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Growth and Development in Plants

We know that all plant organs are made up of a variety of tissues. Is there any relationship between the structure of a cell, a tissue, an organ and the function they perform? Can the structure and the function of these be changed? All cells of a plant are descendents of the zygote. Development is considered as the sum of two process-(1) Growth and (2) Differentiation. It is essential to know that the development of a mature plant from a zygote follows the highly ordered succession events. During this process, a complex body organization is formed that produces roots, leaves, branches, flowers, fruits, seeds and eventually they die. In this chapter, let us study some of the internal as well as external factors which govern and control these developmental processes.

Growth

Growth can be defined as an irreversible increase in the size and weight of an organism.

Growth as the Progressive Development of an Organism : New cells are added through the process of cell division. These cells cause growth in tissues and organs. Physiologically growth is an outcome of metabolism. Anabolic activities are synthetic and catabolic activities are degrading. Both, anabolic and catabolic activities are interlinked. When anabolic activities occur in excess of catabolic activities, growth results. There is an increase in the dry weight as an outcome of growth.

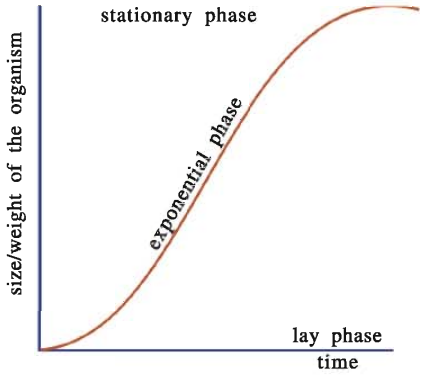
Characteristics of Growth : In plants, growth is limited to meristematic tissues only. Such a tissue constitutes shoot apex and root apex. New cells are added there and the cells increase in size. These newly added cells differentiate into tissues.

Process of Growth : Thus, three main activities are involved in the process of growth : (1) Cell division of meristematic cells (2) Enlargement of newly formed cells (3) Cellular differentiation.

Primary Growth and Secondary Growth : Growth takes place in stem, root and their sub-branches. Length increases from time to time in plant organs due to the activity of apical meristems arranged at their tips. Such a growth is called-primary growth.

In the stems and roots of dicot plants, after the completion of primary structure of organs, through the activity of lateral meristem known as cambium, the addition of new and more cells in the girth of concerned organ occurs, this is called-secondary growth. The intercalary meristem located in the nodal region of monocot plants is also responsible for growth.

Rate of Growth : The increased growth per unit time is termed as growth rate. Initially, the rate of growth in plant is slow. Then it increases very rapidly. In course of time, it again slows down. Suppose we draw a graph of growth-rate based on the increase in number of cells against time taken. Such a graph will be a typical - S - shaped graph. (S = sigmoid curve). After an initial period of slow growth-rate, an exponential period of growth follows and finally a stable state of growth occurs.

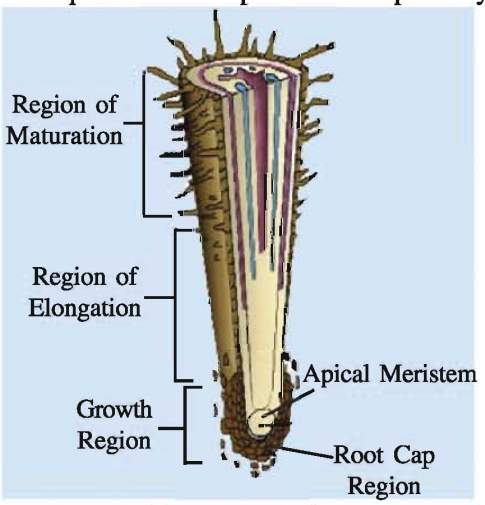


Growth Curve

We should note that such a graph of growth is obtained for growth of an organism and that of a population also. Parameters other than an increase in the number of cells can also be used in measurement of Growth.

Phases of Growth : Growth is divided into three phases : (1) Phase of cell division, (2) Phase of cell enlargement and (3) Phase of cell differentiation.

(1) Phase of Cell Division (Formation or Meristematic) : The meristematic cells located in shoot apex and root apex divide repeatedly and continuously and add new cells. The meristematic cells possess dense protoplasm, a large nucleus and a thin cell wall made up of cellulose. Faster rate of metabolism occurs in them.



Region of Root

(2) Phase of Cell Enlargement (Elongation) : In this phase, the new cells formed through cell divisions increase in size. The volume of cells increases. The growth in cell wall is mainly responsible for such enlargement. The size of vacuole in the cell also increases.

(3) Phase of Cell Differentiation (Maturation) : Now, the cells assume forms based on their functions. Their size and form become permanent. They become associated with the constitution of various tissues. The phase of becoming differentiated is called-differentiation phase.

These phases of growth are also known as distinct regions. These regions are called respectively - region of formation; region of enlargement and region of maturation. These regions can be observed in the longitudinal sections of root apex and shoot apex. The entire period, covering the period from cell division to cell differentiation is called-grand period of growth.

Factors Affecting Growth

(1) Water : Water is essential for turgidity of cells undergoing growth. Water is also required as a medium for various biochemical processes.

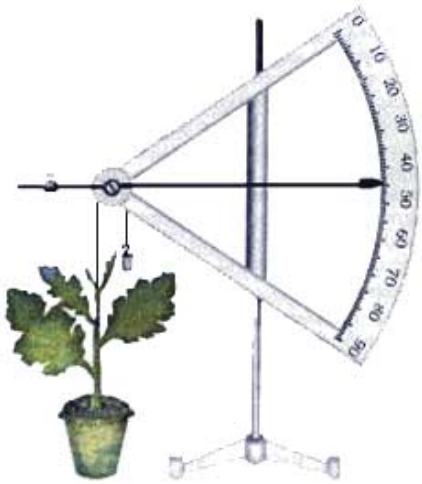
(2) Oxygen : Oxygen is inevitable for respiration.

(3) Temperature : Proper temperature is required for germination. Normally, the optimum range is between 28°C and 30°C.

(4) Light : Light is required for photosynthesis. Food is prepared in this way.

(5) Nutrients : Availability of proper amount of nutrients is required for plant growth. The materials and energy required for synthesis of protoplasm are obtained from the nutrients. Deficiency of various nutrients and various kinds of stresses hinder the process of growth.

Measurement of Growth : At a cellular level, growth is an increase in the amount of protoplasm. Since it is difficult to measure it directly, so it can be measured in some quantity which is more or less proportional to it.



Arc-Auxanometer

There are various methods of measuring growth. The growth in length of a plant can be measured by a simple measuring-tape. It can also be measured by counting an increase in the number of branches, number of leaves etc. from time to time. Similarly, it can be measured by considering the normal weight or the dry weight of the plant. The aerial spread of plant can also be taken into account.

For a more exact measurement of growth in length of a plant, an arc- auxanometer is employed. One end of a thread is tied to the apical bud area of the plant. The thread is then passed over a pulley which is attached to the apparatus and suspended by a weight attached to the other end of the thread. The position of the indicator on the arch is noted. As growth occurs, the weighed end of the thread is lowered. As this happens, the indicator also moves along the arch. This distance is measured at proper time-intervals and growth is calculated.

Development

Development is a term that includes all changes that an organism goes through during its life cycle from germination of the seed to senescence. Growth, differentiation and development are very closely related events in the life of a plant. It means that development is the sum of two processes: growth and differentiation. Development in plants(both growth and differentiation) is under the control of internal and external factors. The earlier includes intracellular(genetic) or intercellular(plant growth regulators) while the later includes light, temperature, water, oxygen, nutritients etc.

Growth-Regulators

The life of plants is controlled by a number of different hormones. The plant growth regulators(PGRs) are small, simple molecules of diverse chemical composition. Plants synthesize specific organic chemicals which act as growth regulators. Their synthesis occurs in specific regions. From there, they are conducted to some specific regions and influence growth occurring there or influence some activities there. Such an influence may be either stimulatory or inhibitory. Such chemicals are called plant-growth regulators or plant hormones. They are classified into five main groups : Auxins; Gibberrelins; Cytokinins; Ethylene and Abscisic acid. Some vitamins also act as growth-regulators.

Growth Promoters (Auxins, Gibberrelins and Cytokinins)

(I) Auxins : Auxin was first isolated from human urine. This and other such substances obtained naturally or synthesized are known as *Indole-Acetic-Acid*(IAA). The effect of auxin and its hormone like properties were studied first of all in Oat coleoptile. IAA and IBA (*Indole-Butyric-Acid*) are obtained from plants. 2-4-D (2, 4–*Di-chlorophenoxy-acetic-acid*), NAA (*Napthalene Acetic Acid*) are synthetic auxins.

Effects of Auxins

- Induces formation of adventitious roots, apical dominancy and development of seedless fruits(parthenocarpy).
- Stimulates the process of flowering.
- Stimulates the respiration process.
- Stops premature fall of leaves and fruits.
- Regulates phototropic movement of plant organs.
- Acts as weed-controllers and weed-eradicators.
- Are useful in stimulating cell division in tissue-culture also.

(ii) Gibberrelins : Gibberellins are another kind of promoter plant growth regulator. This hormone was discovered during the investigation of disease in paddy plants. It was discovered in Japan. The disease was named 'bakane' which means *'foolish plant'*.

Such diseased plants are abnormally long, yellow, thin and normally sterile. This happens due to the disease induced by secretion of *gibberrela* fungus. Their secretion is called-gibberrelin.

Later, occurrence of gibberrelin was established in other plants also. More than 100 different kinds of gibberrelins have been discovered from fungi and other higher plants. These are known as GA_1, GA_2, GA_3... etc. Their synthesis is higher in darkness. All kinds of gibberrelins are acidic in nature. There is a great variation in their effects. Their structure and mode of action are different from those of auxins.

Effects of Gibberrelins

- Remove the expression of genetic dwarfism.
- Induce elongation of stem. The internodes develop longer. They also increase leaf area.
- Mobilization of storage compounds during germination
- Responsible for removal of dormancy of buds and seeds. They stimulate synthesis of various enzymes which activate the embryo.
- Induce flowering in some plants.

(iii) Cytokinins : Cytokinin was first discovered as kinetin(a modified form of adenine-a purine) from the sperms of herring fish. These hormones have a remarkable influence on cell division. It does not occur naturally in plants. A substance called *zeatin*, having effects similar to that of cytokinin was obtained from maize grain as well as from coconut milk. Later, it has become possible to obtain some natural cytokinins and other synthetic compounds having similar effects. They are produced in the regions actively involved in cell division.

Effects of Cytokinins

- Stimulate the processes of cell division, cell enlargement and cell differentiation.
- Reduce apical dominance.
- Retard the process of senescence.
- Retened chlorophyll in leaves.
- Translocate nutritients and organic substances.

Growth Inhibitors (Abscisic Acid and Ethylene)

(iv) Abscisic Acid(ABA) : It was first discovered as a substance inducing fall of cotton fruits. It contributes in regulating abscission and dormancy. Generally ABA acts as a general plant growth inhibitor and an inhibitor of plant metabolism.

Effects of Abscisic Acid

- The most remarkable effect of abscisic acid is inducing leaf fall and seed dormancy.
- Under the condition of water-stress, it stimulates the process of closing of stomata.
- It inhibits seed germination and the development of excised embryo.
- Resistance to stress conditions.

(v) Ethylene : Ethylene is a simple gaseous plant growth regulator, which is volatile in nature. Its concentration remains high in tissues undergoing senescence and in the ripening fruits.

Effects of Ethylene

- It inhibits the length wise growth in root, stem and leaves
- It induces senescence in plants.
- It induces leaf-fall and fall of flowers.
- It stimulates the process of ripening of fruits.
- It induces drooping of leaves and flowers.

Seed Dormancy

Seed dormancy is defined as a state in which seeds are prevented from germinating even under favorable environmental conditions. For this various internal factors are responsible.

During the period of dormancy, the growth of seed is arrested. Some seeds remain dormant for days, while others remain dormant over months or even years.

Types of Seed Dormancy : There are mainly four types: (1) Exogenous dormancy, (2) Endogenous dormancy, (3) Combinational dormancy and (4) Secondary dormancy.

(1) Exogenous Dormancy : Exogenous dormancy is caused by conditions outside the embryo and is often classified into three subgroups:

(a) Physical Dormancy : Which occurs when seeds are impermeable to water or to the exchange of gases.

(b) Mechanical Dormancy : Mechanical dormancy occurs when seed coats or other coverings are too hard to allow the embryo to expand during germination.

(c) Chemical Dormancy : Includes growth regulators that are present in the coverings around the embryo.

(2) Endogenous Dormancy : Endogenous dormancy is caused by conditions within the embryo itself, and it is also often divided into the following three subgroups.

(a) Physiological Dormancy : Physiological dormancy prevents embryo growth and seed germination until chemical changes occur.

(b) Morphological Dormancy : It occurs when the embryos are not differentiated into different tissues at the time of fruit ripening; it means embryo is underdeveloped or undifferentiated.

(c) Combined Dormancy : Seeds have both morphological and physiological dormancy (Morpho-physiological dormancy).

(3) Combinational Dormancy : Combinational dormancy is caused by both exogenous (physical) and endogenous (physiological) conditions in some seeds.

(4) Secondary Dormancy : The conditions that are not favorable for seed germination, like high temperatures causes secondary dormancy.

Various Causes for Seed Dormancy

- Underdeveloped embryo.
- Seed coats impermeable to water.

- Mechanically hard and strong seed coats which do not permit germination.
- Physiologically immature embryo.
- Presence of some germination-inhibiting chemicals. Amongst them the main one is Abscisic acid.

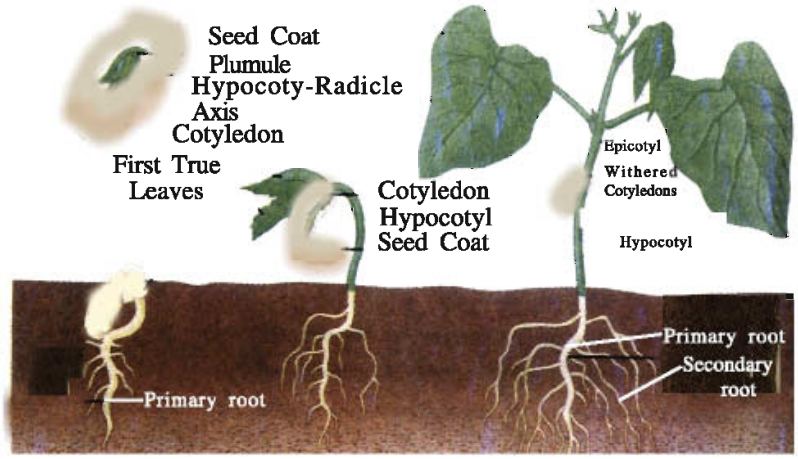
Amongst hormones, Gibberrelins are absent in dormant seeds. At this time, ABA remains active. It inhibits the transcription of genes. As a result, proper enzymes are not synthesized.

Removal of Seed Dormancy

When production of Gibberrelins begins in the seed and when their concentration exceeds that of ABA, the effect of ABA is removed and the embryo becomes active. To induce germination of seed, it is necessary to remove its dormancy. Such a removal of dormancy can also be artificially achieved. Some of these methods are as under -

- Seeds can be scraped lightly with sandpaper. Thus, their seed coats become permeable to water and germination is induced.
- A similar result can be achieved by using chemicals.
- Soaked seeds in an O_2 containing environment, can be provided higher or lower temperature for a definite period. Dormancy is removed in this way.

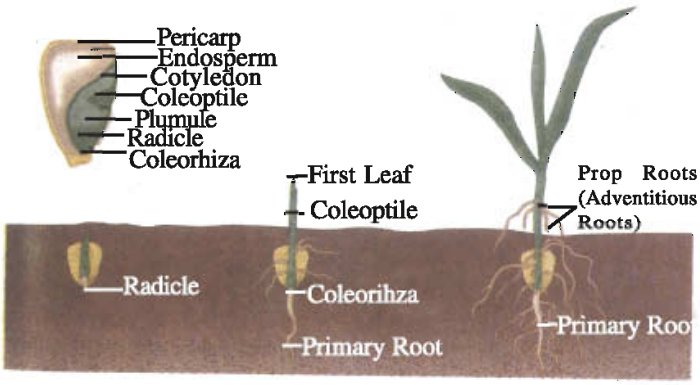
Seed Germination



Germination of Bean Seed

The entire process from the sowing of the seed in the soil to the emergence of a young sapling from it, constitutes germination. With seed-germination the growth of a plant begins. After the completion of the dormancy period, if suitable environmental factors are available, germination occurs. Optimum water, sufficient O_2 and favourable temperature are preconditions for germination.

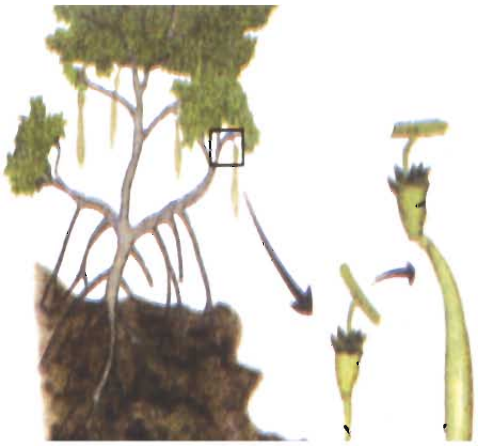
The seed, first of all, imbibes water. As the seed coats become loose, rapid absorption of water occurs through the micropyle. Embryo becomes active. Digestion of food, either stored in endosperm or in the cotyledons, begins with the help of proper enzymes. The developing embryo is nourished in this way. First of all, the radicle of the embryo develops into a primary root which comes out from the micropyle. This is known as 'sprouting'. This indicates initiation of germination. The primary root develops and forms a root system.



Germination of Maize Grain

In the meantime, development of plumule also begins. Shoot, that is stem and leaves, is formed through development of plumule.

Growth-related processes like cell division, cell enlargement and cell differentiation take place in the formation of root-system and shoot-system during germination. During the entire process a high respiratory rate is maintained. Some hormones are secreted and some enzymes become active.



Viviparous Germination

Viviparous Germination : 'Mangrooves' are a special type of vegetation which live in the bassein [creek] region around sea-shore. They exhibit a different kind of germination..The seed germinates while it is still in the fruit and attached to the parent plant. Later, as the weight of the sapling increases, it drops vertically straight into the mud and becomes anchored. Lateral roots develop and proper establishment is achieved. Such a germination is called- 'Viviparous Germination'. *Rhizophora* and *Avicennia* are the examples.

Senescence : Senescence is a period between complete maturation of an individual and the death of that individual. It is also known as 'ageing'.

During senescence, the rate of catabolic activities remains high. There is depreciation in the organ and in the body. Efficiency decreases. It seems that hormones have an influence on this process.

Such senescence affects the individual organs as well as the entire body. Annual plants like wheat, other cereals and other plants experience senescence of the entire body. All organs are involved. In some biennial plants, the aerial shoot experiences this. In autumn, all leaves drop off in this way.

Abscission : The phenomenon of the dropping of leaf, flower and fruit is called - abscission. In such organs a specific 'abscision layer' develops. The cells in this layer undergo degradatory processes and become weak. As a result, a weakness is generated in that region. At a proper time, the leaf, flower or the fruit breaks away from that region and drops off. A hormonal-imbalance is responsible for inducing abscission.

In a healthy leaf, the synthesis of auxins is higher. During senescence it is reduced. Synthesis of growth-inhibiting hormones like ethylene and abscisic acid increases. Under their influence, the middle lamella which is made up of pectin and which interconnects the cellulose cell wall, become degraded. With other accompanying degradatory activities, the abscission layer develops.

Photoperiodism : In the development of plants and process of flowering, response to the stimulus of 'period of available light' by plants is called-Photoperiodism. The stems of plants growing in dark are long, thin, yellow and weak and it is called "etiolated position" . In adequate light, they are normal, healthy and with green leaves. The period for which light is available has a remarkable influence on flowering.

Long Day Plants : Some plants require a longer period of light to come into flowering. Such plants are called-long day plants. Wheat, Poppy, Oat, Beet etc. are long day plants.

Short Day Plants : Some plants require a shorter period to flower. Such plants are called - short day plants. Paddy, Soyabean, *Xanthium* etc. are short-day plants.

Day Neutral plants : In some other plants the period of available light does not have any influence on their flowering. Such plants are called - Day neutral plants. Tomato, *Cucumis* and *Maize* etc. are day neutral plants.

For a photoperiodic response, the continuity of the period of available light and its following period of dark is inevitable. When a momentary period of dark breaks the continuity of light period in the long-day plants or such a period of light breaks the continuity of dark period in the short-day plants, the response of flowering to this stimulus is not observed. It is believed that some specific pigment as well as some specific hormone is responsible for this process.

Vernalization : Better and earlier germination is induced when seeds are provided with specific low temperatures for a definite period of time. Flowering is also earlier in the plants which develop from them. This artificial treatment is called- vernalization.

Seeds of Wheat, Paddy, Millet and Cotton are provided low temperature between 1°C to 10°C and earlier and higher yield of crop is obtained.

Plants growing under normal natural conditions must get low temperature for a specific period. Only then, they come into flowering. This natural uncertainity can be avoided by vernalization and timely yield can be obtained.

Plant Movements : Plants do not show locomotion as animals do. They live a 'fixed' life at one place. However, plants show movements. Even these movements are not quick. Thus, they are not easily observed. There are two main types of plant movements : (A) Movements of locomotion (B) Movements of curvature.

(A) Locomotory Movements : Such a movement can be that of the protoplasm; that of an organ or that of the entire organism. There are two main kinds of movements of locomotion.

(1) Autonomous Movement : No external factor is responsible for causing this type of movements. (i) Amoebic movement- Plasmodia of slime mold (ii) Ciliary movement- *Chlamydomonas* algae (iii) Circulatory movement- Cytoplasm in *Tradeschantia* anther (iv)Rotation movement- Cytoplasm in *Hydrilla* leaves.

(2) Induced Movement : The induced movements of locomotion are caused as a response to the external stimulus. Such a locomotory movement inducing a change of place is called - Taxis. (i)Phototaxis- Zoospore of *Volvox*. (ii) Chemotaxis- Antherozoids of bryophytes and pteridophytes. (iii) Thermotaxis- *Diatoms* and (iv) Thigmotaxis- Zoospore in *Oedogonium*.

(B) Curvature Movements : Higher plants show the movements of curvature which help them to orient their organs for their work-efficiency. Uneven or unbalanced growth causes such a curvature. There are two main kinds of movements of curvature.

(1) Autonomous Movement : No external factor is responsible for causing such uneven growth. (i) Epinasty : Growth ratio of upper surface is more than lower surface in leaves-open leaf blade. (ii) Hyponasty : Growth ratio of lower surface is more than upper surface in leaves-closing of leaves. (iii) Nutation : Zigzag movement in apical bud of stem (iv) Circumnutation : Spiral and helical growth of shoot in climbers and tendrilar plants (v) Variation : Pulsation in leaflets of Indian telegraph plant(*Desmodium gyrans*).

(2) Induce Movement : The induced movements of curvature are caused as a response to the external stimulus. There are two types-(i) Tropism and (ii) Nastism.

(i) Tropism or Tropic Movements : If the movement of curvature in a plant organ is induced by an external and directional stimulus, it is called-tropism. The curvature induced by tropism is having a directional relationship with the direction of the stimulus. Kinds of tropism are derived on the basis of the directional stimulus.

(a) Phototropism : Light – Stem shows positive phototropism and root shows negative phototropism-Oat Coleoptiles. (b) Geotropism : Gravitation – Stem shows negative geotropism and root shows positive geotropism-Radicle of Maize seedling. (c) Hydrotropism : Water – Roots of higher plants. (d) Thigmotropism : Touch – *Coccinia*.

(ii) Nastism or Nastic Movements : This kind of movement depends on the presence and intensity of external stimulus. It is not necessary that it should affect from any definite direction. Based on the external stimulus these movements are called –

(a) Photonasty : The flowers in lotus and sunflower open in the morning. (b) Thermonasty : Flowers of Crocus and Tulip open at higher temperature. (c) Hydronasty : Plants show nastism through heavy rain and water flow. (d) Thigmonasty : The leaves of *Drocera* and *Mimosa* close and droop when they are touched.

Drocera

Before Touched

Mimosa

After Touched

Thigmonasty

SUMMARY

In plants development is considered as the sum of two process-(1) Growth and (2) Differentiation. During this process a complex body organisation is formed that produces roots, leaves, branches, flowers, fruits, seeds and eventually they die. Growth can be defined as an irreversible increase in the size and weight of an organism. Physiologically speaking, growth is an outcome of metabolism. There is an increase in the dry weight as an outcome of growth.

In plants, growth is limited to meristematic tissues only. There are three main activities involved in the process of growth - (1) Cell division of meristematic cells (2) Enlargement of newly formed cells (3) Cellular differentiation. Growth in length is called-primary growth and growth in the girth is called-secondary growth. The increased growth per unit time is termed as growth rate. Growth is divided into three phases : Phase of cell division; Phase of cell enlargement and Phase of cell differentiation. The entire period, covering the period from cell division to cell differentiation is called-grand period of growth.

Factors which affect growth are Water, Oxygen, Temperature, Light and Nutrients. For a more exact measurement of growth in length of a plant, an auxonometer is employed.

Development is a term that includes all changes that an organism goes through during its life cycle from germination of the seed to senescence. The plant growth regulators(PGRs) are small, simple molecules of diverse chemical composition. Such chemicals are called plant-growth regulators or plant hormones. They are classified into five main groups : Auxins; Gibberrelins; Cytokinins; Abscisic acid and Ethylene. Some Vitamins also act as growth-regulators.

Seed dormancy is defined as a state in which seeds are prevented from germinating even under environmental conditions or external factors normally favorable for germination. There are mainly four types of seed dormancy: (1) Exogenous dormancy, (2) Endogenous dormancy, (3) Combinational dormancy and (4) Secondary dormancy. The entire process from the sowing of the seed in the soil to the emergence of a young sapling from it, constitutes germination. 'Mangrooves' are a special type of vegetation which live in the bassein [creek] region around sea-shore. They exhibit a different kind of germination. Such a germination is called- 'Viviparous Germination'.

Senescence is a period between complete maturation of an individual and the death of that individual. The phenomenon of the dropping of leaf, flower and fruit is called - abscission. In the development of plants and process of flowering, response to the stimulus of 'period of available light' by plants is called-Photoperiodism. Better and earlier germination is induced, when seeds are provided with specific low temperatures for a definite period of time. Flowering is also earlier in the plants which develop from them. This artificial treatment is called-vernalization.

There are two main types of plant movements : (a) Locomotory Movements : (1) Autonomous movement, (i) Amoebic movement, (ii) Ciliary movement, (iii) Circulatory movement and (iv)Rotation movement. (2) Induced movement (i)Phototaxis, (ii) Chemotaxis, (iii) Thermotaxis and (iv) Thigmotaxis. (b) Curvature Movements : (1) Autonomous movement (i) Epinasty, (ii)Hyponasty, (iii) Nutation, (iv) Circumnutation and (v) Variation. (2) Induced movement : There are two types. (i) Tropism (a) Phototropism (b) Geotropism (c) Hydrotropism and (d) Thigmotropism (ii) Nastism (a) Photonasty (b) Thermonasty (c) Hydronasty and (d) Thigmonasty.

EXERCISE

1. Put a dark colour in a given circle for the correct answer :

(1) Anabolic activities are ..... .

(a) Analytical ○ (b) Synthetic ○

(c) Degrading ○ (d) Physiognomic ○

(2) All kinds of gibberellins are in nature ..... .

(a) Basic ○ (b) Neutral ○ (c) Acidic ○ (d) None of these ○

(3) The phases of becoming differentiated is called ..... .

(a) Cell Formation ○ (b) Cell Enlargement ○

(c) Cell Fusion ○ (d) Cell Differentiation ○

(4) Which factor is essential for turgidity of cells undergoing growth ?

(a) Water ○ (b) Light ○ (c) Temperature ○ (d) Oxygen ○

(5) Which apparatus is employed for measurement of growth in length of a plant ?

(a) Abneymeter ○ (b) Psycrometer ○

(c) Auxanometer ○ (d) Spectrometer ○

(6) From where was the first auxin isolated ?

(a) Human urine ○ (b) Plant tissue ○

(c) Sperm of fish ○ (d) Paddy plant ○

(7) The effects of inducing senescence and drooping of leaves are due to .....

(a) Auxin ○ (b) Ethylene ○ (c) Abscisic acid ○ (d) Cytokinin ○

(8) The example of viviparous germination is...

(a) Maize ○ (b) Bean ○ (c) *Rhizophora* ○ (d) *Mimosa* ○

(9) The flowers of lotus and sunflower are the examples of ..... .

(a) Thermonasty ○ (c) Hydronasty ○

(c) Thigmonasty ○ (d) Photonasty ○

(10) The phenomenon of drooping of leaf, flower and fruit is called ..... .

(a) Abscission ○ (b) Ageing ○

(c) Photoperiodism ○ (d) Vernalization ○

2. Answer the following questions in short :

(1) Mention the three phases of growth.

(2) State the name of factors affecting growth.

(3) Give the full form of IBA, NAA and 2-4-D.

(4) Mention the examples of long day plants.

(5) State the names of two types of plant movements.

(6) What is the meaning of BAKANE ?

(7) What is the grand period of growth ?

(8) Name the synthesized auxins in plants.

(9) State the causes of seed dormancy.

(10) State the factors responsible for seed germination.

(11) What is nutation ?

(12) Define it : Growth, Vivipary germination, Seed dormancy, Tropism, Nastism.

3. Write short notes on :

(1) Characteristics of growth
(2) Rate of growth
(3) Measurement of growth
(4) Plant growth regulators
(5) Effects of Abscissic acid
(6) Effects of Ethylene
(7) Seed dormancy
(8) Removal of seed dormancy
(9) Seed germination
(10) Senescence
(11) Abscission
(12) Photoperiodism
(13) Vernalization
(14) Locomotory movements
(15) Tropism

4. Answer the following questions in detail :

(1) What is growth ? Describe phases of growth.

(2) Mention the factors affecting growth and discuss them.

(3) What are growth-regulators ? Mention growth regulators and describe growth-regulator containing Indole.

(4) Describe seed germination in detail.

(5) What are Plant movements ? Describe types of movements.