13 Plant Growth and Development

When fruit-sellers need to transport fruits over a long distance, they do so in a raw state, but once there, they use ethylene hormone to make it ripe. Together with other hormones and signals, ethylene is a gaseous plant hormone that plays an important role in inducing the ripening process for many fruits.

Topic Notes

- *Plant Growth and it's Phases*
- *Plant Development and Growth Regulators*

PLANT GROWTH AND ITS PHASES 1

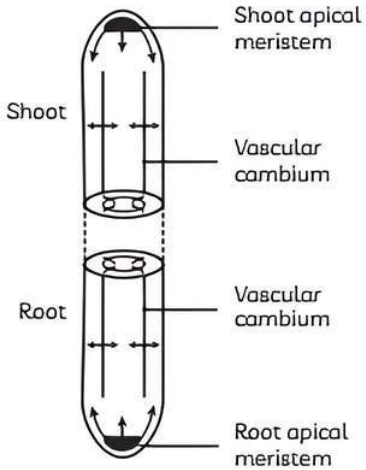
TOPIC 1
GROWTH

Growth is an irreversible permanent increase in the size of an organ, its parts or even an individual cell. Growth is a characteristic feature of a living organism, and it is accompanied by metabolic processes. For example, the digestion of food produces nutrients that are then given to the cells of the body, which use these nutrients to produce energy. Now, this energy will help in normal physiological function, growth, and the development of the organism.

Indeterminate Plant Growth

Plants have the capacity for unlimited growth for their whole life which makes them unique. This ability of plants is due to the presence of meristem at various locations inside their body. The meristematic cells can divide continuously throughout the life of the plant. Due to this, new cells are always being added to the body of the plant, and such growth is called an open form of growth.

Various types of meristem are present in the plant body like apical meristem, lateral meristem, and intercalary meristem. Lateral meristem causes an increase in the girth of the plant, whereas apical meristem helps in increasing the height of the plant. Vascular cambium and cork cambium appear later in the life of the plant, which also causes an increase in girth. This form of growth in which the girth of plants increases is called the secondary growth.



Diagrammatic representation of locations of root apical meristem, shoot apical meristem, and vascular cambium.
(Arrows exhibit the direction of growth of cells and organs)

Important

➥ *Primary growth occurs in the earlier life stage of the plant whereas secondary growth occurs in the later stage of plant life. The stem of monocot plants does not have meristems, so there is no secondary growth in them. This is evident by observing the thin or herbaceous stems of monocot plants.*

Phases of Growth

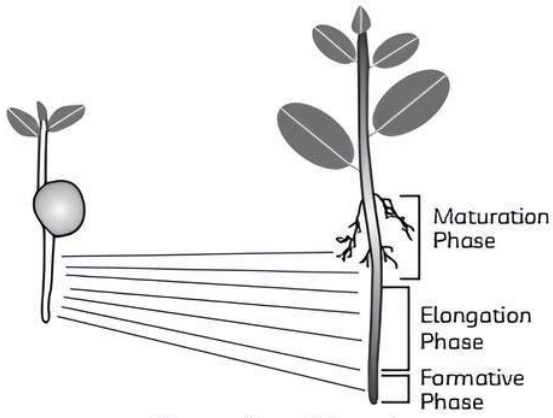
Phases of growth are divided into three phases: Meristematic phase or (Formative Phase), Elongation phase, and Maturation phase or (Phase of differentiation).

Meristematic Phase (Formative Phase)

It is also called the phase of cell division. It occurs in the areas where meristematic cells are present and it is the first phase of growth in plants. It generally occurs at the root and shoot tip of the plants and other areas also where meristematic tissues are present. At this phase of growth, cells have dense protoplasm, contain a large nucleus, have a high respiration rate, and the cell wall is thin and made up of cellulose with abundant plasmodesmata connections so that cells can communicate with each other. Cells of this phase divide fast by mitosis.

Phase of Elongation

It is the second phase of growth. The cells formed in the formative phase undergo enlargement. Cells found in this zone have increased vacuolation, deposition of materials on the cell wall, and increase in cell size.



Phases of growth in root

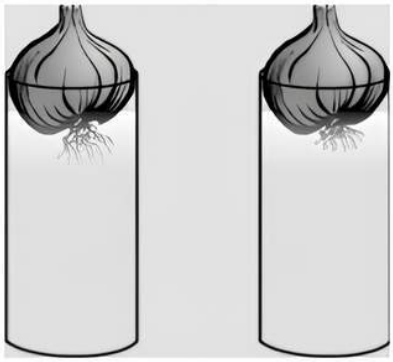
Phase of Maturation (Phase of Differentiation)

This is the third and last phase of growth. After the phase of elongation, the cells undergo specialisation to perform special functions. In this phase, there is structural and physiological changes occur in the cells. The cells are the largest and the walls are thickest in this phase.

Example 1.1: Case Based:

Kirti is doing an experiment in her school biology lab, where she has to conduct an experiment on an onion by putting the onion over a glass filled with water, such that the lower part of the onion, from where root arises, is touching the water surface. After a few days, she observed that roots started growing from the onion.

It is hypothesised that a large proportion of the cells would undergo mitotic nuclear division, and relative to interphase or non-dividing cells more number of cells would be seen in one of the four phases – prophase, metaphase, anaphase and telophase. The reason for making this hypothesis is that the roots continue to profusely grow both apically and laterally in search of nutrients and water and root tips are mainly responsible for absorption, hence the cells should be continuously rejuvenating by repeated cycles of cell division.



(A) **Which growth phases are shown by the root of the onion?**
- (a) Meristematic phase
- (b) Elongation phase
- (c) Maturation phase
- (d) Both (a) and (b)

(B) **Which phase of growth shows cells with the thickest walls?**
- (a) Maturation phase
- (b) Meristematic phase
- (c) Elongation phase
- (d) Fornative phase

(C) **What are the characteristic features of cells present in the meristematic growth phase?**

(D) **What is the reason behind the growth of roots from the onion tip which was touching the water surface?**

(E) **Assertion (A):** The last phase of growth is the maturation phase.

Reason (R): It is named so because, in this phase, the elongation for enlargement of cells occurs the most.
- (a) Both A and R are true and R is the correct explanation of A.
- (b) Both A and R are true and R is not the correct explanation of A.
- (c) A is true but R is false.
- (d) A is false but R is true.

Ans. (A) *(d) Both (a) and (b)*

Explanation: Plant tissues in the root of the onion shows both meristematic and elongation phase. The log phase is not shown by plants in their growth.

(B) *(a) Maturation phase*

Explanation: In the maturation phase, the cell wall becomes thickest. The cell wall is thinnest in the meristematic phase and intermediate in the elongation phase.

(C) At the meristematic phase of growth, cells have dense protoplasm, contain a large nucleus, have a high respiration rate, and the cell wall is thin and made up of cellulose with abundant plasmodesmata connections so that cells can communicate with each other.

(D) Root tips of onion contain meristematic tissues, which when coming in contact with water, get essential nutrients for its growth. Therefore it starts growing when it comes in contact with water.

(E) *(c) A is true but R is false.*

Explanation: The maturation phase is the last phase of growth in which the cells get matured, and become bigger with thick walls. Maximum elongation of cells occurs at the elongation phase of growth.

Growth Rates

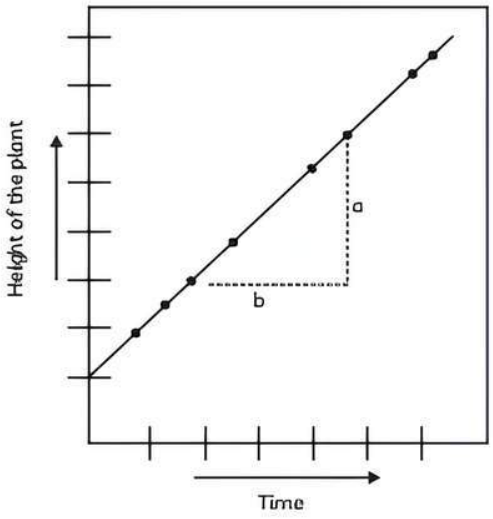
An increase in growth per unit time is called a growth rate. The growth rate can be measured mathematically. The growth rate can be arithmetic or geometric.

Arithmetic growth

Arithmetic growth is a type of growth rate in which cell division occurs by mitosis and only one daughter cell divides continuously whereas other cells undergo differentiation and become mature and permanent. Here growth occurs at a constant rate from the start and it progresses arithmetically. It occurs in the case of root elongation where elongation occurs at a constant rate. The graph for arithmetic growth is plotted by taking time at the X-axis and height of the plant organ at the Y-axis, and the linear curve is obtained. The mathematical expression of arithmetic growth is:

$$L_t = L_0 + rt$$

Where, L_t = length at time t.
L_0 = length at beginning.
r = growth rate or elongation per unit time.



Graph of arithmetic growth

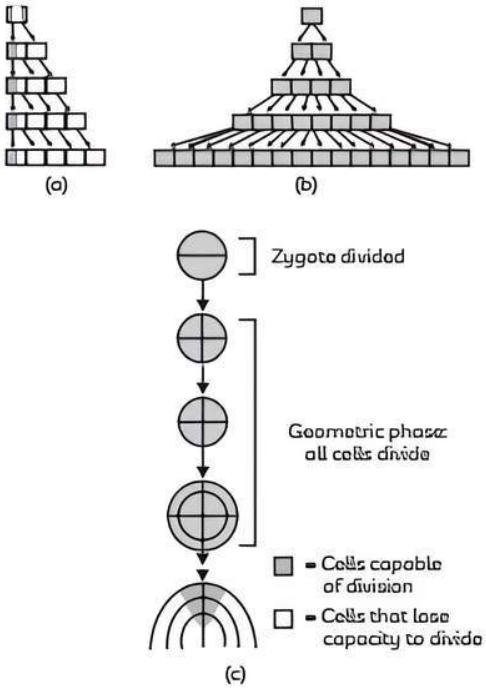
Geometric growth

In Geometrical growth, growth and division occur in every cell with all the daughters growing and dividing again. This growth occurs in three phases:

(1) **Lag phase:** It is the first phase of growth where the rate of growth is very slow.

(2) **Log phase:** In this phase, growth progress is rapid and reaches its maximum. This growth phase is called log phase or exponential phase.

(3) **Stationary phase:** The last phase is called the stationary phase, which happens due to limited food, space, and accumulation of toxins which slows down the growth.

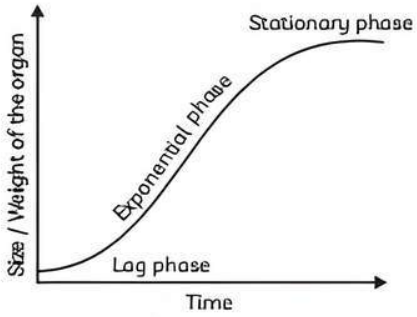


Diagrammatic representation of (a) Arithmetic growth (b) Geometric growth and (c) stages during embryo development showing geometric and arithmetic phases

The slope of the graph in geometric growth is sigmoidal or S-shaped. The mathematical expression of geometric growth is:

$$W_1 = W_0 e^{rt}$$

Where, W_1 = final size (weight, height, number, etc.)
W_0 = initial size at the beginning of the period
r = growth rate
t = time of growth
e = base of natural logarithms



Graph of geometric growth

Example 1.2: Case Based:

Bharti is researching plant tissue culture, where she is performing organogenesis. While observing the plant cells undergoing organogenesis, she found that only one daughter cell divides continuously whereas other cells undergo differentiation and become mature.

Plant tissue culture (PTC) techniques are the most frequently used biotechnology tools ranging from basic to applied investigation purposes in plant sciences. The history of PTC research dates back to 1902, when Haberlandt cultured tissue from a Tradescantia plant species. Since then, PTC has significantly impacted the current agriculture system worldwide and every year, hundreds of results and reports regarding the application of tissue culture techniques, applied to breeding programs, genetic and biodiversity conservation, and biopharmaceutical production are documented.

(A) What is the term for growth in which only one daughter cell divides continuously whereas other cells undergo differentiation and become mature?

(a) Meristematic growth phase
(b) Arithmetic growth phase
(c) Elongation phase
(d) Maturation phase

(B) What is the term for growth in which growth and division occur in every cell with all the daughters growing and dividing again?
   (a) Arithmetic growth phase
   (b) Geometric growth phase
   (c) Both (a) and (b)
   (d) None of the above

(C) What is the shape of the graph in geometric growth?

(D) What are the three phases in the geometric growth curve?

(E) Assertion (A): The graph for arithmetic growth is plotted by taking time at the X-axis and height of the plant organ at the Y-axis, and the linear curve is obtained.
Reason (R): In arithmetic growth, only one daughter cell divides continuously whereas other cells undergo differentiation and become mature.
   (a) Both A and R are true and R is the correct explanation of A.
   (b) Both A and R are true and R is not the correct explanation of A.
   (c) A is true but R is false.
   (d) A is false but R is true.

Ans. (A) *(b) Arithmetic growth phase*

(B) *(b) Geometric growth phase*

(C) The shape of the graph in geometric growth is sigmoidal or S-shaped.

(D) Three phases in the geometric growth curve are lag phase, log phase and stationary phase.

(E) *(a) Both A and R are true and R is the correct explanation of A.*

Explanation: The graph for arithmetic growth is plotted by taking time at the X-axis and height of the plant organ at the Y-axis, and the linear curve is obtained because in arithmetic growth only one daughter cell divides continuously whereas other cells undergo differentiation and become mature.

Absolute and relative growth rate

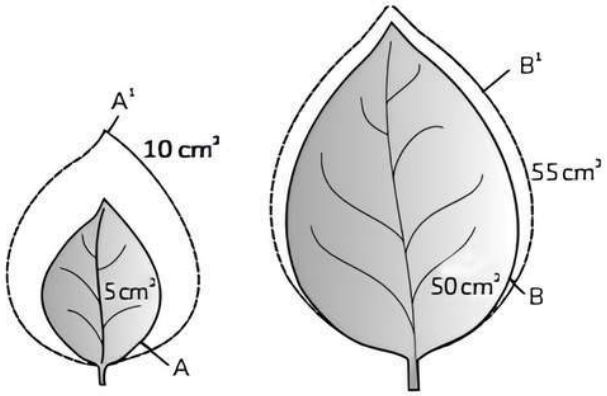
The 'r' expressed in the above growth equations is the relative growth rate. This ability of plants to produce new plant material is called the efficiency index. The increase in the plant material is deduced by looking at the initial size of the plant *i.e.*, W_0.

Quantitative comparison between the growths of living system can be made using two ways:

(1) First is the absolute growth rate, which is the measurement and comparison of total growth per unit time.

(2) The second is the relative growth rate, which is defined as the growth per unit time per unit of initial growth or, the relative growth rate is the growth rate per unit of initial growth.

Absolute growth rate = Growth/ time
Relative growth rate = Growth rate/initial size.



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.

Caution

➥ *Students usually consider absolute growth rate and relative growth rate as the same. On one hand, where absolute growth rate is the growth per unit time, on the other hand, the relative growth rate is the growth rate per unit initial size of the plant.*

Conditions for Growth

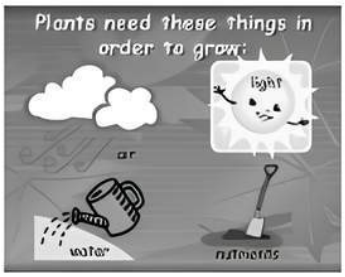
The necessary requirements for the growth of plants are water, oxygen, nutrients, temperature, light, gravity, and plant regulators. Water maintains the turgidity of growing cells and provides a medium for enzymatic activities.

Oxygen is essential for aerobic respiration and thus release of energy. This energy is utilised to perform various biosynthetic activities and it is essential for the growth and development of plants. The plants cannot grow in water logging conditions because their growth of roots is inhibited due to the reduced availability of oxygen to roots.

Nutrients are required for the synthesis of protoplasm and for the production of energy.

Temperature is also essential because only at optimum temperature plants show maximum growth.

Light is required for the synthesis of food by photosynthesis, whereas gravity determines the direction of orientation of the main root stem and branches.



Factors affecting growth in plants

Important

➥ *The factors which affect the growth of plants are very important and complex topics to study. Since there are a lot of factors that can affect the growth of a particular plant and there are chances that at one particular time, more than one factor might be affecting the growth, we can not consider only one factor to be responsible for the growth of plant at a time.*

TOPIC 2

DIFFERENTIATION, DEDIFFERENTIATION AND REDIFFERENTIATION

The phenomenon where cells undergo permanent changes in their structure, biochemistry, size, physiology of cell wall, and protoplasm contents, thus enabling the cell to perform a specific function is called differentiation. These differentiated cells form primary permanent tissue which is formed from the primary meristem. It occurs in cells derived from the root and shoots apical meristems.

Examples: Formation of tracheary elements, chlorenchyma, etc.

Dedifferentiation is the phenomenon where certain differentiated cells regain the ability to divide and become meristematic again. These cells start dividing again and add new cells. Example: Formation of meristems—interfascicular cambium and cork cambium from fully differentiated parenchymatous cells. These are formed from primary permanent tissue hence these are called secondary meristem.

Redifferentiation is the process where dedifferentiated cells (secondary meristem) again lose their ability to divide and become permanent cells. These are called secondary permanent. Examples: Secondary phloem, secondary xylem, etc.

Caution

➥ *Students usually get confused between differentiation and re-differentiation. These are different but in both cases, cells lose the ability to divide and produce new cells.*

Example 1.3: **Define growth, differentiation, development, dedifferentiation, re-differentiation, determinate growth, meristem, and growth rate. [NCERT]**

Ans. **(1) Growth:** It is irreversible and permanent, it is an increase in mass, number and cells of an organism.

(2) Differentiation: It is the phenomenon where cells undergo permanent changes in their structure, biochemistry, size, physiology of cell wall, and protoplasm contents, thus enabling the cell to perform a specific function.

(3) Development: It is the progressive change in the size, shape, and function of an organism throughout its life.

(4) Dedifferentiation: Dedifferentiation is the phenomenon where certain living differentiated cells regain their ability to divide and form new cells.

(5) Re-differentiation: The process during which dedifferentiated cells again lose their ability to divide to form permanent cells.

(6) Determinate growth: A type of growth in which an organism does not show growth for its whole life. It is a limited form of growth.

(7) Meristem: These are a group of cells found in a particular region of the plant which shows great dividing capacity.

(8) Growth rate: It can be defined as the increased growth in plants per unit time. It can be calculated by taking the change in size and dividing it by the amount of time it has been growing.

OBJECTIVE Type Questions

[1 mark]

Multiple Choice Questions

1. Growth can be measured in various ways. Which of these can be used as parameters to measure growth?

(a) Increase in cell number

(b) Increase in cell size

(c) Increase in length and weight

(d) All of the above **[NCERT Exemplar]**

Ans. *(d) All of the above*

Explanation: Growth can be measured by using various parameters like an increase in cell number, cell size, length, and weight.

2. Name the act in which root apical, shoot apical meristem and cambium differentiate and mature to perform specific functions and lead to maturation.

(a) Differentiation (b) Dedifferentiation

(c) Redifferentiation (d) Plasticity [Diksha]

Ans. *(a) Differentiation*

Explanation: Differentiation is the process in which immature cells change to mature cells to perform specific functions. On the other hand, dedifferentiation is a process in which differentiated cells regain their ability to divide. Redifferentiation is the process in which the dedifferentiated cells again lose their ability to divide to form permanent cells.

3. What is incorrect for meristematic tissues?

(a) Rich in Protoplasm

(b) Cell walls are primary

(c) Increased vacuolation

(d) Large conspicuous nuclei [Diksha]

Ans. *(c) Increased vacuolation*

Explanation: Meristematic tissues are rich in protoplasm, the cell wall is of primary nature, and large conspicuous nuclei.

4. Growth in plants is defined as:

(a) Reversible increase in mass

(b) Irreversible increase in mass

(c) Infinite increase in size

(d) Both (a) and (c)

Ans. *(b) Irreversible increase in mass*

Explanation: Growth in plants is an irreversible increase in mass. A reversible increase in mass is found in non-living objects, and growth cannot be an infinite increasing size.

Caution

Students should remember that there is a limit up to which a plant can grow its height.

5. Secondary growth in plants is shown by:

(a) Apical meristem

(b) Intercalary meristem

(c) Lateral meristem

(d) All of the above

Ans. *(c) Lateral meristem*

Explanation: Lateral meristem shows secondary growth in plants. While apical meristem and intercalary meristem shows primary growth.

6. Which phase of growth shows the maximum deposit of materials on the cell wall?

(a) Elongation phase

(b) Meristematic phase

(c) Maturation phase

(d) Both (a) and (b)

Ans. *(c) Maturation phase*

Explanation: Maturation phase shows a maximum deposit of materials on the cell wall due to which cell wall becomes thick. The meristematic phase shows a minimum deposit and the elongation phase shows an intermediate deposit of materials on the cell wall.

7. What are the examples of dedifferentiation?

(a) Secondary phloem and xylem.

(b) Interfascicular cambium or cork cambium.

(c) Formation of tracheary elements and collenchyma.

(d) All of the above.

Ans. *(b) Interfascicular cambium or cork cambium*

Explanation: Interfascicular cambium and cork cambium are examples of dedifferentiation. Secondary phloem and xylem are examples of redifferentiation. The formation of tracheary elements and collenchyma is an example of differentiation.

8. What are the phases present in the graph of geometric growth?

(a) Log phase (b) Lag phase

(c) Elongation phase (d) Both (a) and (b)

Ans. *(d) Both (a) and (b)*

Explanation: The phases present in the graph of geometric growth are the log phase, lag phase, and stationary phase. The elongation phase is not present.

Related Theory

Lag phase shows the initial growth rate which is not very much. Log phase shows a sudden high growth rate and Stationary phase shows a constant growth rate.

9. Why do plants need a periodic exposure to light?

(a) For the root elongation

(b) For fruit formation

(c) To induce flowering

(d) For seed germination

Ans. *(c) To induce flowering*

10. The cells of tracheary elements lose their protoplasm and become dead at maturity

due to the deposition of lignocellulosic secondary cell wall formation. This is an example of ..... .

(a) redifferentiation

(b) development

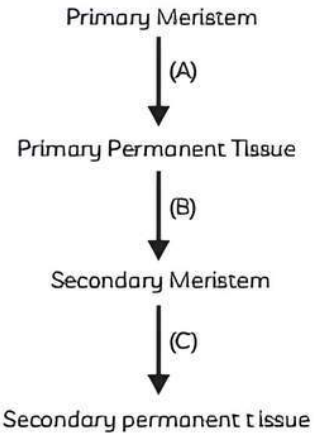
(c) dedifferentiation

(d) differentiation

Ans. *(d) differentiation*

Explanation: The formation of secondary cell wall around tracheids and vessels is an example of differentiation. Development is the overall changes occurring in the life cycle of an organism. Dedifferentiation is regaining the lost capacity of cells or tissues of plants to divide under special conditions. Redifferentiation is the further maturation of dedifferentiated cells thereby specializing for a particular function.

11. Which of the following processes takes place in (C)?



(a) Vascularisation

(b) Dedifferentiation

(c) Differentiation

(d) Redifferentiation

Ans. *(d) Redifferentiation*

Explanation: Following processes are:

A: Differentiation

B: Dedifferentiation

C: Redifferentiation

Vascularisation occurs in procambium to form primary xylem and phloem along with the intrafascicular cambium.

Assertion-Reason (A-R)

Given below are two statements labelled as Assertion (A) and Reason (R). Select the most appropriate answer from the options given below:

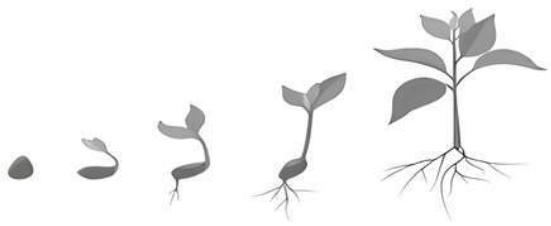
(a) Both A and R are true and R is the correct explanation of A.

(b) Both A and R are true and R is not the correct explanation of A.

(c) A is true but R is false.

(d) A is false but R is true.

12. Growth is a universal and fundamental process of life on earth. The analysis and modelling of plant growth has therefore been a particular concern in plant science as well as in production biology including forestry, agriculture and fishery to name but a few. This research has the important objective to identify growth patterns in response to environmental factors or treatments.



Assertion (A): Plant shows unlimited growth throughout their life.

Reason (R): Meristem in plants can divide continuously throughout the life of the plant.

Ans. *(a) Both A and R are true and R is the correct explanation of A.*

Explanation: Plants have meristems that divide continuously and this is the main reason behind the unlimited plant growth.

13. Assertion (A): Arithmetic growth occurs at a constant rate.

Reason (R): In Arithmetic growth, division occurs in every cell with all the daughter cells growing and dividing again.

Ans. *(c) A is true but R is false.*

Explanation: In Arithmetic growth, only one daughter cell divides continuously whereas other cells undergo differentiation and become mature or permanent. The increase in growth occurs in the arithmetic progression at a constant rate.

14. Assertion (A): Water is an important factor for growth in plants.

Reason (R): Water maintains the turgidity of growing cells and provides a medium for enzymatic activities.

Ans. *(a) Both A and R are true and R is the correct explanation of A.*

Explanation: Water is an important factor for growth in plants because

it serves a major role in turgidity and also acts as a medium for enzymatic activities.

15. **Assertion (A):** **The elongation phase has the thickest cell wall.**

Reason (R): **Cell wall thickens due to deposition of materials on them.**

Ans. *(d) A is false but R is true.*

Explanation: Elongation phase has intermediate cell wall thickness.

CASE BASED Questions (CBQs)

[**4** & **5** marks]

Read the following passages and answer the questions that follow:

16. *Rohit is a curious kid having good knowledge of plants. One day, he was watching two plants, the first one being very tall and the second one had thick stems. The first plant is redwood, which is one of the tallest plants in the world, and the second plant is the banyan tree. Both of these plants are grown in the same area, suffering from the same climatic conditions, and the same human care. Rohit is having a problem and is confused due to the difference in the morphology of both plants. Help Rohit.*

(A) What are the two types of growth seen here?

(B) Which type of growth is predominant in each plant?

(C) Write one difference and one similarity between these two types of growth.

Ans. (A) Primary growth and secondary growth.

(B) In the first plant, primary growth is predominant, and in the second plant, secondary growth is predominant.

(C) **Difference:** In primary growth, the length of the plant increases, whereas in secondary growth the girth of the plant increases.

Similarity: In both of these growths, meristematic tissues are involved.

17. *Guava is one of the most important fruits of India, it is considered to be a poor man's apple. The guava tree is a native of Tropical America, but now it is found in all parts of the tropics. Guava is cultivated in 148200 hectares (ha), with a production of 163 million tons all over the country.*

(A) What are the factors the plant was lacking?

(a) Water **(b) Light**

(c) Soil nutrients **(d) Both (a) and (b)**

(B) What is the role of water in the growth of plants?

(a) Maintains turgidity of cell.

(b) Provide a medium for enzymatic activity.

(c) Production of energy.

(d) Both (a) and (b).

(C) What is the role of light in the growth of plants?

(a) Synthesis of photosynthetic pigments.

(b) Maintains turgidity of cell.

(c) Synthesis of protoplasm.

(d) None of the above.

(D) What are the other factors that affect the growth of plants?

(a) Light **(b) Temperature**

(c) Hormones **(d) All of these**

(E) The correct chronological sequence of developmental stages in plants:

(a) Germination → Vegetative growth → Flowering → Fruiting

(b) Flowering → Fruiting → Germination → Vegetative growth

(c) Germination → Flowering → Vegetative growth → Fruiting

(d) Flowering → Fruiting → Vegetative growth → Germination

Ans. (A) *(d) Both (a) and (b)*

Explanation: Since leaves of plants have wilted so, it means transferred plant is not getting enough water. The plant was also kept in dark which indicates that the plant was not getting any sunlight.

(B) *(d) Both (a) and (b)*

Explanation: Water helps to maintain the turgidity of cells and also provides a medium for enzymatic activity.

(C) *(a) Synthesis of photosynthetic pigments*

Explanation: Sunlight is required for the synthesis of photosynthetic pigments like chlorophyll.

(D) *(d) All of the above*

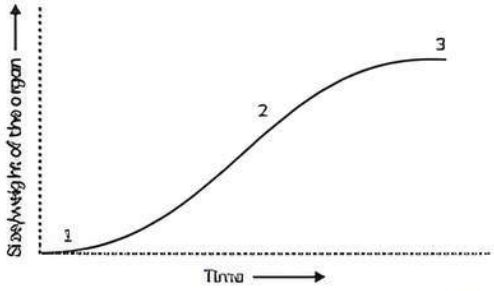
Explanation: Light, temperature, and phytohormones, all are important factors that affect the growth of plants.

(E) *(a) Germination → Vegetative growth → Flowering → Fruiting.*

VERY SHORT ANSWER Type Questions (VSA)

[1 mark]

18. In the figure of the sigmoid growth curve given below, label segments 1, 2, and 3.



[NCERT Exemplar]

Ans. This graph indicates geometric growth in plants where 1 represents lag phase; 2 represents log/exponential phase; and 3 represents stationary phase.

19. Growth is one of the characteristics of all living organisms. Do unicellular organisms also grow? If so, what are the parameters?
[NCERT Exemplar]

Ans. Yes, unicellular organisms also grow by increasing the number of cells.

Growth of unicellular organisms can be measured using two different parameters *i.e.*, changes in cell mass and cell number.

Related Theory

Growth is defined as the increase in mass and cell number of an organism. Living beings show internal growth (intrinsic growth) whereas non-living things show external growth also called extrinsic growth.

20. Write the mathematical expression for geometric growth with the meaning of each term.

Ans. The mathematical expression of geometric growth is $W_1 = W_0 e^{rt}$

Related Theory

Where, W_1 = final size (weight, height, number, etc.)
W_0 = initial size at the beginning of the growth
r = growth rate
t = time of growth
e = base of natural logarithms

21. Name the meristem which is responsible for primary and secondary growth.

Ans. **Primary growth:** Apical meristem and intercalary meristem.

Secondary growth: Lateral meristems, namely, vascular cambium and cork cambium.

Related Theory

Primary growth is the type of growth that causes an increase in the length of plant parts whereas secondary growth increases the girth or diameters of plants.

22. What is the relative growth rate?

Ans. Relative growth rate is defined as the growth per unit time per unit of initial growth or, the relative growth rate is the growth rate per unit of initial growth.

23. What are the conditions required for plant growth? **[Diksha]**

Ans. Water, oxygen, nutrients, optimum temperature, light, gravity, and plant growth regulators.

SHORT ANSWER Type-I Questions (SA-I)

[2 marks]

24. A primary root grows from 5 cm to 19 cm in a week. Calculate the growth rate and relative growth over the period.
[Delhi Gov. QB 2022]

Ans. (1) Growth = 19 – 5 = 14 cm, Period = 7 days

$$\text{Growth rate} = \frac{14}{7} = 2 \text{ cm/day}$$

(2) Initial growth = $\frac{7}{5}$ cm

$$\text{Growth rate per day} = \frac{19-5}{7} = 2 \text{ cm}$$

$$\text{Relative growth rate} = \frac{2}{5} \times 100 = 40\%$$

25. What are the structural characteristics of:

(A) Meristematic cells near root tip?

(B) The cells in the elongation zone of the root?

[NCERT Exemplar]

Ans. (A) Meristematic cells near the root tip have a large nucleus, dense protoplasm, thin cellulose walls and plasmodesmatal connections occur abundantly amongst the meristematic cells.

(B) The cells in the elongation zone of the root show thickened walls due to the deposition of material, increase in cell size, and many vacuoles.

26. In a slide showing different types of cells, can you identify which type of the cell may be meristematic and the one which is incapable of dividing and how? [NCERT Exemplar]

Ans. Meristematic cells have very thin walls and are rich in protoplasm, whereas the cells which are incapable of dividing will have very thick walls and fewer vacuoles. These characteristics can be used for the given identification.

27. What is the reason behind the growth being unique in plants?

Ans. Plants have the capacity for unlimited growth for their whole life. This makes them unique. This ability of plants is due to the presence of meristematic cells at various locations inside their body. The meristematic cell can divide continuously throughout the life of the plant. Due to this, new cells are always being added to the body of the plant, and such a type of growth in plant is called an open form of growth.

SHORT ANSWER Type-II Questions (SA-II)

[3 marks]

28. What is the difference between primary and secondary growth?

Ans.

Primary growth	Secondary growth
Growth in which the length of the plant increases.	Growth in which the girth or diameter of the plant increases.
Occurs by the action of apical and intercalary meristem.	Occurs by the action of lateral meristem.

29. Arithmetic is found to be different from geometric growth. How?

Ans.

Arithmetic growth	Geometric growth
Cell division occurs by mitosis and only one daughter cell divides continuously whereas other cells undergo differentiation and become permanent.	Growth and division occur in every cell with all the daughter cells growing and dividing again.
Its graph is linear.	Its graph is sigmoid.
$L_t = L_0 + rt$	$W_1 = W_0 e^{rt}$

30. In the chapter, you studied three phases of growth. Define each.

Ans. Phases of growth are divided into three phases: meristematic phase, elongation phase and maturation phase.

(1) The meristematic phase or phase of cell division occurs in the areas where meristematic cells are present and it is the first phase of growth in plants. It generally occurs at the root and shoot tip of the plant. At this phase of growth, cells have dense protoplasm, contain a large nucleus, have a high respiration rate, high rate of mitosis, and the cell wall is thin and made up of cellulose with abundant plasmodesmata connections so that cells can communicate with each other.

(2) The second phase of growth is called the elongation phase or phase of enlargement. Cells found in this zone have increased vacuolation, deposition of materials on the cell wall increases, and increase in cell size.

(3) The third and last phase of growth is called the maturation phase or phase of differentiation. The cells are the largest and the walls are thickest in this phase.

LONG ANSWER Type Questions (LA)

[4 & 5 marks]

31. There are some conditions which are essential for the growth of plants. What are they? Describe in detail.

Ans. The necessary conditions for the growth of plants are water, oxygen, nutrients, optimum temperature, light, gravity, and plant growth regulators. Water maintains the turgidity of growing cells and provides a medium for enzymatic activities. Oxygen helps in releasing energy by oxidising food and is essential for the growth and development of plants. The plants which grow in water logging conditions, their growth of roots is inhibited due to the reduced availability of oxygen to roots. Nutrients are required for the synthesis of protoplasm and the production of energy. Temperature is also essential because only at optimum temperature do plants show maximum growth, and at temperatures higher or lower than the optimum temperature, the growth is reduced. Optimum temperature is required for efficient functioning of enzymes in plant. Light is required for the synthesis of photosynthetic pigments and photosynthesis. Light plays an important role in photoperiodism. Whereas, gravity determines the direction of orientation of the main root stem and branches.

32. What is the efficiency index, absolute, and relative growth rate?

Ans. The 'r' expressed in the equations of growth is the relative growth rate. This ability of plants to produce new plant material is called the efficiency index. The increase in the plant material is deduced by looking at the initial size of the plant, *i.e.* W_0. Quantitative comparison between the growths of living system can be made using two ways:

First is the absolute growth rate, which is the measurement and comparison of total growth per unit time.

The second is the relative growth rate, which is defined as the growth per unit time per unit of initial growth or, the relative growth rate is the growth rate per unit of initial growth.

Absolute growth rate = growth/ time

Relative growth rate = growth rate/initial size.

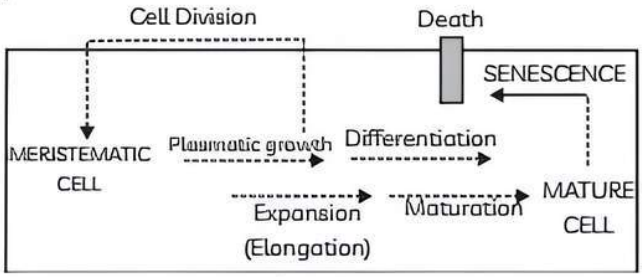
PLANT DEVELOPMENT AND GROWTH REGULATORS

2

TOPIC 1

DEVELOPMENT

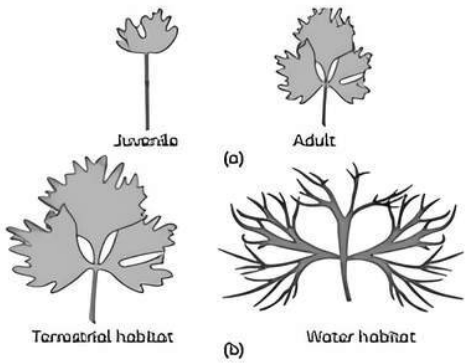
All changes that an organism goes through during its life cycle from seed germination to senescence are called development. It is also applicable to tissue and organs. Development can be indicated by sequence in plants as:



Sequence of the developmental process in a plant cell

Plants generate various structures by following distinct paths in response to their environment or phases of life. This ability is known as plasticity, as shown in cotton, coriander, and larkspur heterophylly. In such plants, the leaves of the juvenile plant differ from those of the adult plant in shape. It is called developmental heterophylly. In buttercup, however, the difference in the shape of leaves generated in the air and those produced in the water reflects heterophyllous development as a function of the environment. This is called environmental heterophylly.

As a result, growth, differentiation, and development are all tightly linked events in a plant's existence. Development is defined as the sum of growth and differentiation in a broad sense. Plant development (both growth and differentiation) is influenced by both internal and extrinsic influences. The former covers both intracellular (genetic) and intercellular (chemicals like plant growth regulators), whereas the latter includes light, temperature, water, oxygen, nutrition, etc.



Heterophylly in (a) Larkspur and (b) Buttercup

Plant Growth Regulators

Characteristics

PGRs (plant growth regulators) are small, simple molecules that come in a variety of chemical configurations. They could be indole-3-acetic acid (IAA), adenine derivatives (N6-furfuryl amino purine, kinetin), carotenoids (abscisic acid, ABA), terpenes (gibberellic acid, GA_3), or gases (ethylene, C_2H_4). In the literature, plant growth regulators are referred to as plant growth chemicals, plant hormones, or phytohormones. Based on their roles in a living plant body, PGRs can be separated into two classes, plant growth promoters and plant growth inhibitors. Plant growth promoters perform growth promoting activities like cell division, cell expansion, pattern creation, tropic growth, flowering, fruiting, and seed formation. Auxins, gibberellins, and cytokinins are examples of plant growth promoters. Plant responses to wounds and biotic and abiotic stresses are influenced by the PGRs of the other group. Plant growth inhibitors generally induce dormancy and abscission. Abscisic acid is purely a plant growth inhibitor. Ethylene, a gaseous PGR, could belong to either of these classes, but it is primarily a growth inhibitor.

Discovery of Plant Growth Regulators

Interestingly, each of the five major classes of PGRs was discovered by chance. All of this began with Charles Darwin and his son Francis Darwin's discovery that the coleoptiles of canary grass bend towards the light when exposed to unilateral illumination (phototropism). Following a series of trials, it was determined that the coleoptile's tip was the source of transmittable effect that caused the entire coleoptile to bend. F.W. Went isolated auxin from the tips of coleoptiles of oat seedlings.

The fungal pathogen *Gibberella fujikuroi* causes the 'bakanae' (foolish seedling) disease of rice seedlings. When rice seedlings were treated with sterile fungal filtrates, symptoms of the disease appeared, according to E. Kurosawa (1926). That active substance was later identified as gibberellic acid.

F. Skoog and his co-workers found that callus from internodal segments of tobacco proliferate only when in addition to auxin, the nutritive medium is provided with vascular tissue extracts, yeast extract,

coconut milk, or DNA. Miller et al later discovered and crystallised the active molecule that promotes cytokinesis which he named kinetin.

During the mid 1960s, three independent researchers reported the purification and chemical characterisation of three different kinds of inhibitors: inhibitor-B, abscission II and dormin. Later all three were proved to be chemically identical. It was named Abscisic Acid (ABA).

Cousins confirmed the release of a volatile substance from ripened oranges that hastened the ripening of stored unripened bananas. Later this volatile substance was identified as ethylene, a gaseous plant growth regulator/hormone.

Important

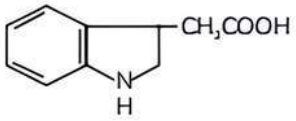
➥ *Phytohormones or plant hormones are examples of plant growth regulators. Technically a plant hormone is a chemical substance other than a nutrient produced naturally in plants, which may be translocated to another region, for regulating one or more physiological reactions when present in low concentration.*

Physiological Effects of Plant Growth Regulators

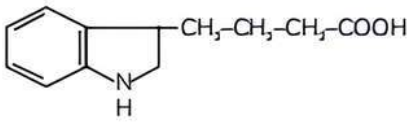
Auxins

Auxins (from the Greek '*auxein*' to grow) were discovered in human urine for the first time. The term 'auxin' refers to indole-3-acetic acid (IAA) as well as other natural and synthetic chemicals with growth-regulating capabilities. They are produced primarily by the developing apices of stems and roots, from which they travel to their action zones.

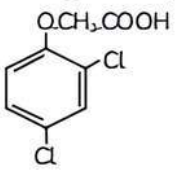
Plant auxins such as IAA and indole butyric acid (IBA) have been identified. These are natural auxins. Synthetic auxins include NAA (naphthalene acetic acid) and 2,4-D (2,4-dichlorophenoxyacetic acid). All of these auxins have a long history of application in agricultural and horticultural practices.



Indole Acetic Acid (IAA)



Indole Butyric Acid (IBA)



2-4 Dichlorophenoxy acetic acid (2-4 D)

some common auxins

Functions:

(1) They aid in the rooting of stem cuttings, which is a common method of plant multiplication.

(2) Auxins encourage flowering in plants, such as pineapples. They help to prevent early fruit and leaf drop but encourage the abscission of older mature leaves and fruits.

(3) In most higher plants, apical dominance occurs when the developing apical bud controls the growth of the lateral (axillary) buds.

(4) The growth of lateral buds is common after decapitation (removal of the shoot tips). It is commonly used in tea plantations and hedge-making.

(5) Auxins can also induce parthenocarpy in plants, such as tomatoes.

(6) Herbicides are commonly used with them. The herbicide 2,4-D, which is commonly used to control dicotyledonous weeds, has no effect on mature monocotyledonous plants. Gardeners use it to prepare weed-free lawns.

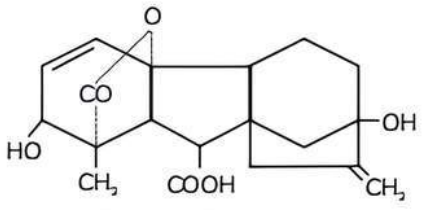
(7) Auxin also aids cell division and governs xylem differentiation.

Important

➥ *Auxins are weakly acidic growth hormones having an unsaturated ring structure and capable of promoting cell elongation, especially of shoots (more pronounced in decapitated shoot and shoot segments) at a concentration of less than 100 ppm which is inhibitory to the roots. Among the growth regulators, auxins were the first to be discovered.*

Gibberellins

Gibberellins are another type of PGR that promotes growth. Gibberellins have been found in a wide variety of species, including fungi and higher plants. GA_1, GA_2, GA_3, and so on are the designations. Gibberellic acid (GA_3), on the other hand, was one of the first gibberellins to be discovered. It (GA_3) is one of the most intensively studied gibberellins. All GAs are acidic in nature. Plants have a wide range of physiological reactions when we treat them with gibberellins.



Gibberellic Acid (GA_3)

Functions:

(1) Gibberellins are used to increase the length of stalk of grape stems because of their potential to promote an increase in axis length.

(2) Gibberellins cause fruits to elongate and improve their shape, such as apples.

(3) Gibberellins also delay senescence. As a result, the fruits can be left on the tree for a longer period, to extend the market period.

(4) In the brewing industries, GA_3 is used to speed up the malting process.

(5) Sugarcane stems store carbohydrates in the form of sugar. Spraying gibberellins on sugarcane crops improves stem internode length, resulting in the yield by as much as 20 tonnes per acre. Spraying GAs on juvenile conifers shortens the maturation process, resulting in earlier seed production.

(6) Gibberellins also promote bolting process (internode elongation just prior to flowering) in beets, cabbages, and many other plants with rosette habits. It can replace cold treatment.

Important

➥ *All GAs are acidic and GA_3 was the first gibberellin to be discovered. Gibberellins are weakly acidic growth hormones having gibbane ring structure which causes cell elongation of intact plants in general and increased internodal length of genetically dwarfed plants. For example: Pea, Corn.*

Example 2.1: Case Based:

PGRs (plant growth regulators) are small, basic molecules that come in a variety of chemical configurations. They could be indole-3-acetic acid (IAA), adenine derivatives (N6-furfuryl amino purine, kinetin), carotenoids (abscisic acid, ABA), terpenes (gibberellic acid, GA_3), or gases (ethylene, C_2H_4). In the literature, plant growth regulators are referred to as plant growth chemicals, plant hormones, or phytohormones. Based on their roles in a living plant body, PGRs can be separated into two classes: Plant growth promoters and plant growth inhibitors. Auxins, gibberellins, and cytokinins are examples of plant growth promoters. While abscisic acid is purely a plant growth inhibitor and ethylene (a gaseous PGR) could belong to either of these classes, but it is primarily a growth inhibitor.

(A) Plant growth regulator which was first isolated from human urine?

(a) Auxins (b) Gibberellins

(c) Cytokinins (d) Abscisic acid

(B) Which of the following is a natural auxin?

(a) IBA (Indole Butyric Acid)

(b) NAA (Naphthalene Acetic Acid)

(c) 2, 4-D (2, 4-Dichlorophenoxyacetic acid)

(d) 2, 4, 5-T (2, 4, 5-Trichlorophenoxyacetic acid)

(C) Define the term phytohormones.

(D) Define the term apical dominance and also write the name of the hormone that controls this process.

(E) Assertion (A): Lack of sufficient Gibberellin is responsible for the smaller size of the grapes.

Reason (R): Gibberellin is a type of PGR that promotes growth.

(a) Both A and R are true and R is the correct explanation of A.

(b) Both A and R are true and R is not the correct explanation of A.

(c) A is true but R is false.

(d) A is false but R is true.

Ans. (A) *(a) Auxins*

Explanation: Auxins (from the Greek '*auxein*': to grow) were discovered in human urine for the first time.

(B) *(a) IBA (Indole Butyric Acid)*

Explanation: Plant auxins such as IAA and indole butyric acid (IBA) are natural auxins. Synthetic auxins include NAA (naphthalene acetic acid) and 2, 4-D (2, 4-dichlorophenoxyacetic acid) and 2, 4, 5-T (2, 4, 5-Trichlorophenoxyacetic acid). All of these auxins have a long history of application in agricultural and horticultural practices.

(C) Phytohormones are referred to as plant growth chemicals, plant hormones, or plant growth regulators. These are small, basic molecules that come in a variety of chemical configurations. They could be naturally produced within the plants or synthesised in laboratories. These PGRs mainly control and modify the physiological processes like growth, development and movement of plants.

(D) Apical dominance is defined as the phenomenon of higher plants in which the developing apical bud becomes dominant and it controls or suppresses the growth of the lateral (axillary) buds. Auxin is the hormone that controls the process of apical dominance.

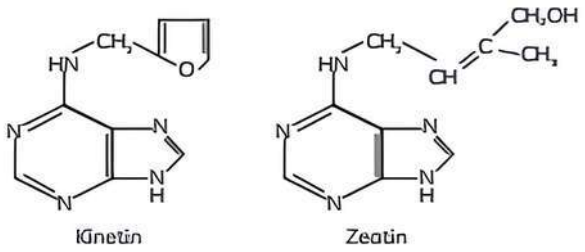
(E) *(a) Both A and R are true and R is the correct explanation of A.*

Explanation: Gibberellins are a type of PGR that promotes growth. This hormone is used to increase the length of the stalks of grape stems because of its potential to promote an increase in axis length. So, it clearly states that a lack of this hormone will be responsible for the smaller size of the grapes.

Cytokinins

Cytokinins were identified as kinetin (a modified form of adenine, a purine) in autoclaved herring sperm DNA and have unique effects on cytokinesis. Kinetin is not found in plants naturally. Zeatin was isolated from corn kernels and coconut milk during a search for natural compounds with cytokinin-like properties.

Several naturally occurring cytokinins, as well as several synthesised compounds with cell division-promoting action, have been discovered since the discovery of zeatin.



Two common cytokinins

Natural cytokinins are produced in areas with fast cell division, such as root spices, growing shoot buds, and immature fruits. It helps with the formation of new leaves, chloroplasts in leaves, lateral shoot growth, and adventitious shoot formation. Cytokinins overcome the apical dominance. It promotes nutrient mobilisation, which helps to delay leaf senescence. Thus, its function is antagonistic to auxin which promotes apical dominance.

Ethylene

Ethylene is a gaseous PGR. It is produced in huge quantities by senescent tissues and ripening fruits. The effects of ethylene on plants include horizontal seedling growth, axis swelling, and apical hook development in dicot seedlings. Ethylene causes senescence and abscission in plant organs, especially leaves and flowers. Ethylene is highly effective in fruit ripening. It hastens the ripening of the fruit by increasing the rate of respiration.

Ethylene breaks seed and bud dormancy, initiates germination in peanut seed, potato tuber sprouting. Ethylene promotes rapid internode/petiole elongation in deep water rice plants. It aids in keeping the leaves and upper sections of the shoot above water. Ethylene also encourages root growth and formation of root hairs, allowing plants to expand their absorption surface. In pineapples, ethylene is used to start flowering and synchronize the fruit set. It also induces flowering in mango.

Ethylene is one of the most extensively used PGRs in agriculture since it governs so many physiological processes. The compound ethephon is the most commonly used source of ethylene. In an aqueous solution, ethephon is quickly absorbed and carried throughout the plant, where it slowly releases ethylene. Ethephon stimulates abscission in flowers and fruits and hastens fruit ripening in tomatoes and apples (thinning of cotton, cherry, walnut). It promotes female flowers in cucumbers and thus increases yield.

Example 2.2: Priya loved to do gardening. She used to take care of her plants very well. A gardener suggested her to spray ethylene over the plants as it is found to be very helpful. Write a few effects of ethylene as the gardener.

Ans. The various functions performed by ethylene hormone are as follows:

(1) Ethylene helps in horizontal seedling growth, axis swelling, and apical hook development in dicot seedlings.

(2) This hormone is highly effective in fruit ripening. It hastens the ripening of the fruit by increasing the rate of respiration.

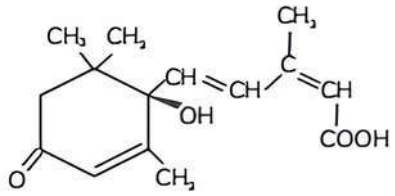
(3) Ethylene breaks seed and bud dormancy.

(4) It promotes rapid internode / petiole elongation in deep water rice plants.

(5) Ethylene also encourages root growth and formation of root hairs, allowing plants to expand their absorption surface.

Abscisic acid

Abscisic acid (ABA) is known for its role in controlling abscission and dormancy, as previously stated. However, like other PGRs, it has a variety of additional effects on plant growth and development. It serves as a general plant growth inhibitor as well as a metabolic inhibitor. Seed germination is inhibited by ABA. ABA enhances plant tolerance to environmental stress by stimulating the closure of stomata in the epidermis. As a result, it is also known as the 'stress hormone'. Seed development, maturity, and dormancy are all aided by ABA.



Abscisic Acid

ABA induces dormancy in seeds, allowing them to tolerate desiccation and other growth-inhibiting conditions. In the majority of cases, ABA is antagonistic to GA. To summarise, one or more PGRs play a role in every phase of plant growth, differentiation, and development. Complementary or antagonistic functions are possible. These could be synergistic or individualistic. Similarly, there are a variety of events in a plant's life where many PGRs interact to influence that event, such as dormancy in seeds/buds, abscission, senescence, apical dominance, and so on.

Keep in mind that PGR is simply one type of intrinsic control. Along with genomic control and extrinsic factors, they play a key role in plant growth and development. Many of the extrinsic factors like temperature and light control plant growth and development *via* PGR. Some examples of such incidents include vernalisation flowering, dormancy, seed germination, plant movements, etc.

Important

➥ *ABA is known as the stress hormone as it enhances plant tolerance to diverse stresses like drought, flood, salinity, climate stresses, etc.*

Example 2.3: **Case Based:**

Plants require various chemical components to control their growth and development since they require oxygen, water, sunlight, and nutrients to develop and thrive. Plant Growth Regulators are a class of chemical compounds that are naturally produced by plants. These are simple organic molecules with a variety of chemical make-ups. Phytohormones, plant growth chemicals, and plant growth hormones are other names for them. They have the ability to both accelerate and slow plant growth.

(A) Kinetins are not found in plants naturally and is a modified form of:

(a) Guanine **(b) Adenine**

(c) Cytosine **(d) Thymine**

(B) Gibberellins are a category of PGR that helps in growth. Which gibberellin was the first one to be discovered?

(a) GA_1 **(b) GA_2**

(c) GA_3 **(d) None of the above**

(C) Give two applications of auxins in agricultural and horticultural practices.

(D) Ethylene is produced in large quantities by senescent tissues and ripening fruits. Elaborate.

(E) Assertion (A): **ABA functions as a metabolic inhibitor.**

Reason (R): **ABA is a gaseous PGR.**

(a) Both A and R are true and R is the correct explanation of A.

(b) Both A and R are true and R is not the correct explanation of A.

(c) A is true but R is false.

(d) A is false but R is true.

Ans. **(A)** *(b) Adenine*

Explanation: Cytokinins were first identified as kinetins and kinetin is a modified form of adenine which is a purine.

(B) *(c) GA_3*

Explanation: The first gibberellin that was discovered is GA_3.

(C) The two applications of auxins in agricultural and horticultural practices are as follows:

(1) Auxins help in the promotion of rooting in stem cuttings and this feature of auxin can be used for plant propagation.

(2) They promote flowering in pineapples and induce parthenocarpy in tomatoes.

(D) The effects of ethylene on plants include horizontal growth of seedling, axis swelling, and apical hook formation in dicot seedlings. Ethylene causes senescence and abscission in plant organs, especially leaves and flowers. Ethylene works as a ripening agent. It hastens the ripening of the fruit by increasing the rate of respiration.

(E) *(c) A is true but R is false.*

Explanation: ABA or abscisic acid functions as a plant growth inhibitor and a metabolic inhibitor so the assertion (A) is correct. But ABA is not a gaseous PGR, in fact, ethylene is a gaseous PGR. So the reason (R) is incorrect.

Example 2.4: **Why is abscisic acid also known as stress hormone?** **[NCERT]**

Ans. Abscisic acid works as a metabolic inhibitor as well as a general plant growth inhibitor. ABA stops seed germination. By promoting the closure of stomata in the epidermis, ABA improves plant tolerance to a variety of environmental stresses. As a result, it is also referred to as the stress hormone. ABA helps in seed growth, maturation, and dormancy. Seeds can resist desiccation and other growth-inhibiting environments because ABA induces dormancy in them.

OBJECTIVE Type Questions

[1 mark]

Multiple Choice Questions

1. Ethylene is used for:

(a) Retarding ripening of tomatoes.

(b) Hastening the ripening of fruits.

(c) Slowing down the ripening of apples.

(d) Both (b) and (c)

[NCERT Exemplar]

Ans. *(b) Hastening the ripening of fruits.*

Explanation: Ethylene is used for hastening the ripening of fruits like tomatoes and apples. It is not used to slow down the ripening.

Related Theory

➥ *The compound ethephon is the most commonly used source of ethylene. In an aqueous solution, ethephon is quickly absorbed and transported to various parts of the plant, where it releases ethylene slowly. Ethephon stimulates abscission in flowers and fruits and hastens fruit ripening in tomatoes and apples (thinning of cotton, cherry, walnut).*

2. Coconut water contains:

(a) ABA **(b) auxin**

(c) cytokinin **(d) gibberellin**

[NCERT Exemplar]

Ans. *(c) cytokinin*

Explanation: It has been mentioned that zeatin which has cytokinin-like properties is isolated from coconut milk or coconut water.

Related Theory

Zeatin was isolated from corn kernels and coconut milk during a search for natural compounds with cytokinin-like properties.

3. Which of the following is not a biennial plant?

(a) Mango **(b) Sugar Beet**
(c) Cabbage **(d) Carrot** **[Diksha]**

Ans. *(a) Mango*

Explanation: Sugar beet, cabbage, and carrot are biennial plants but mango is not.

Related Theory

Biennials include sugar beets, cabbages, carrots, etc. These plants complete their life cycle in two growing seasons.

4. The chemicals that originate at the tip of the stem and govern growth elsewhere are called:

(a) Ethylene **(b) Cytokinins**
(c) Auxins **(d) Gibberellins**

Ans. *(c) Auxins*

Explanation: Auxins were isolated from the tip of the stem and they had a transmittable influence that caused the bending of the coleoptile.

5. Gibberellins were discovered for the first time in:

(a) Sperm DNA
(b) Ripening fruits
(c) Fungus
(d) Coleoptiles of oat seedlings

Ans. *(c) Fungus*

Explanation: Gibberellins caused the disease of rice seedlings and were isolated from fungi. The other three options are incorrect as auxins were isolated from coleoptiles of oat seedlings and cytokinins were discovered from sperm DNA.

Related Theory

Gibberellin was first recognized in 1926 by a Japanese scientist. Kurosawa was studying bakane, the 'foolish seedling disease' in rice. It was first isolated in 1935 by Teijiro Yabuta and Sumiki from fungal strains provided by Kurosawa from Gibberella fujikurol. Yabuta named the isolate as gibberellins.

6. Statement A: Vitamins are considered as plant growth hormones.
Statement B: Vitamins have no specific influence on growth of plants.

(a) Both A and B are correct.
(b) Both A and B are incorrect.
(c) Only A is correct.
(d) Only B is correct.

Ans. *(c) Only B is correct.*

Explanation: Vitamins have no particular effect on how plants develop. They are necessary food components that an organism needs in minute amounts. Through indirect nutritional effects, they have an impact on growth and metabolism.

7. Statement A: Response of plants to low temperatures is regulated by a hypothetical hormone.
Statement B: Response of plants to different periods of light is also regulated by a hypothetical hormone.

(a) Both the statements are true.
(b) Both the statements are false.
(c) Statement A is true but statement B is false.
(d) Statement B is true but statement A is false.

Ans. *(a) Both the statements are true.*

Explanation: Vernalisation is the process which improves qualitative and quantitative flowering in plants by exposure to cold conditions. Response of plants to low temperatures is regulated by a hypothetical hormone, Vernalin. Photoperiodism is the response of plants to the duration of exposure to light and dark conditions. It is also regulated by a hypothetical hormone, Florigen.

8. Which of the following is known to cause flowering in pineapples?

(a) Cytokinins **(b) Ethylene**
(c) Gibberellins **(d) Auxins**

Ans. *(b) Ethylene*

Explanation: Initiation of flowering and synchronising fruit-set in pineapples is caused by ethylene.

9. It acts as an inhibitor of plant metabolism and helps seeds to withstand desiccation:

(a) IAA **(b) GA_1**
(c) ABA **(d) Cytokinins**

Ans. *(c) ABA*

Explanation: Among the above-mentioned plant hormones, only ABA is a plant growth inhibitor. It promotes seed dormancy which allows seeds to tolerate desiccation and extremes of temperature.

Caution

Students must remember the abbreviations of the PGRs for a better understanding of the chapter. Here, IAA means Indole-3 Acetic acid while ABA means Abscisic acid.

10. **The main group of natural plant growth regulators are:**

(I) Cytokinins **(II) Auxins**

(III) Abscisic acid **(IV) Gibberellins**

Options:

(a) Only (I) **(b) (I) and (III)**

(c) Only (IV) **(d) All of these**

Ans. *(d) All of these*

Explanation: There are five main groups of natural plant growth regulators. These are:

(1) Auxins (2) Gibberellins

(3) Cytokinins (4) Abscisic acid

(5) Ethylene

Assertion-Reason (A-R)

Given below are two statements labelled as Assertion (A) and Reason (R). Select the most appropriate answer from the options given below:

(a) Both A and R are true and R is the correct explanation of A.

(b) Both A and R are true and R is not the correct explanation of A.

(c) A is true but R is false.

(d) A is false but R is true.

11. **Assertion (A):** **Plants respond to the environment or phases of life to form different kinds of structures.**

Reason (R): **This phenomenon is called plasticity.**

Ans. *(a) Both A and R are true and R is the correct explanation of A.*

Explanation: Plasticity is the ability to change under the influence of internal or external stimuli. Due to plasticity, plants follow different pathways to respond to the environment or phases of life to form different structures. For example, heterophylly in cotton.

12. **Assertion (A):** **Auxins were isolated from human urine.**

Reason (R): **Auxins are sometimes used as herbicides.**

Ans. *(b) Both A and R are true and R is not the correct explanation of A.*

Explanation: Both the statements are correct as auxins were isolated from human urine and they are also used as herbicides. But (R) is not the explanation of (A).

CASE BASED Questions (CBQs)

[**4** & **5** marks]

Read the following passages and answer the questions that follow:

13. *Ethylene is a straightforward gaseous PGR. It is produced in huge quantities by senescent tissues and ripening fruits. Horizontal seedling growth, axis swelling, and apical hook development in dicot seedlings are all effects of ethylene on plants.*

Ethylene is a gaseous phytohormone and the first of this hormone class to be discovered. It is the simplest olefin gas and is biosynthesized by plants to regulate plant development, growth, and stress responses via a well-studied signalling pathway. One of the earliest reported responses to ethylene is the triple response. This response is common in dicot seedlings grown in the dark and is characterised by reduced growth of the root and hypocotyl, an exaggerated apical hook, and a thickening of the hypocotyl.

(A) Given below are the names of a few compounds. Which of them is used as a source of ethylene?

(a) Enamides **(b) Ethephon**

(c) Enol **(d) Ethers**

(B) Which statement is incorrect?

(a) Ethylene can cause fruit ripening.

(b) Ethylene helps in root growth and root hair formation.

(c) Ethylene induces parthenocarpy in tomatoes.

(d) Ethylene causes flowering in mango.

(C) Ethylene enhances the respiration rate during the ripening of fruits. This is called:

(a) Respiratory climactic

(b) Climatic respiration

(c) Climatic breathing

(d) None of the above

(D) Which of the following PGRs is one of the most commonly used in agriculture?

(a) ABA **(b) Auxins**

(c) Cytokinins **(d) Ethylene**

(E) How does ethylene help deepwater rice plants?

(a) Promoting female flowers

(b) Germination in their seeds

(c) Internode elongation

(d) Apical hook formation

Ans. (A) *(b) Ethephon*

Explanation: Ethephon is widely used as a source of ethylene as it is readily absorbed in aqueous solutions and is transported within the plants. It then releases ethylene slowly.

(B) *(c) Ethylene induces parthenocarpy in tomatoes.*

Explanation: Ethylene is used for fruit ripening, root growth and root hair formation, and it causes flowering in mango. But ethylene does not induce parthenocarpy in tomatoes, this is caused by auxins.

(C) *(a) Respiratory climactic*

Explanation: Ethylene is an excellent ripening agent. By raising the rate of respiration, it speeds up the ripening of the fruit. This is called the respiratory climactic.

(D) *(d) Ethylene*

Explanation: Ethylene regulates many physiological processes and so it is one of the most widely used PGRs in agriculture and horticulture.

(E) *(c) Internode elongation*

Explanation: Ethylene helps deepwater rice plants by promoting fast petiole or internode elongation.

14. *PGRs are classified into two groups based on their functions in the living plant body. These are Plant Growth Promoters and Plant Growth Inhibitors. Growth-promoting mechanisms include cell division, cell expansion, pattern creation, tropic growth, flowering, fruiting, and seed generation. Plant growth promoters include auxins, gibberellins, and cytokinins. The PGRs of the other group impact plant responses to wounds and biotic and abiotic stresses. They are also involved in growth-slowing processes like dormancy and abscission. PGR abscisic acid is a member of this group. ABA is purely a plant growth Inhibitor hormone. Ethylene, a gaseous PGR, can fall under either of these categories, but its primary function is to impede growth.*

(A) Describe the observation of Charles and Francis Darwin.

(B) Which PGR was isolated by F.W. Went from oat seedlings?

(C) (i) A fungal pathogen caused the disease of rice seedlings known as 'bakane'. Name the fungal pathogen and name the scientist who reported this.

(ii) Inhibitor-B, abscission II and dormin were proved to be chemically identical later. What was the common name given to them?

Ans. (A) Charles Darwin and his son Francis Darwin discovered that the coleoptiles of canary grass bend towards the light source when exposed to unilateral illumination (phototropism). Following a series of trials, it was determined that the coleoptile's tip was the source of the transmittable effect that caused the entire coleoptile to bend.

(B) Auxin was isolated by F.W. Went from oat seedlings.

(C) (i) The name of the fungal pathogen is *Gibberella fujikurol.* E. Kurosawa reported the symptoms of the disease in the uninfected rice seedlings when they were treated with sterile filtrates of the fungus.

(ii) The common name given to these chemically identical compounds was abscisic acid or ABA.

VERY SHORT ANSWER Type Questions (VSA)

[1 mark]

15. A farmer observed some broad-leaved weeds on a wheat crop farm. Which plant hormones, would you suggest removing them? [Delhi Gov. QB 2022]

Ans. 2, 4-D

16. Flowering in certain plants occur only when they are exposed to low temperatures for a few weeks. Name this phenomenon. [Delhi Gov. QB 2022]

Ans. Vernalisation

17. **The cytokinesis-promoting active substance called kinetin was first discovered by which scientists?**

Ans. Skoog and Miller discovered kinetin.

18. **A farmer grows cucumber plants in his field. He wants to increase the number of female flowers in them. Which plant growth regulator can be applied to achieve this? [Diksha]**

Ans. Ethylene can be applied as it has the ability to increase the number of female flowers and hence fruits in the cucumber plants.

19. **Which phytohormone regulates apical dominance in plants?**

Ans. Auxin is the phytohormone which regulates apical dominance. If the apical bud is removed, the lateral buds sprout.

20. **IAA is also known as what?**

Ans. Indole acetic acid. It is a natural auxin.

Caution

Indole-3-acetic acid belongs to the Auxins class of plant hormones.

21. **Which hormone is also called the 'stress hormone'?**

Ans. Abscisic acid is also called the stress hormone.

22. **What was the volatile substance that was confirmed by Cousins?**

Ans. The volatile substance was ethylene that caused the ripening of unripe bananas and was discovered by Cousins.

23. **Name, the hormone released from over-ripe apples and affects all other apples in a small wooden box. [Delhi Gov. QB 2022]**

Ans. Ethylene

SHORT ANSWER Type-I Questions (SA-I)

[**2** marks]

24. **In botanical gardens and tea gardens, gardeners trim the plants regularly so that they remain bushy. Does this practice have any scientific explanation? [NCERT Exemplar]**

Ans. For plants to remain bushy, there must be some growth of lateral buds. When apical buds inhibit the growth of lateral buds then this phenomenon is called apical dominance and to avoid this gardeners trim their plants. They reduce the number of apical buds by this practice so that lateral buds can grow.

25. **Discuss the physiological functions performed by the auxins.**

Ans. (1) Auxins help to prevent early fruit and leaf drop but encourage the abscission of older mature leaves and fruits.

(2) Auxin also aids in cell division and governs xylem differentiation.

(3) It also helps in root formation in stem cuttings.

(4) It also causes apical dominance.

26. **Gibberellins were first discovered in Japan when rice plants were suffering from bakane (the foolish seedling disease) disease caused by a fungus *Gibberella fujikuroi*.**

(A) Give two functions of this phytohormone.

(B) Which property of Gibberellin caused foolish seedling disease in rice? [NCERT Exemplar]

Ans. (A) Gibberellins improve the shape and size of fruits such as apples. They also delay the onset of senescence. As a result, the fruits can be left on the tree for longer, increasing the market time.

(B) Because gibberellin stimulates internode elongation, it produces foolish seedling disease in rice.

SHORT ANSWER Type-II Questions (SA-II)

[**3** marks]

27. **Many discoveries in science have been accidental. This is true for plant hormones also. Can you justify this statement by giving an example? Also what term is used for such accidental findings? [NCERT Exemplar]**

Ans. Many discoveries in science have been accidental and this is certainly true for plant hormones. Charles Darwin and his son Francis Darwin noticed the response of coleoptiles of canary grass to unilateral illumination and how they grow towards the light source. After

a few more studies, it was concluded that the bending of the entire coleoptile was due to the fact that the tip of the coleoptile was the site of transmittable influence. F.W Went isolated auxins from the tips of coleoptiles of oat seedlings. The term 'serendipity' is used for accidental discovery.

28. Shyamlal is a farmer and he is suggested to use PGRs in his field by a shopkeeper when he went to buy some fertilizer. Mention some agriculture/horticulture applications of PGR auxin.

Ans. (1) Auxin promotes flowering in case of orchards. For example: Pineapple, litchi, etc.

(2) Auxins also induce parthenocarpy in some plants like tomatoes, cucumber, pepper, etc.

(3) Auxins like IAA, IBA, and NAA induce rooting in stem cuttings of various plants.

(4) Auxin like 2, 4-D is widely used as an herbicide to kill dicotyledonous weeds and to prepare weed-free lawns by gardeners.

(5) Auxins regulate the maturation of fruits on trees of apples, oranges and grapefruit.

29. Give three reasons why GAs are helpful for plant growth.

Ans. (1) They increase the length of grape stalks as they have the ability to increase the length of the axis.

(2) They delay senescence in plants and fruits can be left on the trees for a long time period. This extends the period of marketing.

(3) They hasten the maturity period and cause early seed development in juvenile conifers.

Caution

Students must remember that Gibberellins are utilised to lengthen grape stems because of their potential to promote an increase in axis length. Gibberellins cause fruits to elongate and improve their shape, such as apples.

30. What is development?

Ans. Development refers to all the changes that an organism goes through during its life cycle from seed germination to senescence. As a result, growth, differentiation, and development are all tightly linked events in a plant's existence. Development is defined as the sum of growth and differentiation in a broad sense. Plant development (both growth and differentiation) is influenced by both internal and external factors.

31. What would be expected to happen if :

(A) GA_3 is applied to rice seedlings?

(B) rotten fruit gets mixed with unripe fruits?

(C) you forget to add cytokinin to the culture medium? [Delhi Gov. QB 2022]

Ans. (A) If GA_3 is applied to rice seedlings, then the rice seedlings will exhibit hyper elongation of internodes of rice seedlings.

(B) When a rotten fruit gets mixed with the unripened fruits, then the rotten fruit starts releasing ethylene which ripens the unripened fruits. If the rotten fruit is kept with the unripened fruits for a prolonged-term, then it will rot all the unripened fruits too.

(C) If you forget to add cytokinin to the culture medium, then cell division, growth, and differentiation will not be observed.

Caution

Students should know that the cytokinin is added along with auxin in the culture medium. This is because both of these help in organ differentiation. The auxin helps in the development of the roots from the callus whereas the cytokinin helps in the development of the shoot from the callus. Auxin and cytokinin are used in an equal ratio to promote adequate growth.

LONG ANSWER Type Questions (LA)

[**4** & **5** marks]

32. It is known that plant growth hormones have various practical applications and they are extensively used by farmers for agriculture and horticulture practices.

(A) Name the hormone which causes the sprouting of potato tuber.

(B) Name the hormone which accelerates the malting phenomena in brewing industries.

(C) Name the plant hormone which is used to manipulate and stimulate the maturation of sugarcane crops.

(D) A hormone that influences femaleness in cucumber flowers.

(E) The hormone which is responsible for hindering the seed germination.

Ans. (A) Ethylene is the hormone which causes the sprouting of potato tuber.

(B) Gibberellin hormone is utilised to accelerate the malting phenomena in brewing industries.

(C) Ethylene is the plant hormone which is also known as the ripening hormone and is used to manipulating and stimulating the maturation of sugarcane crops by increasing the storage of sucrose in plants.

(D) Ethylene (C_2H_4) is the hormone that influences the femaleness in cucumber flowers.

(E) Abscisic acid (ABA) is the hormone which is responsible for hindering the seed germination.

33. How were cytokinins discovered and how do they help in plant growth and development?

Ans. Cytokinins were identified as kinetin (a modified form of adenine, a purine) in autoclaved herring sperm DNA and have unique effects on cytokinesis. Kinetin is not found in plants naturally. Zeatin was isolated from corn kernels and coconut milk during a search for natural compounds with cytokinin-like properties. Several naturally occurring cytokinins, as well as several synthesized compounds with cell division-promoting action, have been discovered since the discovery of zeatin. In places with rapid cell division, such as root apices, budding shoot buds, and immature fruits, natural cytokinins are produced. It helps with the formation of new leaves, chloroplasts in leaves, lateral shoot growth, and accidental shoot formation. The overthrow of apical dominance is aided by cytokinins. They promote nutrient mobilisation, which helps to delay leaf senescence.