Plant Growth and Development: Differentiation, Dedifferentiation and Redifferentiation

Key Takeaway

1. Measurement of growth in plants
2. Phase of growth
3. Types of growth
4. Sigmoid growth curve
5. Differentiation
6. Dedifferentiation

Redifferentiation

7

8

Heterophylly

Factors affecting plant growth

9

10

Plant growth regulators

Seed dormancy

11

Auxin

Gibberellin

Cytokinin

Ethylene

Abscisic acid

12

Photoperiodism

Photoperiodic perception

Types of plants

13

Vernalisation

Types of plants

Summary

Growth

Indeterminate growth

- Growth continues till the plant lives.
- The plant grows from seed to tree due to shoot apical meristem and root apical meristem.
- Growth in girth is due to **lateral meristem.**

Determinate growth

- Growth does not continue throughout the life of plant.
- It is often seen in the fruits and leaves.
- **Intercalary meristem** is involved in the **formation of fruits/organs**.
- Growth stops at a point as seen in animals.

Measurement of Growth in Plants

The amount of growth can be measured using different parameters.

Surface area

- An increase in the surface area helps to **measure the growth in flat organs like leaves**.
- The leaf is placed on a graph and its outline is traced.
- Based on the outline, the surface area covered by the leaf is measured.
- Hence, the growth is measured based on the increase in surface area.

Volume

- An increase in volume is used to measure the **growth of fruits**.
- The fruit is dipped in water.
- The difference in the volume of water before and after the fruit was added indicates the volume of the fruit.

Number of cells

- The rate of growth can be estimated by the **increase in the number of cells**.
- The rate of growth is directly proportional to the increase in the number of cells.
- Example: Algae, plant cells growing in a culture.

Measurement of Growth in Plants

The amount of growth can be measured using different parameters.

Weight

- An increase in the **weight of the plants** is used to measure the growth.
- There are two standards for this measurement.
  - **Dry weight:** The plant material is dried in an oven at 110 degree Celsius for a few hours or air dried for a few days to remove the water content.
    - It is the weight of the plant material after the removal of the water content.
  - **Fresh weight:** It is the weight of the living tissue along with the water content.

Girth

- An **increase in the diameter of the tree is a parameter for growth** in terms of girth.
- Example: Globular and cylindrical plant organs (Examples: Fruits, tree trunk).
- It can be measured by a tape or vernier callipers.

Phases of Growth

Meristematic phase

- Predominantly at the tip of the root and shoot, there are a lot of meristematic cells.
- This phase is responsible for the **growth of the roots** and **shoot tips** of the plants.
- This phase is responsible for production of new cells by the mitosis of meristematic cells.
    - **The rate of respiration is high** in these cells.
    - The meristematic cells have a **dense protoplasm**.
    - Meristematic cells also have a thin cell wall that aids in cell division.
        - Example: Single apical meristem of maize adds 17,500 new cells per hour.

Phases of Growth

Enlargement phase

- This occurs in the new cells formed due to meristematic activity.
- In this phase, the cells are not **capable of dividing**.
- The **new cells enlarge and elongate**.
- Enlargement of cells is helped by vacuolation which is the process of the development of **vacuoles**.
- **Secondary cell wall depositions** are observed.
- Example: Watermelon cells can enlarge up to 3,50,000 times.

Phases of Growth

Maturation phase

- The cells completely lose the ability to divide in this phase. No new cells are formed.
- Structural and physiological differentiation occurs.
- They **gain permanent functions**.
  - The cells constituting this phase form the region of **differentiation**.
- The cell wall becomes thick along with some protoplasmic modifications.

Growth Rate

- It is a measure of how much growth has taken place in a given time.
- Alternatively, the **increase in growth per unit time** is termed as growth rate.

Growth rate

Absolute growth rate

- Growth per unit time

$$AGR = \frac{\text{Final parameter - Initial parameter}}{\text{Time}}$$

Relative growth rate

- Growth per unit time per initial parameter

$$RGR = \frac{\text{Final parameter - Initial parameter}}{\text{Time}} \times \text{Initial parameter}$$

Types of Growth

Arithmetic growth

- As the plant grows, new cells are produced.
- In every generation, new daughter cells are produced.
  - **One daughter cell retains meristematic activity**.
  - The others start to **differentiate**, i.e., undergo maturation.
- The retained meristematic cell undergoes further cell division.
- The growth pattern repeats.

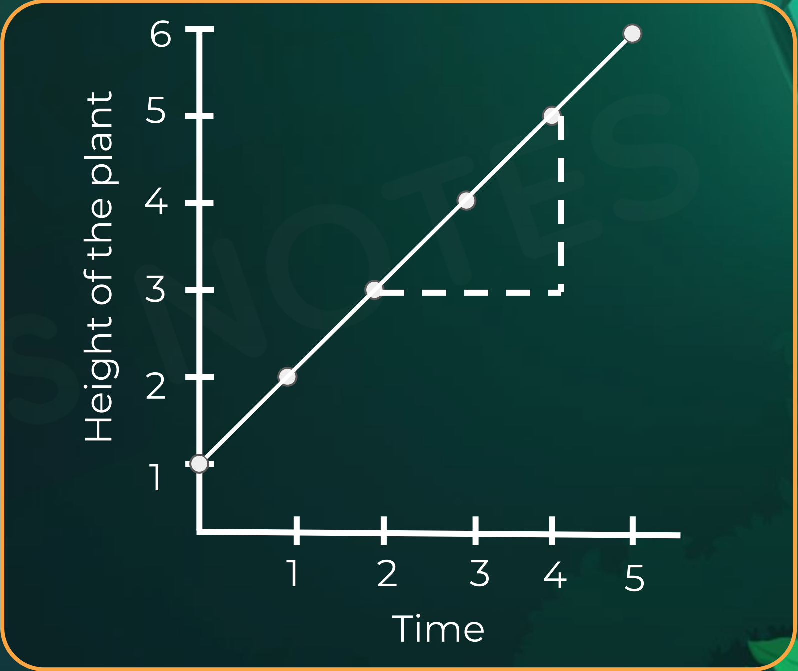
Geometric growth

- In every generation, new daughter cells are produced.
  - **All the daughter cells retain meristematic ability**.
  - So all the cells can divide.
- Rate of growth varies in different species and organs.
  - Examples: i) The growth of cacti is extremely slow.
  - ii) Young leaves of banana grow rapidly
- Growth begins slowly. The graph enters a period of rapid enlargement, i.e., hike in growth is observed.
- It is followed by a decrease in graph till no further enlargement (the cells start to die and no new growth is seen).

Types of Growth

Graphical representation of arithmetic growth

- Plot of length (L) against time (t) for a constant linear growth of root elongation.
- Mathematical expression
  - **$L_t = rt + L_o$**
  - y = mx + c
  - **$G_t = r_t + G_0$**
  - L_t = Length at time t
- L_o = Length at time zero
- r = Growth rate/ elongation per unit time.
- The rate of growth is generally constant.

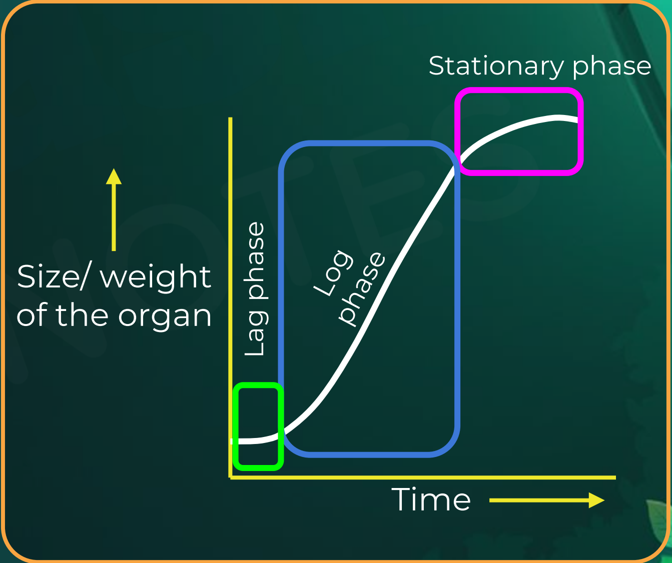


Types of Growth

Graphical representation of geometric growth

- Mathematical expression **$W_1 = W_0e^{rt}$**
  - W_1 = Size at time t (Weight, height, number, and more)
  - W_0 = Initial size
  - r = Growth rate
  - t = Time of growth under consideration
  - e = Base of natural logarithms.

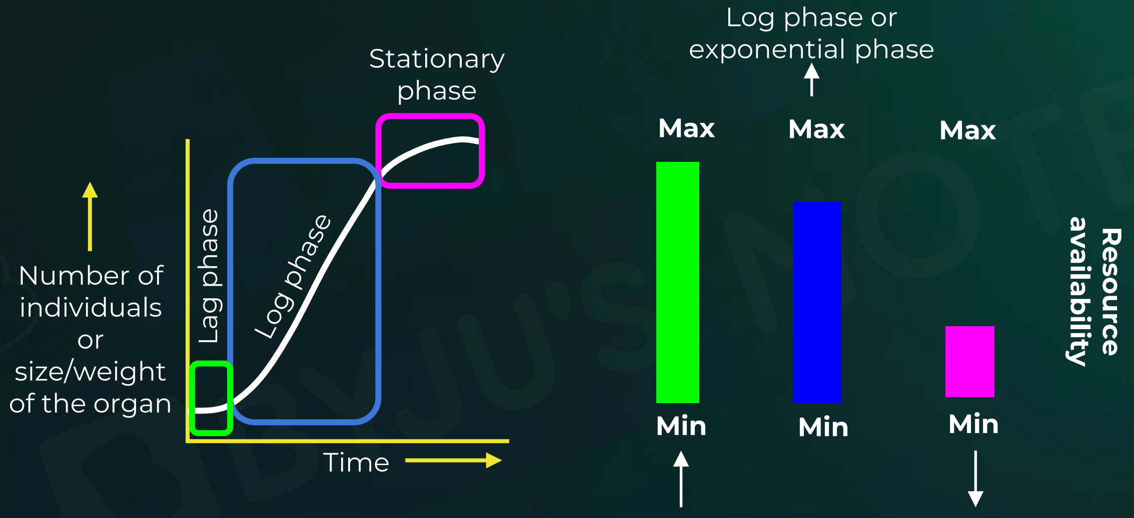
- Note*: Exponential growth cannot continue forever. Thus, as mentioned the growth gradually starts to decrease. After some point, the nutrients required for the growth start to deplete. This leads to slower growth.



Sigmoid growth curve

Sigmoid Growth Curve

- It is an S-shaped growth curve.
- It includes three phases.



Sigmoid growth curve

Sigmoid Growth Curve

Lag phase

- The **growth is very slow**.
- Cells have a lot of resources, i.e., **a lot of nutrients are available**.
- Since **few cells** are only present at an initial stage and they **take time to get accustomed to the surrounding** as well as the nutrients, the growth is slow.

Log phase or exponential phase

- Gradually, the **cells start to grow faster**.
- More number of cells are observed.
- The **exponential growth of cells** is observed as nutrients are also available for all the cells.
- In this phase, **the resources and the number of cells present are high**.
- End of log phase: As cells grow, they deplete the available resources.
- This indicates the end of the log phase.

Sigmoid Growth Curve

Stationary phase

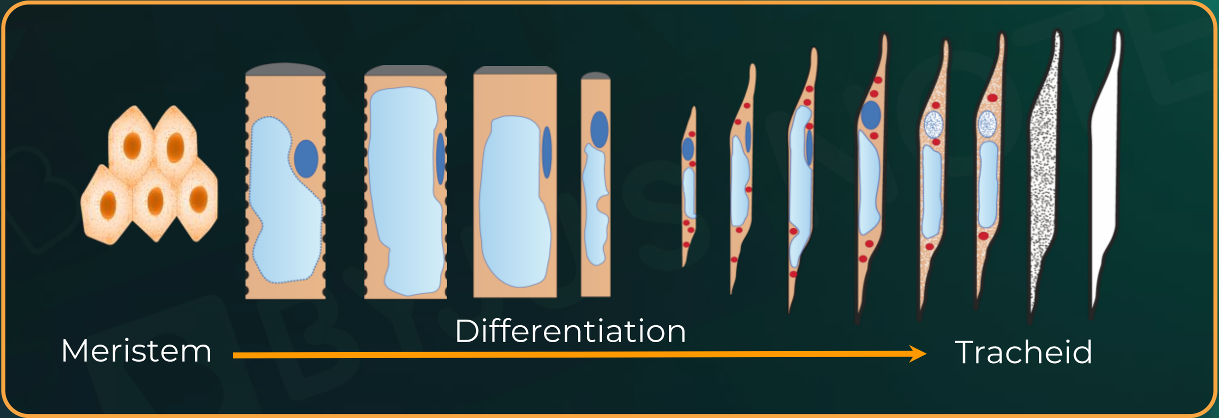
- The stationary phase starts where the log phase ends.
- The **speed of the growth** of the cells gradually **slows down**.
- A **saturation in growth** is observed due to **limited resources**.
- The cells stop dividing as they reach towards saturation.
- In the stationary phase, **no growth is observed**.

Note

- The arithmetic growth and geometric growth may not occur individually.
- Both the types of growths are combined and highly orchestrated to aid in plant growth.

Differentiation

- Differentiation refers to the structural and functional changes that a meristematic cell undergoes to perform a specific function and thereby, loses the ability to divide.
  - **Meristems** differentiate to form **permanent tissues** (simple and complex).
  - Example: **Differentiation of meristematic cell to form tracheary element**.



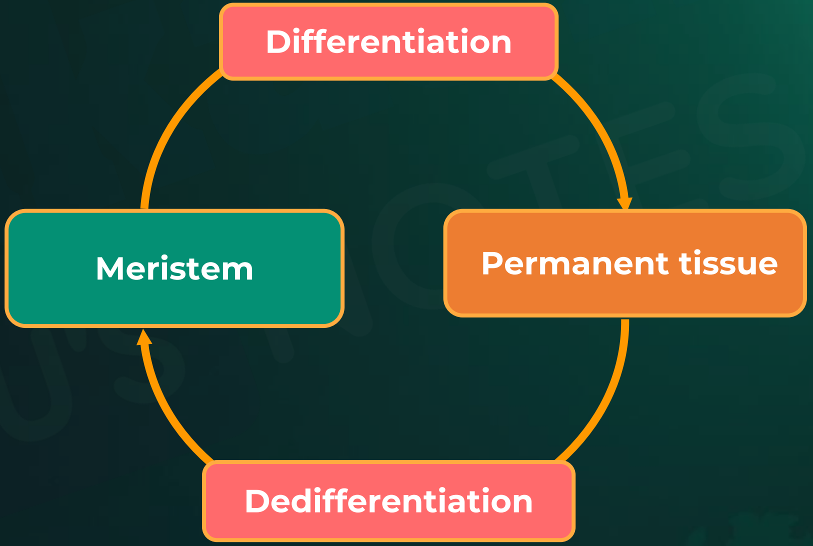
Structural changes: Meristem elongates + Loses protoplasm + Develops very strong, elastic, lignocellulosic secondary cell walls

Function: Long-distance water transport.

Dedifferentiation

- The living **differentiated cells regain the ability to divide** and lose the ability to perform specific functions under certain conditions.
- E.g. - formation of **interfascicular cambium** and **cork cambium** from fully differentiated parenchyma cells in **dicots**.

Meristem develops into a specialised cell to perform a particular function and loses ability to divide.



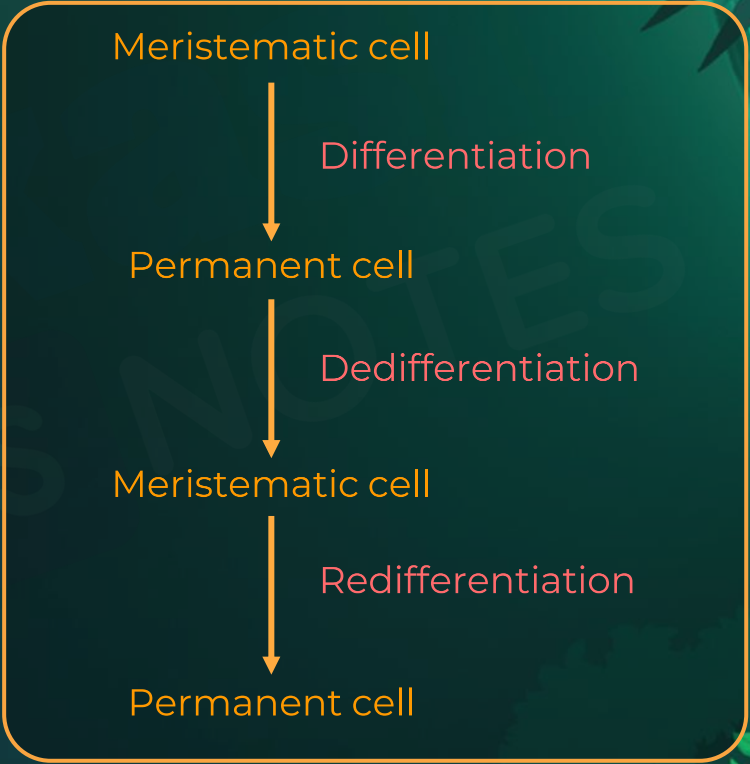
Living differentiated cells regain the ability to divide.

Rediffereniation

- After dedifferentiation, some cells lose their meristematic activity and become specialised once again.
- Differentiation of dedifferentiated cells is known as **redifferentiation**.
    - Cells again lose their capacity to divide but become mature to perform specific functions.

Not all cells can dedifferentiation

- The differentiated **cells that have lost their nucleus** and those that are **dead at maturity cannot dedifferentiate**.

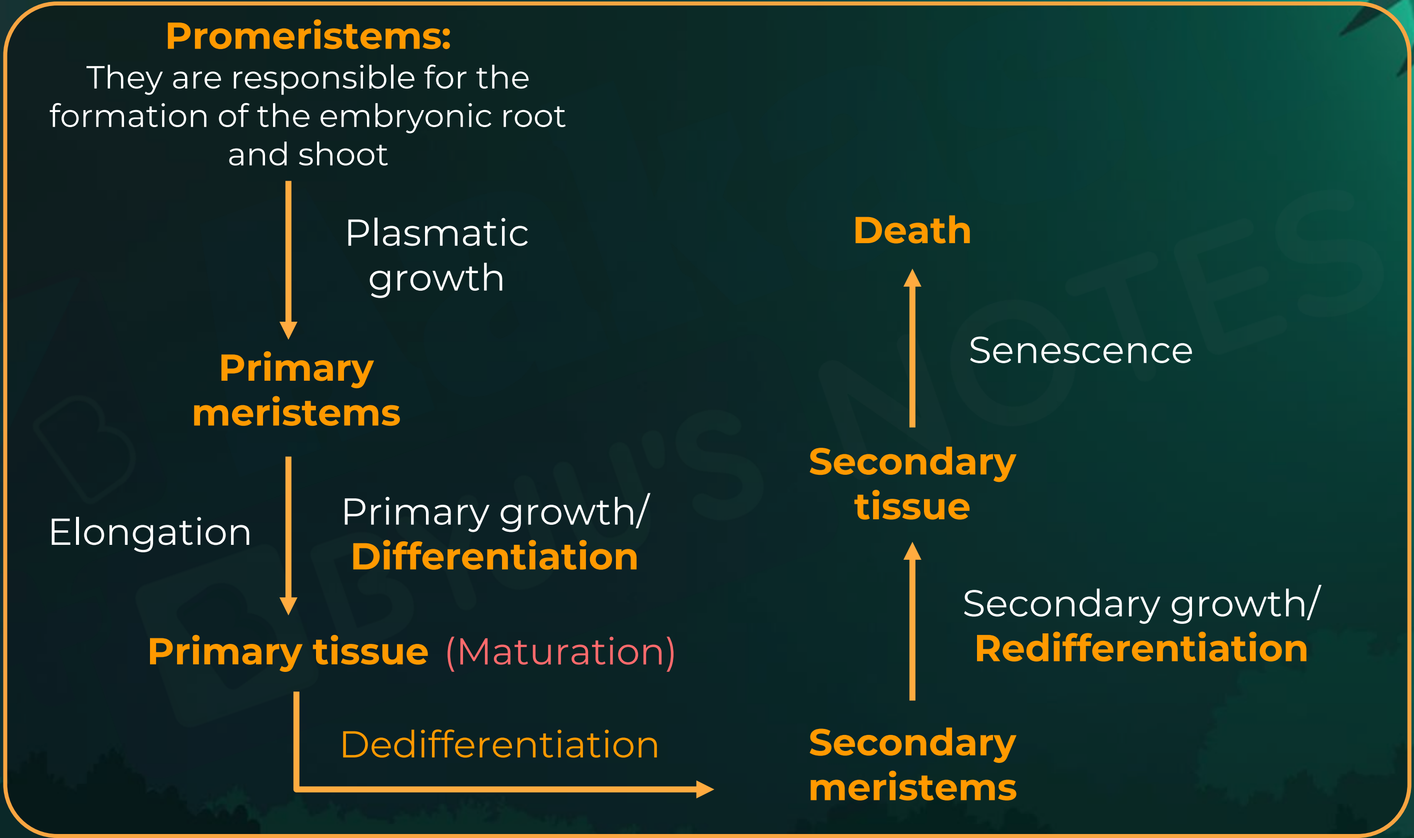


Growth vs Plant Development

- **Growth** is an **irreversible** and **permanent increase in the size** of an organ, an organ's parts, or an individual cell.
- **Plant development** includes all changes that an organism goes through during its life cycle **from germination of the seed to senescence**.
- Development and growth are sometimes used interchangeably.
  - However, botanically, they describe separate events in the organisation of the mature plant body.

Growth

Growth vs Plant Development



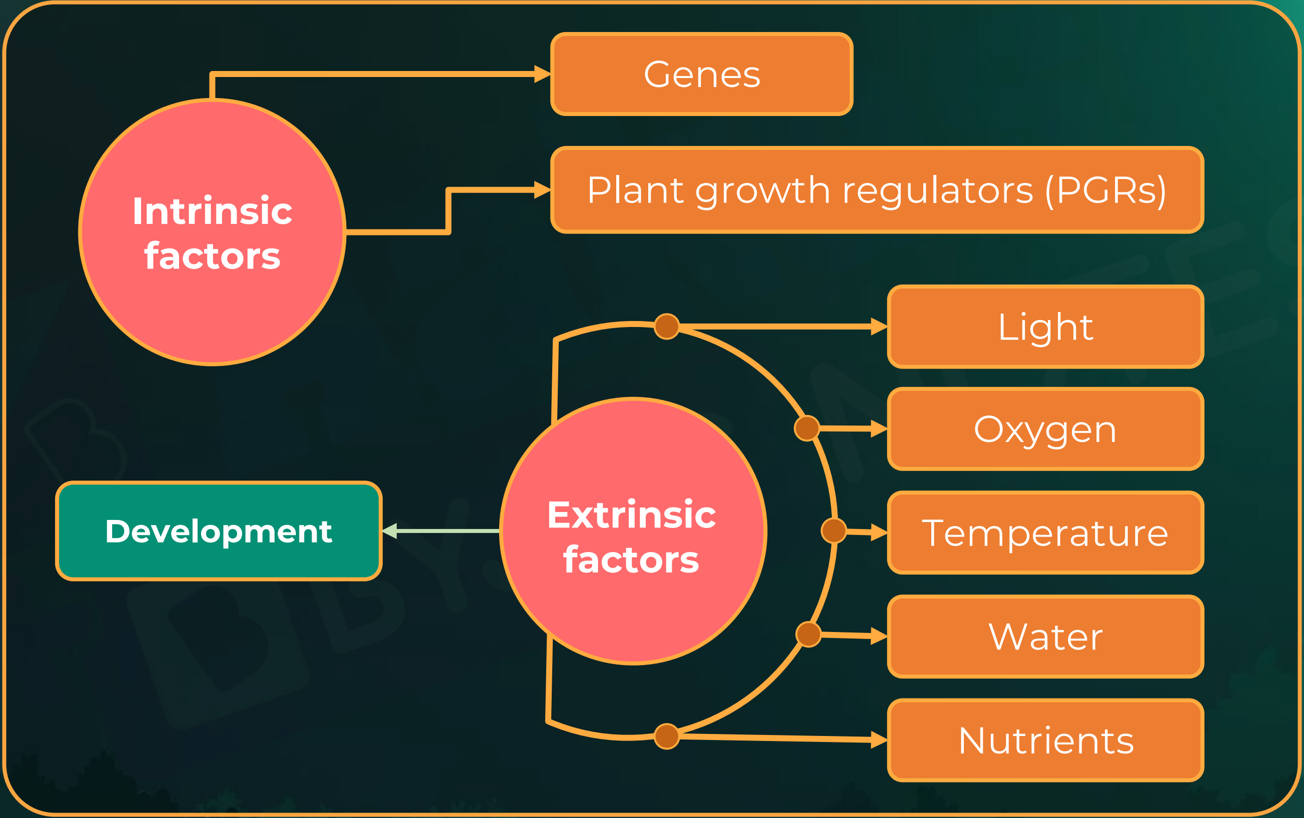
Heterophylly

- Production of **different leaf forms** on the **same plant** during:
  - Different phases of its life cycle
  - Different environmental conditions.
- This ability is also called **plasticity**.
- It is observed in both **terrestrial and aquatic** plants.
- Example- Cotton, coriander and larkspur.

Heterophylly in larkspur

Heterophylly in buttercup

Factors Affecting Plant Development



Plant Growth Regulators

- **Plant growth regulators (PGRs) or phytohormones** are organic compounds that **signal, regulate, and control the growth of plants**.
- Every plant cell can produce these hormones under appropriate conditions.

Types of PGRs

- **Carotenoid derivatives**
  E.g. - Abscisic acid (ABA)
- **Adenine derivatives**
  E.g. - N^6 - furfurylamino purine, kinetin
- **Terpenes**
  E.g. - Gibberellic acid- GA_3
- **Indole compounds**
  E.g. – Indole-3-acetic acid (IAA0
- **Gases**
  E.g. – Ethylene (C_2H_4)

Auxin

Discovery of auxin - Darwin's experiment

- Auxin originated from the Greek word *"Auxein"* meaning "to grow".
- It is an indole derivative plant growth regulator.
- Presence of a growth stimulator in the tip of the stem was discovered by Charles Darwin and his son Francis Darwin.
- Experiment was performed using canary grass (*Phalaris canariensis*).

Hypothesis

- The site of transmittable influence that caused the bending of the entire coleoptile in response to unilateral illumination by growing towards the light source (phototropism).
- Eventually, auxin was **isolated by F.W. Went** from **tips of coleoptile of oat seedlings**.

Auxin

Types of auxins

Natural auxins

- These are produced naturally by the **growing apices of the stems and roots**, from where they migrate to the region of their action.
- Example:
    - **Indole-3-acetic acid (IAA)**
    - **Indole-3-butyric acid (IBA)**
    - **4-chloroindole-3-acetic acid**

Synthetic auxins

- These are synthesised artificially.
- Example:
    - **Naphthalene acetic acid (NAA)**
    - **2, 4-dichlorophenoxyacetic acid (2, 4-D)**
    - **2, 4, 5-trichlorophenoxy acetic acid (2,4,5-T)**

Auxin

Function of auxins

Tropical movements

Phototropism

- Phenomenon of plants bending towards light

Geotropism

- Phenomenon of coordinated growth of plants in response to gravity

Developmental effects

- Root initiation
- Promotes flowering
- Parthenocarpy
- Apical dominance
- Prevention of abscission
- Vascular differentiation

Auxin

Developmental effects

Root initiation

- Promotes **lateral** and **adventitious roots**.
- Initiates **rooting** in stem cuttings
  - Plant propagation.

Flower initiation

- Promotes **flowering, e.g. pineapples**.

Vascular differentiation

- Helps in **differentiation of xylem** and **phloem and cell division and elongation**.

Prevention of abscission

- Auxin **delays abscission** (shedding of young leaves, flowers, fruits).
- But it also helps in shedding of old fruits and old leaves.

Parthenocarpy

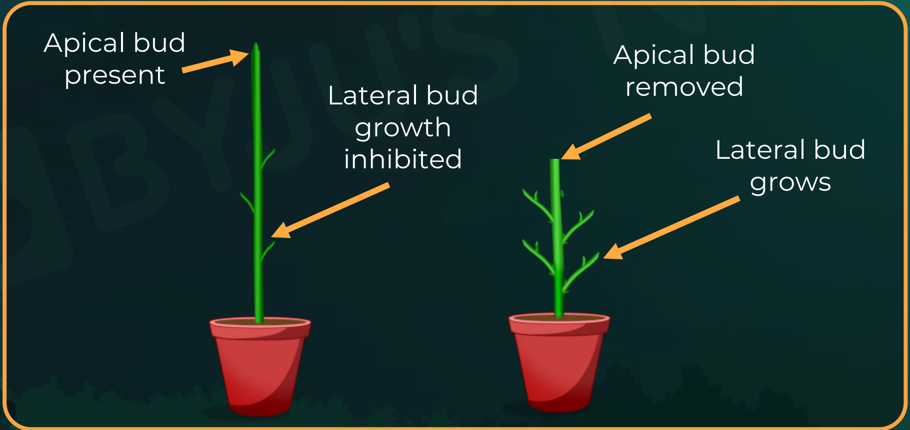
- Production of **seedless fruits, e.g. tomatoes**.
  - Indole acetic acid can be used.

Auxin

Developmental effects - Apical dominance

- Adaptive features seen in plants where the auxin produced in the apical buds **prevents the growth of the lateral buds**.
  - Growth of plants is observed at the tip of the shoot.
  - Growth of the main stem (central) is dominated over the lateral stems.
- Growth is vertical.

- Importance of apical dominance: More **access to light** to perform photosynthesis as they are taller.
  - Adaptive mechanism of some plants.
  - Get dominance over other nearby plants.
  - Helps them to become more fit than the others.



Gibberellins

- More than 100 gibberellins have been identified in a variety of plants and fungi.
- They are denoted as **GA_1, GA_2, and GA_3**.
  - GA_3 was one of the first gibberellins to be discovered.
- **Characteristics**
  - All GAs are **acidic.**

Discovery

- Rice farmers in Asia had long known of a disease.
- It makes the rice plants grow tall but declines seed production.
- This is called the "**foolish seedling**" or **bakanae** ('baka' means fool) in Japan.
- **E. Kurosawa in 1926** reported the symptoms of this disease.
- He reported that the symptoms appeared in seedlings on treatment with sterile filtrate of the fungus.
- The chemical obtained from the sterile filtrate of those tall parts was named as **gibberellin** (after *Gibberella fujikuroi,* the name of the fungus).
  - The chemical compound was identified to be gibberellic acid which induces tallness.

Gibberellins

Functions

Functions

- Stimulates stem growth
- Promotes seed germination
- Delays senescence

Gibberellins

Functions - Stimulation of stem growth

- Gibberellin **induces rapid cell division** and **cell elongation**.
- Stem growth is increased by **internodal elongation** in a wide range of species.
- **Bolting**: Internal nodal elongation prior to flowering is seen in plants like beetroots, cabbages, and other plants with rosette habit.
- **Delays the aging process** in plants.
    - Fruits can be left on the tree longer which helps in extending marketing period.

Gibberellins

Uses

- Increasing the length of the grape stalk.
- Increasing the stem length and aids in yield enhancement.
- Helps in elongating, thus improving shape of apple.
- Helps in speeding up the malting process.
- Helps in hastening maturity in juvenile conifers, leading to early seed production.
- Spraying sugarcane crop with gibberellins increases the length of the stem, thus increasing the yield by as much as 20 tonnes per acre.

Cytokinins

- These plant hormones are called cytokinins as they promote cell division or **cytokinesis**.
- Cytokinin along with auxin **promotes cell division**.
- Naturally occurring cytokinin tends to occur in regions of rapid cell division. E.g. root apices, developing shoot buds, young fruits etc.
- They are **transported via xylem**.
- Some cytokinins (synthetic) have been reported to **work as herbicides.**

Discovery

- Cytokinin was discovered while **F. Skoog** was working on callus.
- While working on tobacco proliferation, F. Skoog and his co-workers discovered that **along with auxins another 'material' leads to rapid cell proliferation (callus)**.
- Use of herring sperm **DNA** showed the **maximum growth**.
- It was later identified and isolated by **Skoog and Miller** and termed as **Kinetin**.

Cytokinin

Functions

Regulates cell division

- It is essential for cell division and it **promotes meristem growth**.
- Excessive cytokinin causes plants to grow tumors.

Overcomes apical dominance and promotes lateral growth

- Cytokinin helps plants **overcome apical dominance**.
- It also initiates **growth of lateral buds**.
- Cytokinin aids in producing **bushy** plants.

Delays senescence

- **Leaf falling** and **yellowing** can be **prevented**.
- Prevents loss of RNA, protein, and chlorophyll.

Cytokinins

Promotes nutrient mobilisation

- The nutrients move from one part to another part of the leaf.
- This is called **cytokine induced nutrient mobilisation**.
- It helps in delay of leaf senescence.

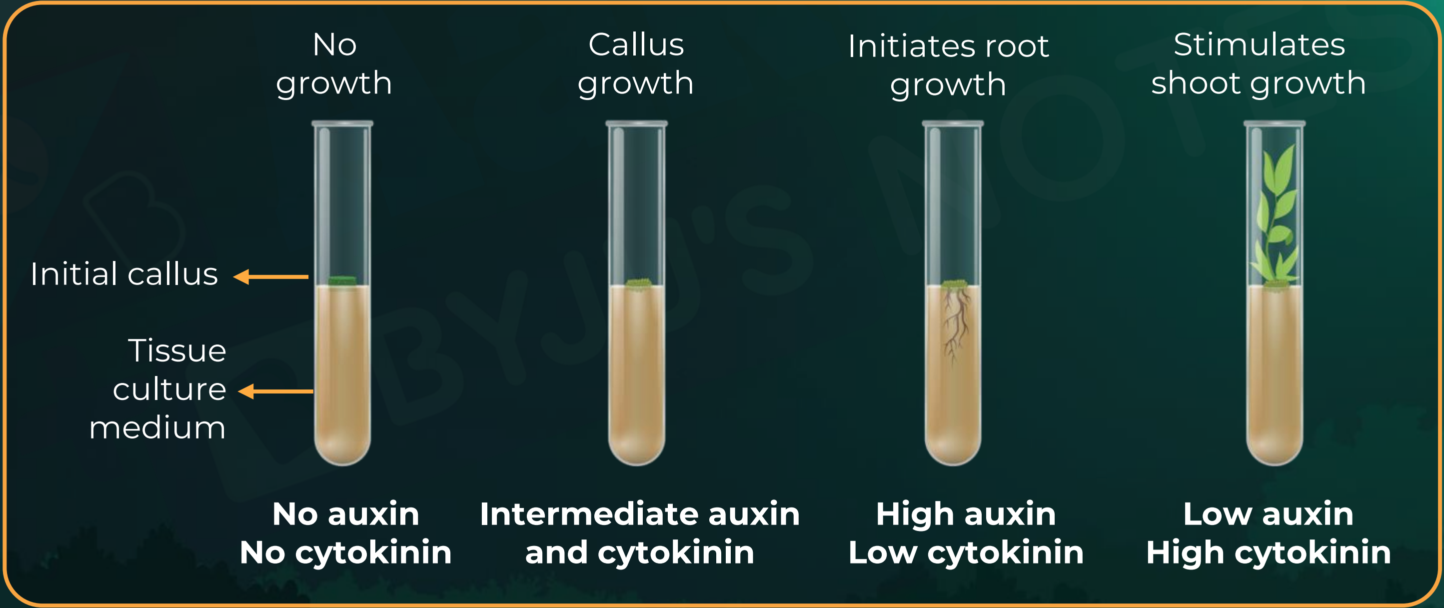
Promotes chloroplast development

- Leaf treated with cytokinins have:
  - Chlorophyll.
  - Extensive grana.
  - Photosynthetic enzymes.

Helps to produce new leaves and shoots

Did You Know?

- Auxin and cytokinin ratio aids in **morphogenesis**.
- Auxins are also **weed killers**.
- Example: 2, 4-D is used as a **dicotyledonous weed killer**.
    - It does not have any effect on **mature monocots**.



Ethylene

- **Ethylene** is a **plant hormone** responsible for the **ripening** of many fruits.
- **H. H. Cousins** showed that ripened oranges hastened the ripening of stored unripened bananas.
- The spoiled oranges released a volatile substance, which was later identified as ethylene.
- Ethylene has a **promoting effect** on all the stages of plant life starting from seed, the growth of the stem, flower, fruit, their maturation, and even senescence (aging).

Parts of plants affected by ethylene

- Seeds and seedlings
- Shoot
- Root
- Flowers
- Fruits
- Various organs

Ethylene

Effects on seeds and seedlings

Breaks seed dormancy

- Some seeds do not germinate as they undergo dormancy for certain period.
- Ethylene breaks this dormancy and makes the seed ready for germination.

Initiates germination

- Ethylene stimulates germination along with gibberellins in some seeds. Example: **peanut**.

Horizontal growth of seedlings

- Ethylene promotes the horizontal growth of seedlings.

Ethylene

Swelling of embryonic axis

- Ethylene causes an increase in the girth of seedlings.

Apical hook formation

- Ethylene promotes the development of the apical hook in dicot seeds that prevents damage to the growing tip.

Breaks bud dormancy

- Sometimes, buds in a plant become dormant due to unfavourable environmental conditions.
- Ethylene helps to break this dormancy.

Ethylene

Sprouting of potato tubers

- It helps in sprouting of tubers.

Internode/petiole elongation

- **Deepwater rice plants** grow in Southeast Asia and India.
- They have evolved to tolerate huge quantities of water.
- Ethylene in these plants promotes the growth of internodes and petioles.
- The leaves and the upper parts of the plants remain above water and do not allow them to suffocate.

Ethylene

Effects on shoot and root

Breaks seed dormancy

- Sometimes, buds in a plant get dormant due to unfavourable environmental conditions.
- Ethylene helps to break this dormancy.

Sprouting of potato tubers

- Ethylene even breaks the dormancy of potato buds and promotes their growth.

Ethylene

Internode/petiole elongation

- Deepwater rice plants grow in Southeast Asia and India.
- They have evolved to tolerate huge quantities of water.
- Ethylene in these plants promotes the growth of internodes and petioles.
- The leaves and the upper parts of the plants remain above water and do not allow them to suffocate.

Promotes root growth

Promotes root hair formation to increase the absorption

Ethylene

Effects on fruits

Ripening

- Ethylene is commercially used to ripen the foods.
    - **Ethephon** or **2-chloroethylphosphonic acid** is the source of ethylene.
    - The plants absorb ethephon and convert it to ethylene.
    - It hastens ripening of tomatoes and apples.
- Ethylene leads to **respiratory climacteric**.
    - Respiratory climacteric is the **concluding stage** of ripening process.
    - It is characterised by increased cellular respiration.
    - It is also the time when the colour changes from green to yellow, red, and more.

Ethylene

Effects on flowers

Flowering in mangoes

- It induces flowering in mangoes.

Promotes female flowers in cucumbers

- Cucumber has separate male and female flowers.
- Ethylene favours female over male flowers.
- It leads to an increase in cucumber yield.

Synchronises fruit set in pineapples

- Fruit set is the transition from flower to young fruit in the development of seed.
- Natural flowering in a pineapple plant is variable.
- Ethylene is used to make all the plants flower at the same time.
- It also leads to the production of fruits at the same time.

Ethylene

Various organs

Induces senescence

- The process of aging and decay in a plant is known as **senescence**.
- It can happen to any part of a plant.

Induces abscission

- It induces the process of shedding of the plant leaves, flowers, seeds, and fruits.
- Ethylene is used for **thinning** in agriculture.
    - Thinning means reducing the number of fruits or other plant parts so that the remaining ones can grow better.
    - **Ethephon** is usually applied to promote abscission of fruits, flowers, and more, which results in thinning.

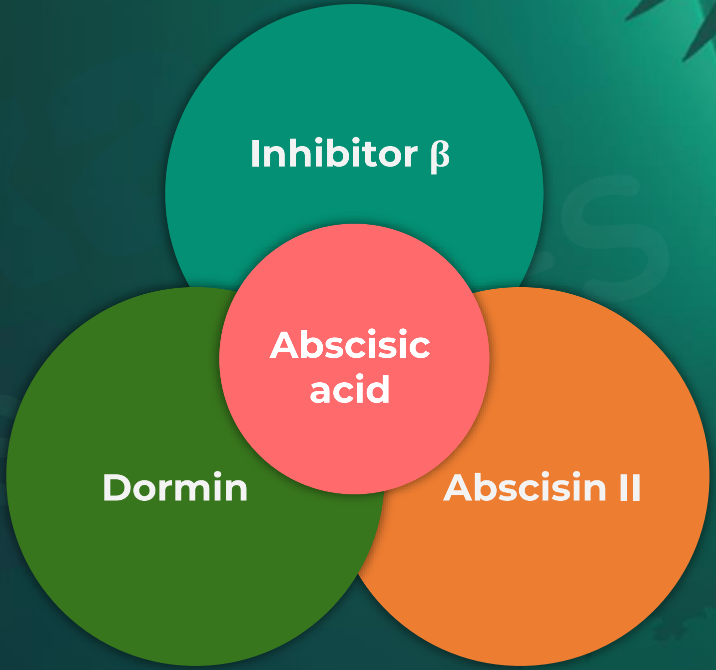
Ethylene

Mnemonic for effects of ethylene

An	**Absolutely**	Abscission
	Rich	Growth of root and root hair
	Ripe	Ripening of fruits
	Old	Aging/Senescence
	German	Germination
	Spinster	Sprouting of potato tubers
her	**Hung Embroidered Floral Sweater**	Horizontal growth of seedlings
		Swelling of embryonic axis
		Flowering
on a	**Hook**	Synchronises fruit set
		Apical hook formation
behind a	**Long**	Elongation of internodes/petioles
	Door	Dormancy breaks in seeds/buds

Abscisic Acid

- **Abscisic acid** (ABA) helps plants to overcome **situations** of **stress** and is, therefore, aptly known as the **stress hormone.**
- Discovery of ABA
  - In the 1960's, different groups of scientists discovered various growth inhibitors such as inhibitor β, abscisin II, and dormin.
  - Later, it was proved that all the three growth inhibitors were chemically identical and were named abscisic acid.



Abscisic Acid

Effects of abscisic acid

- It **increases the tolerance to** stressful environmental conditions, helping the plants to cope with stress.
- It acts as a **growth inhibitor for plants** by inhibiting the metabolic activities during unfavourable environmental conditions.
  - The rate of photosynthesis decreases during unfavourable conditions (like low light and the non-availability of water), and plants survive on stored food. In order to conserve energy, ABA acts to decrease the rate of metabolic activities, which inhibits the growth of the plant.
- It helps in **seed development** by the accumulation of reserved food, helping in **the maturation of the seed**.
- It **induces seed dormancy** and **inhibits germination** during unfavourable conditions.
- It **stimulates the closure of stomata** during unfavourable conditions, helping to **conserve water by minimising transpiration**.
- It acts as an **antagonist to gibberellins**. Gibberellin is a growth promoter and ABA is a growth inhibitor.

Seed Dormancy

- **Seed dormancy** means the lack of seed germination even during favourable conditions.
- It is **not** controlled by the external **environment** but by conditions within the seed itself **(endogenous control)**.

Advantages

- Seed dormancy that leads to delayed germination allows time for the dispersal of seeds, **preventing the overcrowding of seedlings**.
- Seed dormancy prevents germination during **unfavourable environmental conditions** (conditions such as drought, extreme hot or cold, excessive water, and more).

Seed Dormancy

Causes

Impermeable or hard seed coat

- The impermeable seed coat **does not allow the entry of water and oxygen**, which leads to dormancy.
- The hard seed coat acts as a **mechanical barrier** to germination.

Chemical inhibitors

- Chemical inhibitors such as **abscisic acid** and **phenolic acids** present in the seeds prevents germination.

Immature embryos

- Some seeds are released by plants before the embryo has fully matured.
- These seeds remain **dormant until the embryo matures** completely.

Seed Dormancy

Methods to break seed dormancy

Natural

- Hard and impermeable seed coats are broken by the following measures:
  - **Microbial action**
  - **The passage through the digestive system of animals** weakens the seed coat and promotes germination.
- Chemical inhibitors that lead to seed dormancy are often leached off from the seed by the action of rainwater.

Seed Dormancy

Artificial

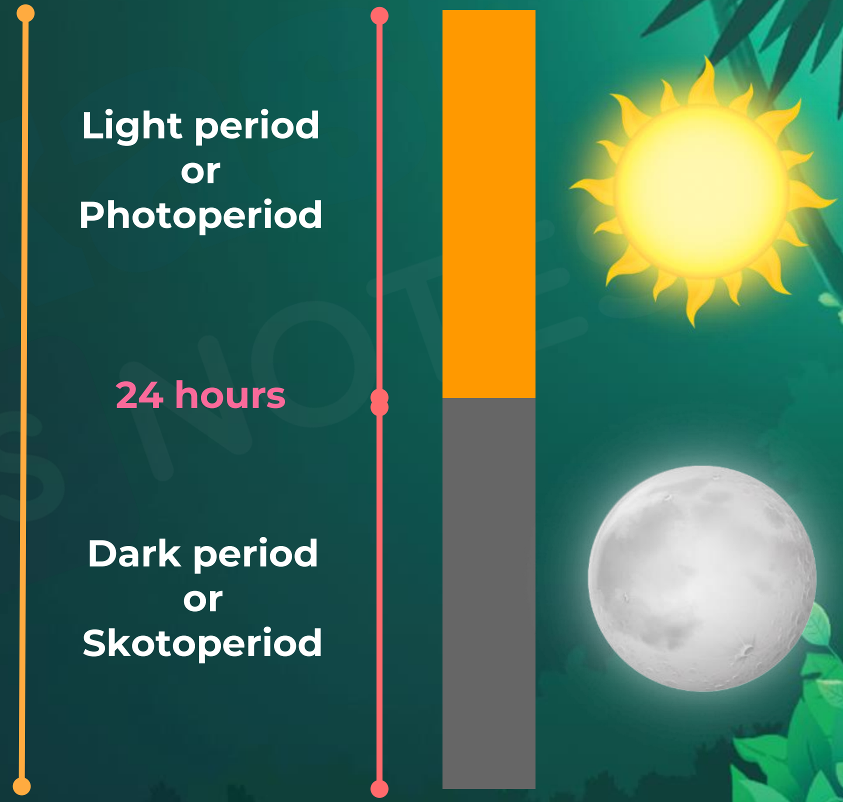
- The seed coat can also be broken by a process known as **scarification** (mechanical abrasion).
- Scarification can be done by using **knives, sandpaper, vigorous shaking,** the actions of harsh chemicals like **strong acids** and hot **water**.
- The effect of inhibitory substances can be removed by subjecting the seeds to **chilling conditions**.
- The seed coat can be broken by the application of **certain chemicals** like gibberellins, potassium nitrate, thiourea, and others.
- Seed dormancy can be overcome by keeping them in the refrigerator for several weeks. A certain wavelength of light can also promote seed germination.

Photoperiodism

- Photoperiodism is the response of plants to the relative length of day and night.
  - It was first studied by Garner and Allard (1920).

Critical photoperiod

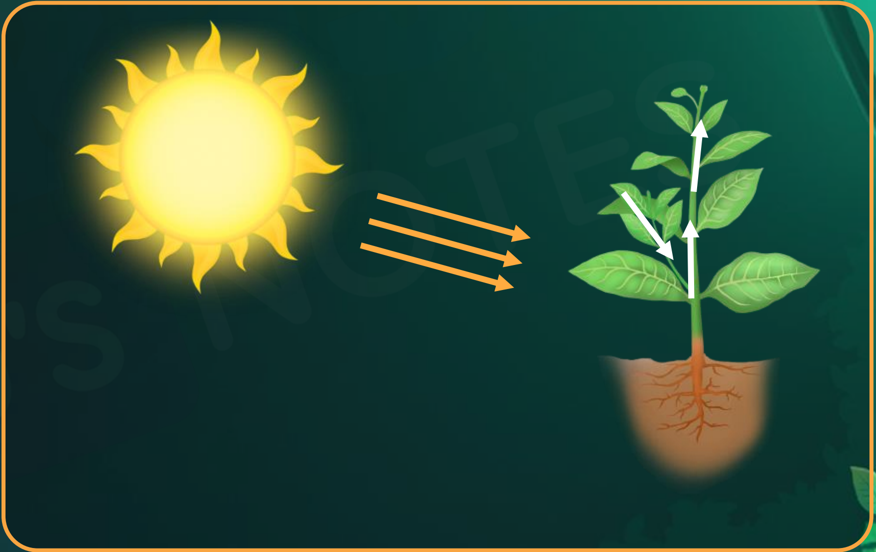
- Critical photoperiod is the **definite period of light exposure above or below which a plant does not flower**.
- This critical photoperiod is different for different plants.



Photoperiodism

Photoperiodic perception

- Leaves are the site of **perception of photoperiod**.
- The hormones and molecules responsible for the photoperiodic response migrate from leaves to shoot apices.
- They, then, induce flowering only when the plants are exposed to the necessary inductive photoperiod.



Types of Plants based on Photoperiod

Types of plants

Short day

- They **flower when** the **photoperiod** or day length is **below the critical period**.
- They are also known as **long-night plants**.

Long day

- These plants **flower when** they receive long photoperiods or **light hours** that are **above the critical length**.
- They are also known as **short-night plants**.

Day neutral

- There is **no correlation between light or dark periods and flowering**.
- Plants blossom throughout the year.

Vernalisation

- Vernalisation is the phenomenon due to which **flowering depends** either quantitatively or qualitatively **on the exposure to low temperature**.
- **It promotes vegetative growth.**
    - It ensures proper development of leaves, stems, and the vascular system.
    - It **prevents premature development of reproductive parts**.

Types of Plants

Annuals

- Annual plants are those which germinate, grow, bloom and die in **one year**.
- Some annual plants like wheat, barley, and rye have two varieties:
  - Winter variety.
  - Spring variety.

Biennials

- These are monocarpic plants that grow and flower over **two years**.
- Examples: Sugar beet and cabbage.
- Bi: Two, Annus: Years

Perennials

- These are the plants that live for more than two years.
- The winter varieties show vernalisation.

Types of Plants

Annuals

Spring varieties

- **Planted in spring**
- Grow over spring and some parts of summer.
- Do not require any exposure to cold conditions to flower.

Autumn varieties

- **Planted in autumn**
- Grow into small seedlings in winter and continue their growth in spring.
- Finally in mid-summer, they flower and produce grain and can be harvested.
- Need to go through the winter cold to produce flowers.

Biennials

- They **germinate in spring**, undergo vegetative growth in summer and once they reach winter, they **enter a period of dormancy**.
- In the **second year**, **the plants flower in spring**, form seeds in summer and **die in winter**.
- The key is the exposure to cold in winter, and this **shows vernalisation**.
- Subjecting the growth of a biennial plant to a cold treatment stimulates a subsequent photoperiodic flowering response.
  - This speeds up the process of flowering in biennials.

Summary

- Germination
  - Epigeal
  - Hypogeal

- Growth
  - Indeterminate growth
  - Determinate growth

Summary

Phases of growth

Meristematic phase
This phase is responsible for the growth of the **roots and shoot tips** of the plants.

Enlargement phase
The cells are not capable of dividing. The new cells **enlarge and elongate**.

Maturation phase
The cells completely lose the ability to divide in this phase. No new cells are formed. **Structural and physiological differentiation** occurs.

Summary

Parameters of growth in plants

- Surface area
- Girth
- Number of cells
- Weight
- Volume

Growth

- **Arithmetic growth:** As plant grows, new cells are produced. The number of cells produced increases with respect to the constant time interval.
- **Geometric growth:** As plant grows, new cells are produced. The number of cells produced increases exponentially up to a certain limit.

Summary

Growth rate

Absolute growth rate

- Growth per unit time

$$AGR = \frac{\text{Final parameter - Initial parameter}}{\text{Time}}$$

Relative growth rate

- Growth per unit time per initial parameter

$$RGR = \frac{\text{Final parameter - Initial parameter}}{\text{Time}} \times \text{Initial parameter}$$

Summary

Meristematic cell

↓ Differentiation

Permanent cell

↓ Dedifferentiation

Meristematic cell

↓ Redifferentiation

Permanent cell

Summary

Auxin	Gibberellins	Cytokinin

• **Indole derivative** plant growth regulators.
Discovery
• Darwin: Discovered the presence of some growth stimulator in the tip of the stem.
• Went isolated auxins from coleoptile tip of oat seedlings .
Types
• Natural
  ○ IAA
  ○ IBA
• Synthetic
  ○ NAA
  ○ 2,4-D
	• All GAs are **acidic.**
	• Formed in the **plastids** by the terpenoid pathway and then transformed into the endoplasmic reticulum and cytosol until they reach their biologically active form.
	• Example: GA_1, GA_2, GA_3.
	Discovery
	• **E. Kurosawa in 1926** reported the phenomenon (the "**foolish seedling**" or bakanae) in rice seedlings which makes the rice plants grow tall.
	• The chemical was later identified as **gibberellin** (after *Gibberella fujikuro*i, the name of the fungus).
		• Plant hormones that promote cell division or **cytokinesis**.
		• They are transported via xylem.
		• Naturally occurring cytokinin - **zeatin**
		Discovery
		• **F. Skoog -** Cytokinin was discovered while F. Skoog was working on callus.
		• **Miller-** Identified another chemical called zeatin which promotes cell division.

Summary

Function of auxins

- **Tropical movements**
  - Phototropism
  - Geotropism
- **Developmental effects**
  - Root initiation
  - Flower initiation
  - Parthenocarpy
  - Apical dominance
  - Feminising effect
  - Prevention of abscission
  - Vascular differentiation

Summary

Functions of gibberellin
- Stimulates stem growth
- Promotes seed germination
- Delays senescence

Summary

Functions of cytokinin

- Regulates cell division
- Overcomes apical dominance and promotes lateral growth
- Delays senescence
- Promotes nutrient mobilisation
- Promotes chloroplast development
- Helps to produce new leaves and shoots

Summary

Effects of ethylene

- Seeds and seedlings
  - Breaks seed dormancy
  - Initiates germination
  - Stimulates horizontal growth of seedlings
  - Causes swelling of embryonic axis
  - Promotes apical hook formation
- Shoot / Root
  - **Breaks bud dormancy**
  - **Helps sprouting of potato tubers**
  - **Promotes internode /petiole elongation**
  - **Promotes root growth**
  - **Promotes root hair formation**
- Flowers / Fruits
  - **Induces flowering in mango**
  - **Promotes female flowers in cucumber**
  - **Synchronises fruit set in pineapples**
  - **Helps in the ripening of fruits**
- Various organs
  - **Induces senescence**
  - **Induces abscission**

Effects of ethylene

Summary

Effects of abscisic acid

- **Increases the tolerance to** stressful environmental conditions
- Acts as **an inhibitor** of plant **metabolism**
- Helps in the seed **development and maturation**
- **Induces seed dormancy** and **inhibits germination**
- **Stimulates the closure of stomata**
- Acts as an **antagonist** to **gibberellins**

- **Abscisic acids** help plants overcome situations of stress and are thus known as **stress hormones**.
- They are derived from **carotenoids**.

- In the 1960s, different groups of scientists discovered chemicals such as **inhibitor β, dormin, abscisin II,** which were later confirmed as abscisic acid.

Summary

Seed dormancy refers to the lack of seed germination even during favourable conditions.

Causes of seed dormancy

- **Impermeable or hard seed coat**
- **Chemical inhibitors**
- **Immature embryos**

Advantages of seed dormancy

- Prevents germination **during unfavourable environmental conditions**
- Prevents the **overcrowding of seedlings**

Summary

Methods to break seed dormancy

- **Natural**
  - Hard and impermeable seed coats are broken
    - **By microbial action**
    - **By passing through the digestive system of animals.**
  - **Chemical inhibitors** that lead to seed dormancy are often leached off from the seed by action of **rainwater**.
- **Artificial**
  - **Scarification** (mechanical abrasion)
    - Using **knives, sandpaper, vigorous shaking, strong acids, hot water**.
  - **Subjecting the seeds to chilling condition.**
  - Application of **certain chemicals** like gibberellins, potassium nitrate, thiourea, etc.