Plant Growth & Development

Characteristics of Plant Growth

What is Growth?

- It is a characteristic of living beings in which an irreversible permanent increase in size of an organ or its parts occur. In smaller living beings, an increase in the size of a cell can also be termed as growth.

Characteristics of Plant growth

- **Plant Growth is Indeterminate**
- Plants retain the capacity of unlimited growth throughout life.
- Meristems are present in plants that have the ability to divide and self perpetuate.
- *Open form of growth* − New cells are always being added to the plant by meristem.
- *Primary Growth* − Occurs due to root apical meristems and shoot apical meristems
- *Secondary growth* − Occurs due to the appearance of lateral meristems, vascular cambium, and cork cambium later in the life of certain dicots and gymnosperms
- **Plant Growth is Measurable**
- Growth is measured by measuring the parameters that are directly proportional to increase in protoplasm.
- Increase in weight (fresh and dry weight both), length, area, volume, and cell number are some parameters.
- Choice of parameters depends upon type of plant.

Examples:

For pollen tube − length is the parameter
For water melon − cell size is used
For dorsiventral leaf − surface area is used

In the above topics we have studied what is plant growth, but you must be aware that a plant can grow only after germination of seed.
This, means that seed germination is the first step in the growth of plants. Lets study more about seed germination.

Seed germination

- It is the first step in the process of growth of plants.

- Seed germination requires certain necessary conditions necessary like availability of water and oxygen. In the absence of these, the seeds may fail to germinate.

- The steps of seed germination include -

    - absorption of water which causes swelling of seeds
    - swelling causes the rupture of seed coat
    - radicle emerges from one end of the embryonal axis and forms the root system
    - plumule emerges from the other end of the embryonal axis and forms the shoot system

- Metabolic activities which take place during this process require oxygen for breaking down the food reserves.

- Rate of respiration increases during germination process.

Certain plants such as *Rhizophora* and *Sonneratia* show vivipary. Vivipary is a special type of germination in which the seed germinates while it is still attached to the parent plant and is nourished by it. Germinating seed forms a seedling and as its weight increases, the seedling separates and falls down into the mud. Lateral roots then develop to help proper anchorage of the seedling.

Seed dormancy

It is not necessary that all the seeds may germinate even if favourable conditions are available. This condition where seeds are unable to germinate even in the presence of favourable conditions is called dormancy.

There are certain factors which can lead to seed dormancy -

- impermeable or mechanically resistant seed coats
- rudimentary or physiologically immature embryos
- presence of germination inhibitors such as abscisic acid, phenolic acid, short chain fatty acids and coumarin

There are two different ways by which dormancy of seeds can be broken:

- Scarification - It involves scratching of seed coat to help break the dormancy caused by hard and impermeable seed coat.

- Stratification - It involves subjecting the moist seeds to oxygen for variable periods of low or high temperatures.

Phases of Growth

- **Three Phases of growth −** meristematic, elongation, and maturation

- **Meristematic Phase**

- Cells rich in protoplasm
- Cells possess large conspicuous nuclei
- Cell wall − Primary, thin, and cellulosic with abundant plasmodesmatal connections
- Constantly dividing cells at root and shoot apex are in this phase.

- **Elongation Phase**

- Cells enlarge and show increased vacuolation.
- New cell wall deposits.
- Cells proximal to the merismatic zone (root and shoot tip) are in this phase.

- **Maturation Phase**

- Cells attain their maximum size.
- Wall thickening and protoplasmic modifications take place completely.

Growth Rate

Types of Growth Rate

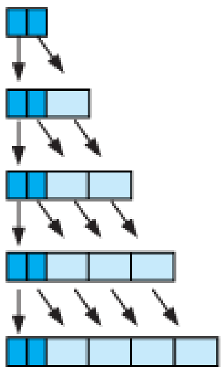
- Growth rate: Increase in growth per unit time

- Plants show two types of growth—Arithmetic and Geometric—according to the increase shown by the growth rate

- *Arithmetic growth*

- Only one daughter cell continues to divide while others differentiate or mature.

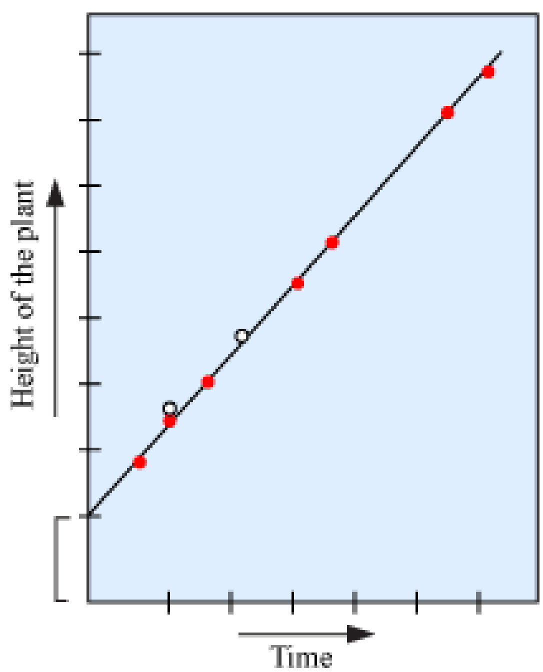
- Example − root elongating at a constant rate



- Mathematically, $L_t = L_0 + rt$
  Where: L_t = Length at time, t

  L_0 = Initial length
  r = Growth rate

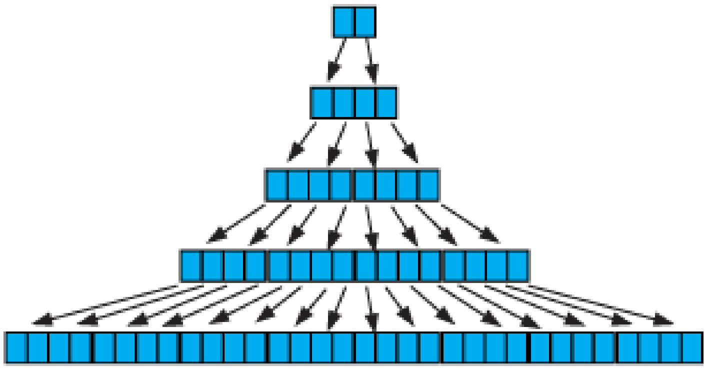
- On plotting length against time, a linear curve is obtained.



- *Geometric Growth*

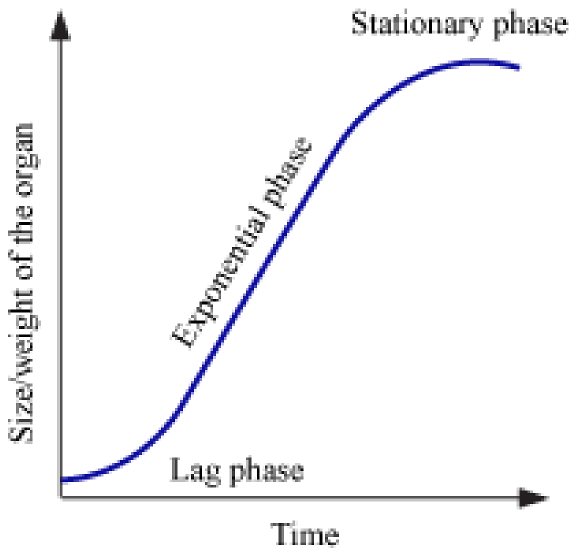
- Initial growth is slow (lag phase), followed by a rapid increase in growth (log/exponential phase), followed by a phase where growth slows down (stationary phase)

- Example − all cells, tissues and organs typically show this type of growth

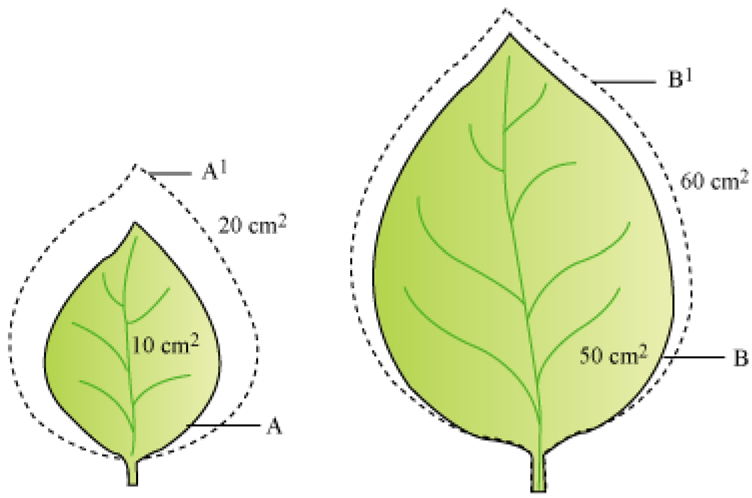


- Mathematically, $W_1 = W_0 e^{rt}$
  W_1 = Final size
  W_0 = Initial size
  r = Growth rate
  t = Time of growth
  e = Base of natural algorithms

- On plotting the size or weight of the organ against time, a sigmoid or S-shaped curve is obtained.



Ways to compare growth quantitatively



- Two ways to compare growth quantitatively: By measuring (i) absolute growth rate and (ii) relative growth rate
- Absolute growth rate:
- Measurement of total growth per unit time
- In the given figure, an absolute increase is shown in the areas of the leaves A and B to form leaves A^1 and B^1.
- Relative growth rate:
- Growth of a given system per unit time expressed on a common basis; e.g., per unit of initial parameter
- In the given figure, both leaves increase by 10 cm^2, but a relatively greater growth has occurred in leaf A.

Conditions for Growth

- Include: water, oxygen, nutrients
- Water:
- Cell enlargement requires water.
- Water provides medium for enzymatic activities.
- Oxygen:
- Releases metabolic energy needed for growth.

- Nutrients:
- Source of energy
- Required for synthesis of protoplasm
- Temperature:
- Plays an important role in growth. Any deviation from the optimum temperature hampers growth.
- Environment signals (light and gravity)

Differentiation and Development in Plants

Differentiation, Dedifferentiation, and Redifferentiation

- **Differentiation**
- In this process, cells derived from root apical and shoot apical meristems and cambium differentiate and mature to perform specific functions.
- Structural changes occur in plant cell (both cell wall and protoplasm).
For example, cells develop strong, elastic, and lignocellulosic cell wall for long distance transport of water.
- **Dedifferentiation**
- Process in which living differentiated cells regain their capacity to divide
- For example: Formation of meristems such as interfascicular cambium and cork cambium from fully differentiated parenchyma cells
- **Redifferentiation**
- Process in which differentiated cells that have lost their ability to divide are reformed from dedifferentiated cells
- Redifferentiated cells have the ability to perform specific functions.
- Just like growth, differentiation in plants is also open since cells arising from same meristem may differentiate to form different structures depending upon its location.

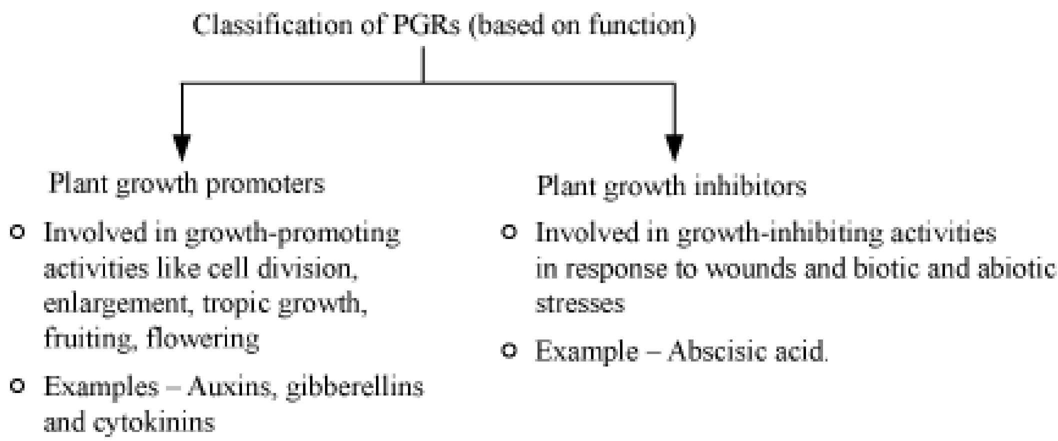
Development − what does it mean?

- Includes all changes that an organism goes through during its life cycle
- Plasticity − Ability of plants to follow different pathways in response to environment or phases to form different kinds of structures Some examples are heterophylly in larkspur and Buttercup. In these plants, leaves have different shapes based on the phase of life cycle as well as the habitat.
- Development can also be termed as − growth + differentiation
- Development is controlled by intrinsic as well as extrinsic factors.
- Intrinsic − Genetic factors and plant growth regulators
- Extrinsic − light, temperature, water, oxygen, etc.

Plant Growth Regulators & Characteristics & Physiological Effects of Auxins

Plant Growth Regulators (PGRs)

- Also called plant growth substances, plant hormones or phytohormones
- PGRs are small, simple molecules of diverse chemical compositions, which regulate the growth of plants.



- Ethylene may fit in either of the two groups, but is largely an inhibitor.

Discovery of Plant Growth Regulators

- Charles Darwin and Francis Darwin: Observed that coleoptiles of canary grass responded to unilateral illumination by growing towards light source (Phototropism)
- F.W. Went: Isolated auxins from the tips of coleoptiles

- E. Kurosawa: Reported the appearance of symptoms of 'bakane' disease of rice seedlings in uninfected rice seedlings when they were treated with sterile filtrate of fungus *Gibberella fujikuroi*; gibberellic acid was later isolated from the fungus

- F. Skoog: Observed that callus proliferates in the tobacco plant only if, in addition to auxin, the nutrient extract is supplemented with extracts from the vascular tissue, yeast, coconut milk or DNA

- Skoog and Miller: Isolated kinetin (Cytokinesis-promoting active substance)

- Three independent workers reported three different kinds of inhibitors in plants: Inhibitor-B, abscission II and dormin; later, all the three inhibitors proved to be chemically identical (abscisic acid − ABA)

- Cousins: Confirmed that a volatile substance being released from ripened oranges leads to the ripening of unripened bananas. Later, this substance was found to be ethylene.

Auxins

- First isolated from human urine

- Produced by growing apices of stems and roots. From stems and roots, these phytohormones migrate to the site of their action.

- Auxins such as Indole acetic acid (IAA) and indole butyric acid (IBA) are isolated from plants. On the other hand, NAA (naphthalene acetic acid) and 2, 4-D (2, 4-dichlorophenoxyacetic acid) are synthetic auxins.

- Physiological effects of Auxin:

- Initiates rooting in stem cuttings, flowering (in pineapples)

- Prevents immature fall of fruit and leaves, but promotes abscission of old, mature fruits and leaves

- Induces apical dominance (by inhibiting growth of axillary bud)

- Induces parthenocarpy

- Possesses herbicidal properties; e.g., 2, 4-D is used for killing dicot weeds, and it does not affect mature monocot weeds

- Controls xylem differentiation and cell division

- Decapitation: Removal of shoot tips to promote the growth of lateral buds; useful in tree plantations and hedge-making

Physiological Effects of Gibberellins and Cytokinins

Gibberellins

- More than 100 gibberellins are found in different organisms such as fungi and higher plants (denoted as GA_1, GA_2, GA_3, etc.).
- All GAs are acidic.
- First gibberellin to be discovered is Gibberellic acid (GA_3). It is also the most extensively used.
- Physiological effects of gibberellins
- Cause an increase in length of axis
  This ability of gibberellin is widely used to increase the length of grapes stalks.
- Cause fruits to elongate and improve its shape
- Delay senescence
- Speed up the malting process in brewing
- Induce bolting (internode elongation prior to flowering) in beet, cabbage, etc.

Cytokinins

- Discovered as kinetin from autoclaved herring sperm DNA
- Kinetins do not occur naturally.
- Zeatin − substance with cytokinin-like activity isolated naturally from corn kernels and coconut milk
- Physiological importance:
- Promotes cytokinesis
- Synthesized naturally in regions undergoing rapid cell division
  For example, root apices, young fruits, etc.
- Helps to produce new leaves and chloroplast in leaves

- Promotes lateral and adventitious shoots; hence, overcomes apical dominance
- Nutrient mobilization, which delays senescence of leaves

Physiological Effects of Ethylene and Abscisic Acid

Ethylene

- It is a gaseous plant growth regulator or PGR.
- Produced in tissues undergoing senescence and ripening fruits
- Physiological effects of ethylene:
- Promotes senescence and abscission of mature parts of plant
- Raises the respiration rate during ripening of fruits
  This phenomenon is also known as Respiratory Climactic.
- Breaks seed and bud dormancy; induces sprouting and germination
- Promotes internode elongation in deep water rice plants and helps these plants to stay above water
- Helps the plants to increase their absorption rates by promoting root growth and root hair formation
- Ethepon, a widely used form of ethylene, enhances fruit ripening in apples and tomatoes.
- Ethepon also accelerates abscission in flowers and fruits.
- Ethepon increases the yield by promoting female flowers in cucumber.

Abscisic Acid (ABA)

- As the name suggests, it plays a major role in abscission.
- It acts as a plant growth inhibitor and plant metabolism inhibitor.
- Acts as an antagonist to GAs
- Physiological effects of ABA:
- Inhibits plant growth and metabolism

- Inhibits seed germination
- Stimulates closure of stomata
- Increases stress tolerance in plants (hence known as stress hormone)
- Plays a vital role in seed development, maturation, and dormancy
- Helps the seeds to resist desiccation and other unfavourable conditions

Photoperiodism

- Response to plants to periods of day/night
- Some plants require periodic exposure to light to induce flowering.
- *Long Day Plants* − Plants that require exposure to light for a period exceeding a well defined critical duration to induce flowering
- *Short Day Plants* − Plants that require exposure to light for a period less than this critical period to induce flowering
- *Day Neutral Plants* − Plants where there is no correlation between exposure to light duration and induction of flowering
- Duration of dark period is equally important for flowering.
- Site of perception of light are the leaves. Short apices modify themselves into flowering apices prior to flowering, but they are not the actual site of light perception.

  Hormonal substance, responsible for inducing flowering, moves from leaves to shoot apices only when plants are exposed to the required inductive photoperiod.

Vernalization

- Phenomenon of dependence of flowering on exposure to low temperature
- This prevents premature reproductive development late in the growing season and enables the plant to have sufficient time to reach maturity.
- Example − Biennial plants

  These are monocarpic plants that flower and then die in second season. Some examples are sugar beet, cabbage, carrot, etc.