generally inhibits growth and metabolism during stress.

Q6 'Both growth and differentiation in higher plants are open'. Comment.

SOLUTION

The statement 'Both growth and differentiation in higher plants are open' means that both processes are indeterminate — they are not fixed at a predetermined developmental stage but can continue or be modified throughout the plant's life.

Open Growth:
Plants retain the capacity for unlimited (indeterminate) growth throughout their life, because meristems continue to add new cells to the plant body indefinitely. This is called the open form of growth. Unlike animals, where growth stops at adulthood, a plant's shoot and root apical meristems and lateral meristems continue to function, producing new organs perpetually. Even when one meristem ceases, new meristems can be initiated.

Open Differentiation:
Differentiation in plants is also open because cells and tissues arising out of the same meristem can have different structures at maturity, depending on their position and environment. The final structure of a cell at maturity is determined not just by its lineage but also by its location within the plant body. For example:
- Cells positioned near the root apex become root-cap cells.
- Cells pushed to the periphery mature as epidermal cells.
- The same meristematic cells can thus produce very different cell types depending on positional signals.

Additionally, differentiated cells can dedifferentiate (regain division capacity) and then redifferentiate into new cell types. This further demonstrates the open (flexible, reversible) nature of differentiation in plants.

Thus, because neither growth nor differentiation follows a rigidly fixed programme but remains responsive to signals from the environment and the plant's developmental context, both are described as 'open' in higher plants.

Answer: Open growth: plants grow indeterminately throughout life via continuously active meristems (not fixed at adulthood). Open differentiation: cells from the same meristem differentiate into different types depending on their position (e.g., root-cap vs epidermis); differentiated cells can also dedifferentiate and redifferentiate. Both processes remain flexible and positionally determined, not rigidly pre-fixed.

Q7 'Both a short day plant and a long day plant can flower simultaneously in a given place'. Explain.

SOLUTION

A short day plant (SDP) flowers when the duration of light (photoperiod) is less than a critical daylength (i.e., it needs a long night/short day). A long day plant (LDP) flowers when the photoperiod exceeds a critical daylength (i.e., it needs a long day/short night).

At first, it may seem impossible for both to flower simultaneously since their photoperiodic requirements appear opposite. However, this is possible because:

1. The critical daylength is different for different plants. Suppose a SDP has a critical daylength of 14 hours (it flowers when day < 14 hours) and a LDP has a critical daylength of 10 hours (it flowers when day > 10 hours).

2. At an intermediate daylength — say, 12 hours of light — the SDP will flower (12 hours < 14-hour critical length) AND the LDP will also flower (12 hours > 10-hour critical length).

3. Thus, at a specific natural daylength that falls between the two critical values, both a SDP and a LDP can flower simultaneously at the same location.

This also highlights that the critical term is not just 'short' or 'long' day in absolute terms, but whether the actual photoperiod is above or below each plant's own specific critical threshold. The overlap in these thresholds allows simultaneous flowering.

Answer: An SDP flowers when photoperiod is below its critical daylength; an LDP flowers when photoperiod exceeds its critical value. If the SDP's critical length (e.g., 14 h) is longer than the LDP's critical length (e.g., 10 h), then at an intermediate natural daylength (e.g., 12 h) both thresholds are satisfied simultaneously — the SDP gets a 'short enough' day and the LDP gets a 'long enough' day — allowing both to flower at the same place and time.

Q8 Which one of the plant growth regulators would you use if you are asked to: (a) induce rooting in a twig (b) quickly ripen a fruit (c) delay leaf senescence (d) induce growth in axillary buds (e) 'bolt' a rosette plant (f) induce immediate stomatal closure in leaves.

SOLUTION

(a) Induce rooting in a twig:
Auxin (IAA / IBA). Auxins help to initiate rooting in stem cuttings and are widely used for plant propagation. IBA (indole butyric acid) is commonly used for this purpose.

(b) Quickly ripen a fruit:
Ethylene. Ethylene is highly effective in fruit ripening and enhances the respiration rate during ripening (respiratory climacteric). Ethephon (which releases ethylene slowly within the plant) is the most widely used source. It hastens fruit ripening in tomatoes and apples.

(c) Delay leaf senescence:
Cytokinin. Cytokinins promote nutrient mobilisation and help in the delay of leaf senescence. They keep leaves green and metabolically active for a longer period.

(d) Induce growth in axillary buds:
Cytokinin. Cytokinins help overcome apical dominance and promote lateral shoot growth and adventitious shoot formation. They counteract the inhibitory effect of auxin on axillary buds.

(e) 'Bolt' a rosette plant:
Gibberellin (GA). Gibberellins promote bolting — the rapid elongation of internodes just before flowering — in rosette plants such as beet and cabbage.

(f) Induce immediate stomatal closure in leaves:
Abscisic acid (ABA). ABA stimulates the closure of stomata, particularly in response to water stress. It is the primary regulator of stomatal movement.

Answer: (a) Auxin (IBA) — initiates rooting; (b) Ethylene (ethephon) — hastens fruit ripening; (c) Cytokinin — delays leaf senescence; (d) Cytokinin — overcomes apical dominance and promotes axillary bud growth; (e) Gibberellin (GA) — induces bolting in rosette plants; (f) Abscisic acid (ABA) — induces stomatal closure.

Q9 Would a defoliated plant respond to photoperiodic cycle? Why?

SOLUTION

No, a defoliated plant (a plant whose leaves have been removed) would not respond to the photoperiodic cycle.

Reason:
The leaves are the primary organs that perceive the photoperiodic stimulus (the duration of light and dark). The photoreceptor involved in photoperiodism is phytochrome, which is present in the leaves.

When a plant is exposed to the appropriate photoperiod, the leaves perceive this signal and produce a chemical stimulus — often called 'florigen' (now understood to be a protein called Flowering Locus T or FT) — that is transported through the phloem from the leaves to the shoot apex, where it triggers the transition from vegetative to reproductive growth (flowering).

If the plant is defoliated (leaves removed), there are no leaves to:
- Perceive the photoperiodic signal.
- Produce and transmit the flowering stimulus to the shoot apex.

Therefore, even if such a defoliated plant is kept under the correct photoperiod, it will not flower, because the site of perception of the photoperiodic stimulus is absent. This demonstrates that leaves are indispensable for the perception of photoperiod and the initiation of flowering.

Answer: No. Leaves are the organs that perceive the photoperiodic stimulus via phytochrome. They produce the flowering stimulus (florigen) which is transported to the shoot apex to trigger flowering. A defoliated plant lacks the site of perception, so even under the correct photoperiod it will not respond or flower.

Q10 What would be expected to happen if: (a) GA3 is applied to rice seedlings (b) dividing cells stop differentiating (c) a rotten fruit gets mixed with unripe fruits (d) you forget to add cytokinin to the culture medium.

SOLUTION

(a) GA3 is applied to rice seedlings:
The rice seedlings would show abnormally tall, spindly growth with excessive internode elongation. This mimics the 'bakanae' (foolish seedling) disease caused by the fungal pathogen Gibberella fujikuroi. The seedlings become weak and eventually fall over (lodging). GA3 promotes stem elongation, so treated

seedlings grow much taller than normal but lack structural strength.

(b) Dividing cells stop differentiating:
If dividing (meristematic) cells stop differentiating, they would continue to divide without maturing into specialised cell types. This would lead to the formation of an undifferentiated mass of cells — a callus (similar to a tumour). No organised plant tissues or organs (xylem, phloem, leaves, etc.) would be formed, and normal plant development would be severely disrupted or arrested.

(c) A rotten fruit gets mixed with unripe fruits:
The unripe fruits would ripen quickly. A rotten (over-ripe) fruit releases large amounts of ethylene gas. Ethylene is a highly effective fruit-ripening hormone that enhances the respiration rate during ripening (respiratory climacteric). The ethylene released by the rotten fruit would diffuse to surrounding unripe fruits and accelerate their ripening process. This is a well-known principle used practically — e.g., ripened apples or bananas placed with unripe fruits to hasten their ripening.

(d) You forget to add cytokinin to the culture medium:
In plant tissue culture, cytokinins are essential for promoting cell division (cytokinesis) and shoot differentiation. If cytokinin is omitted from the culture medium, the cells would fail to divide adequately and would not differentiate into shoots. Root formation might predominate (since high auxin:cytokinin ratio promotes roots). The callus would not proliferate normally, and organised shoot development (shoot organogenesis) would not occur, severely compromising the tissue culture experiment.

Answer: (a) GA3 on rice seedlings: abnormal tall, spindly growth (bakanae-like) with excessive internode elongation. (b) Cells stop differentiating: undifferentiated callus/tumour-like mass forms; no organised organs develop. (c) Rotten fruit with unripe fruits: ethylene released by rotten fruit hastens ripening of unripe fruits. (d) No cytokinin in culture medium: cell division inhibited, shoot differentiation fails, roots may dominate; tissue culture is unsuccessful.