Program	:	B. Pharmacy
Semester	:	1st
Subject /Course	:	Remedial Biology
Subject/Course ID	:	BP106RBT
Module No.	:	05
Module Title	:	Plant respiration and Growth
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Learning Outcome of Module-5

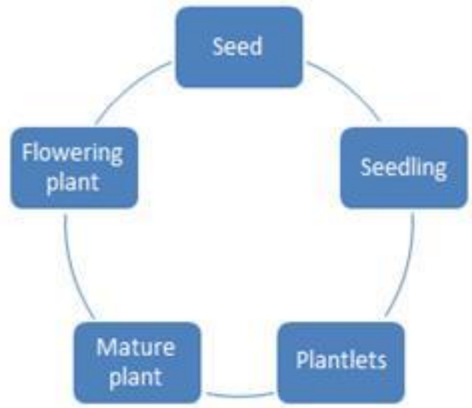
LO	Learning Outcome (LO)	Course Outcome Code
1.	Students will learn about process and mechanism of plant respiration including Glycolysis and Kreb's cycle	BP106.5
2.	Students will learn about meaning, types and phases of growth along with brief knowledge about plant growth regulators.	BP106.5
3.	Students will learn about cell, its types, plant cell, animal cell and various cell organelles.	BP106.5
4.	Students will learn about various types of plant and animal tissues.	BP106.5
5.	Students will learn about types of cell division and their phases.	BP106.5

Module Content Table

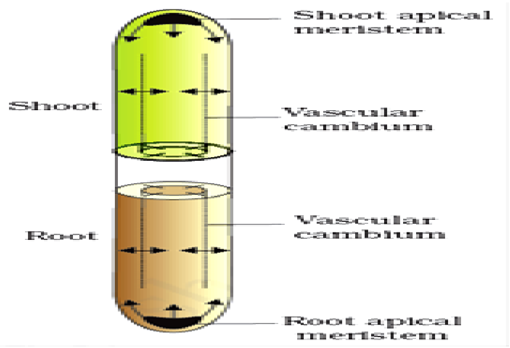
No.	Topic
1.	Plant growth
2.	Plant growth regulators
3.	Plant respiration
4.	Cell division- Mitosis and Meiosis
5.	Plant tissues

PLANT GROWTH

- Root, stem, leaves, flowers, fruits and seeds arise in orderly manner in plants. The sequence of growth is as follows-
- Plants complete their vegetative phase to move into reproductive phase in which flower and fruits are formed for continuation of life cycle of plant.
- Development is the sum of two processes **growth** and **differentiation**. Intrinsic and extrinsic factors control the process of growth and development in plants.



- **Growth** is a permanent or irreversible increase in dry weight, size, mass or volume of cell, organ or organism. It is internal or intrinsic in living beings.
- In plants growth is accomplished by cell division, increase in cell number and cell enlargement. So, growth is a quantitative phenomenon which can be measured in relation to time.
- **Plant growth is generally indeterminate** due to capacity of unlimited growth throughout the life. Meristem tissues are present at the certain locality of plant body.
- The plant growth in which new cells are always being added to plant body due to meristem is called **open form of growth**.
- **Root apical meristem and shoot apical** meristem are responsible for primary growth and elongation of plant body along the axis.
- **Intercalary meristem** located at nodes produce buds and new branches in plants.



- Secondary growth in plants is the function of lateral meristem that is vascular cambium and cork cambium.

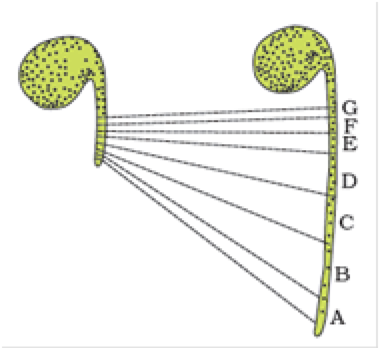
Growth is measurable

- At cellular level, growth is the increase in amount of protoplasm. It is difficult to measure the increase in amount of protoplasm but increase in cell, cell number and cell size can be measured.
- The parameter used to measure growth is increase in fresh weight, dry weight, length, area, and volume and cell number. All parameters are not used for every kind of growth.

Phases of growth

Formative Phase | Phase of Enlargement | Phase of Maturation

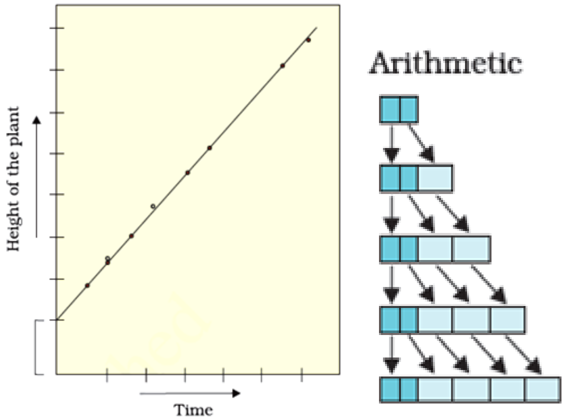
- **Formative phase** is also called as the phase of cell formation or cell division. It occurs at root apex, shoot apex and other region having meristematic tissue. The rate of respiration is very high in the cells undergoing mitosis division in formative phase.
- **Phase of Enlargement-** newly formed cells produced in formative phase undergo enlargement. Enlarging cells also develops vacuoles that further increase the volume of cell.
- Cell enlargement occurs in all direction with maximum elongation in conducting tissues and fibres.



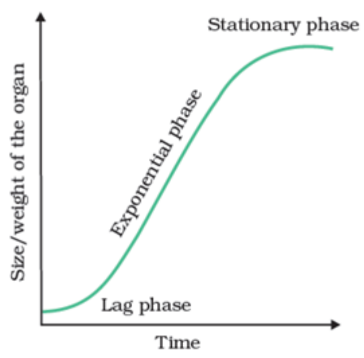
- **Phase of maturation-** the enlarged cells develops into special or particular type of cells by undergoing structural and physiological differentiation.
- **Growth Rate-** increase in growth per unit time is called growth rate. Growth rate may be arithmetic or geometrical.
- **Arithmetic Growth-** the rate of growth is constant and increase in growth occurs in arithmetic progression- 2,4,6,8 ……. It is found in root and shoot elongation.

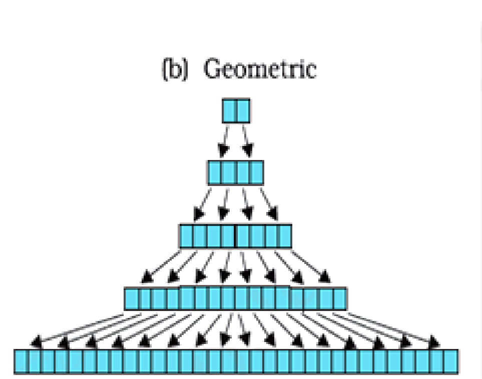
$$L_t = L_0 + rt$$

Length after time = length at beginning + growth rate x time.



- **Geometric Growth-** here initial growth is slow and increase rapidly thereafter. Every cell divides. The daughter cells grow and divide and the granddaughter cells that result into exponential growth.
- Geometrical growth is common in unicellular organisms when growing in nutrient rich medium.





- Sigmoid growth curve consists of fast dividing exponential phase and stationary phase. It is typical of most living organisms in their natural environment.

Exponential growth can be represented as follows-

$W_1 = W_0 e^{rt}$. W1 = final size, W0 = initial size, r = growth rate, t = time of growth and e is the base of natural logarithms (2.71828).

- Quantitative comparison between the growth of living system can be made by

1. Measurement and comparison of total growth per unit time is called the **absolute rate.**
2. The growth of given system per unit time expressed on a common basis is called **relative growth rate.**

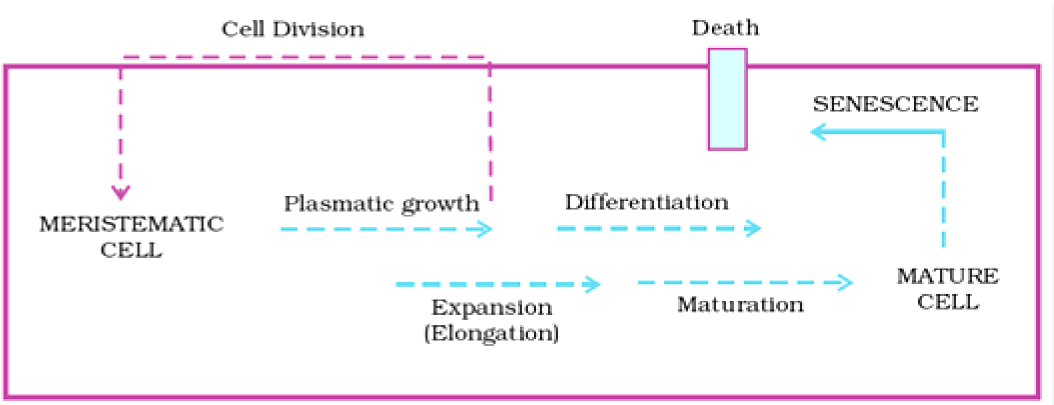
Condition for growth

- Necessary condition for growth includes water, oxygen and essential elements. Water is required for cell enlargement and maintaining turgidity. Water also provide medium for enzymatic conditions.
- Protoplasm formation requires water and micro and macronutrients and act as source of energy.
- Optimal temperature and other environmental conditions are also essential for growth of the plant.
- Cells produced by apical meristem become specialized to perform specific function. This act of maturation is called **differentiation**.

- The living differentiated cells that have lost ability of division can regain the capacity of division. This phenomenon is called **dedifferentiation**. For example interfascicular cambium and cork cambium.
- Dedifferentiated cells mature and lose the capacity of cell division again to perform specific functions. This process is called **redifferentiation**.

Development

It is the sequence of events that occur in the life history of cell, organ or organism which includes seed germination, growth, differentiation, maturation, flowering, seed formation and senescence.



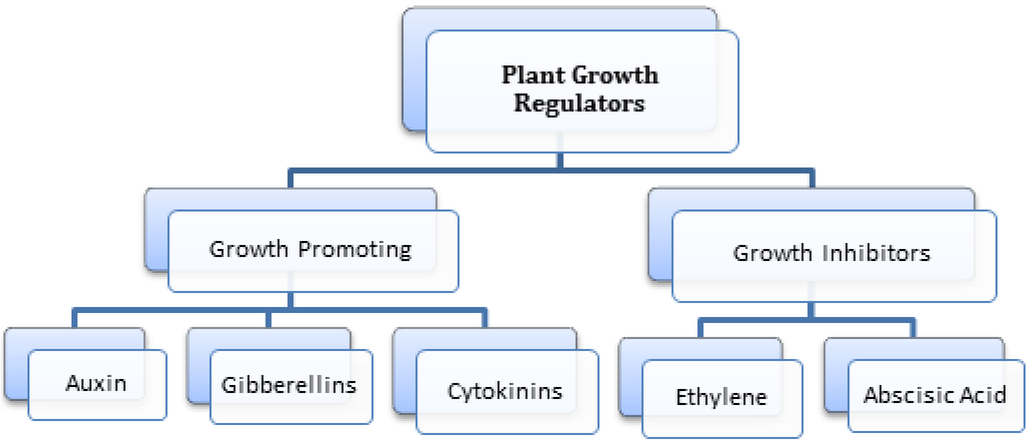
Sequence of development process in plant cell

- Different structures develop in different phases of growth as well as in response to environment. The ability to change under the influence of internal or external stimuli is called **plasticity**. Heterophylly in cotton plant is the example of plasticity.

Plant Growth Regulators are simple molecules of diverse chemical composition which may be indole compounds, adenine derivatives or derivatives of carotenoids.

- Auxin was isolated by F.W. Went from tips of coleoptiles of oat seedlings.
- The 'bakane disease' of rice seedlings is caused by fungal pathogen *Gibberella fujikuroi*. E. Kurosawa found that this disease is caused due to presence of Gibberellin.

- Skoog and Miller identified and crystallized the cytokinesis, promoting active substance called kinetin.



Auxin- was first isolated from human urine. It is commonly indole-3-acetic acid (IAA). It is generally produced at stem and root apex and migrate to site of action.
Functions-

1. Cell enlargement.
2. Apical dominance
3. Cell division
4. Inhibition of abscission
5. Induce Parthenocarpy

Gibberellins- are promotery PGR found in more than 100 forms named as GA_1, GA_2, GA_3 …. GA_{100}. The most common one is GA_3 (Gibberellic Acid).
Functions-

1. Cell elongation.
2. Breaking of dormancy.
3. Early maturity
4. Seed germination.

Cytokinins- the plant growth hormone is basic in nature. Most common forms include kinetin, zeatin, etc. They are mainly synthesized in roots.

Functions-

1. Cell division and cell differentiation.
2. Essential for tissue culture.
3. Overcome apical dominance.
4. Promote nutrient mobilisation.

Ethylene – it is a gaseous hormone which stimulates transverse or isodiametric growth but retards the longitudinal one.

Functions–

1. Inhibition of longitudinal growth.
2. Fruit ripening
3. Senescence
4. Promote apical dominance

Abscisic Acid – it is also called stress hormone or dormin. It acts as a general plant growth inhibitor. Abscisic acid is produced in the roots of the plant and terminal buds at the top of plant.

Function-

1. Bud dormancy
2. Leaf senescence
3. Induce Parthenocarpy
4. Seed development and maturation

Photoperiodism- the effect of photoperiods or day duration of light hours on the growth and development of plant, especially flowering is called Photoperiodism. On the basis of photoperiodic response, flowering plants have been divided into the following categories-

1. **Short Day Plants**– they flower when photoperiod is below a critical period (continuous duration of light which must not be exceeded in short day plants and should always be exceeded in long day plants in order to bring them flower). Example- Xanthium, Rice, Sugarcane, Potato etc.
2. **Long Day Plants**– these plants flower when they receive long photoperiod of light, greater than critical period. Example- Radish, Barley, Lettuce.
3. **Day Neutral Plants** – the plant can blossom throughout the year. Example- Bean, Wild Kidney.

Vernalisation– is the process of shortening of the juvenile or vegetative phase and hastening of flowering by cold treatment. The stimulus of Vernalisation is perceived by meristematic cells.

- Vernalisation helps in shortening of vegetative period of plant and brings about early flowering.
- It is applicable to temperate plants like Wheat, Rice, Millets, etc.

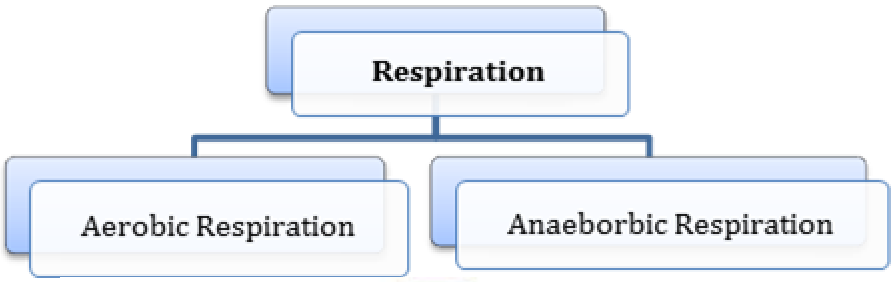
PLANT RESPIRATION

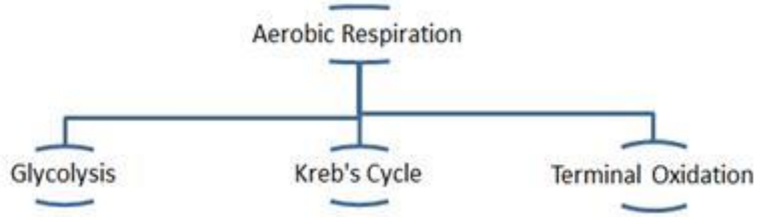
Respiration is an energy releasing, enzymatically controlled catabolic process which involves a step-wise oxidative breakdown of food substance inside living cells.

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + Energy$$

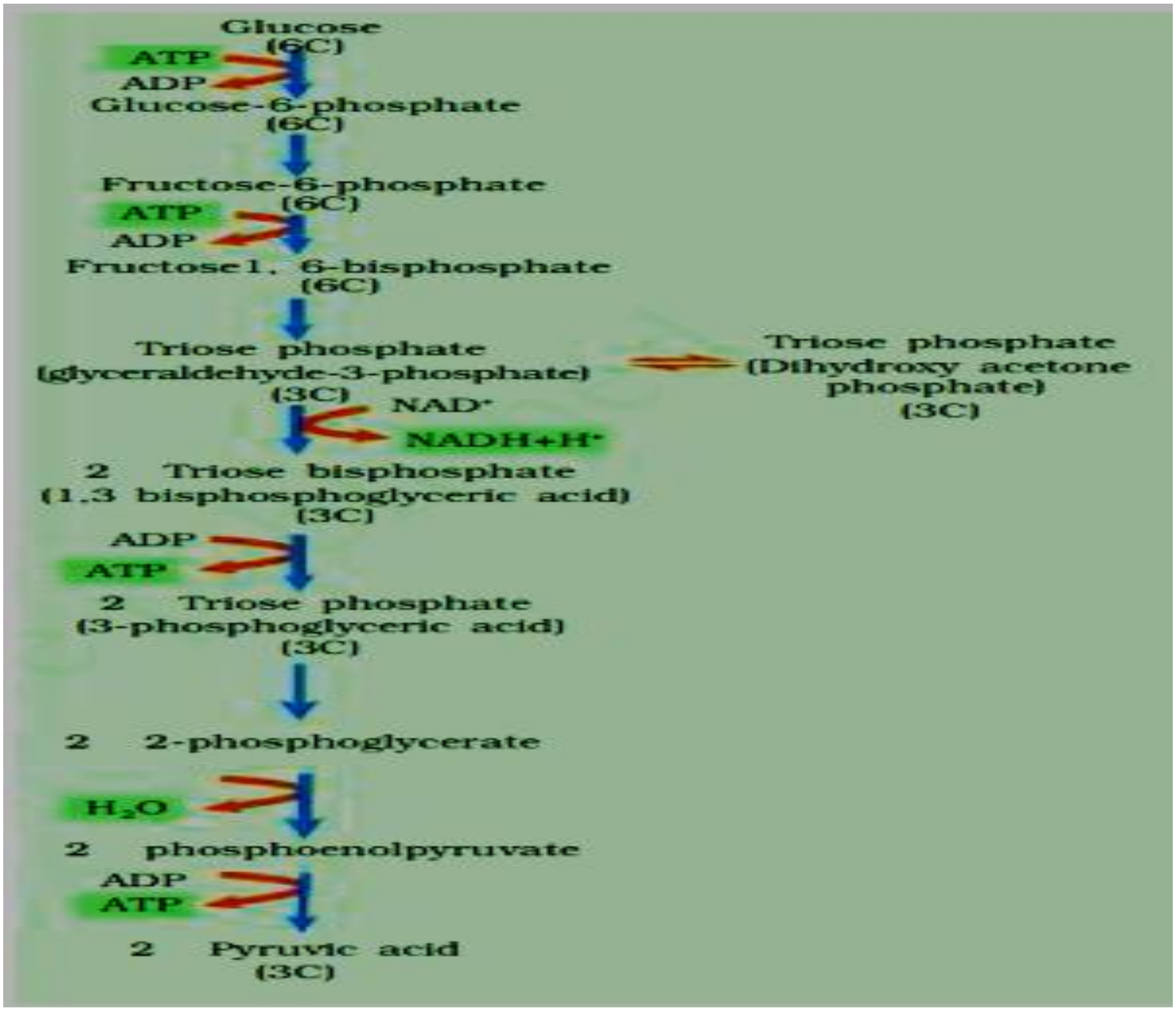
- Living organism require energy for all activities like absorption, movement, reproduction or even breathing. Energy required is obtained from oxidation of food during respiration.
- **Cellular respiration** is the mechanism of breaking down of food materials within the cell to release energy for synthesis of ATP.

- Breaking down of complex molecules takes place to produce energy in cytoplasm and in the mitochondria.
- Breaking down of C-C bond of complex compounds through oxidation within the cells leading to release of energy is called **respiration.** The compounds that get oxidized are called **respiratory substrates**.
- Energy released during oxidation is not used directly but utilized in synthesis of ATP, which is broken down when energy is required. Therefore, **ATP is called energy currency** of cells.
- The process of respiration requires oxygen. In plants oxygen is taken in by stomata, lenticels and root hairs.
- Plants can get along without respiratory organs because:
  1. Each plant part takes care of its own gas-exchange needs.
  2. Plants do not present great demands for gas exchange.
  3. Distance that gases must diffuse in large plant is not great.
  4. During photosynthesis O2 is released in leaves and diffuse to other part of leaves.
- During process of respiration oxygen is utilized and carbon dioxide and water is released along with energy molecules in form of ATP.
- **Respiratory Quotient** is the ratio of the volume of carbon dioxide produced to the volume of oxygen consumed in respiration over a period of time. RQ is equal to one for carbohydrate and less than one for protein and peptones.





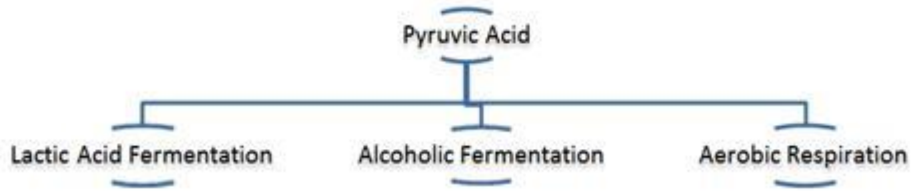
Aerobic Respiration is an enzymatically controlled release of energy in a stepwise catabolic process of complete oxidation of organic food into carbon dioxide and water with oxygen acting as terminal oxidant.



Glycolysis

- The scheme of glycolysis is given by Gustav Embden, Otto Meyerhof, and J. Parnas. It is also called as **EMP pathway**.
- Glycolysis is the partial oxidation of glucose or similar hexose sugar into two molecules of pyruvic acid through a series of enzyme mediated reaction releasing some ATP and NADH2. It occurs in cytoplasm.

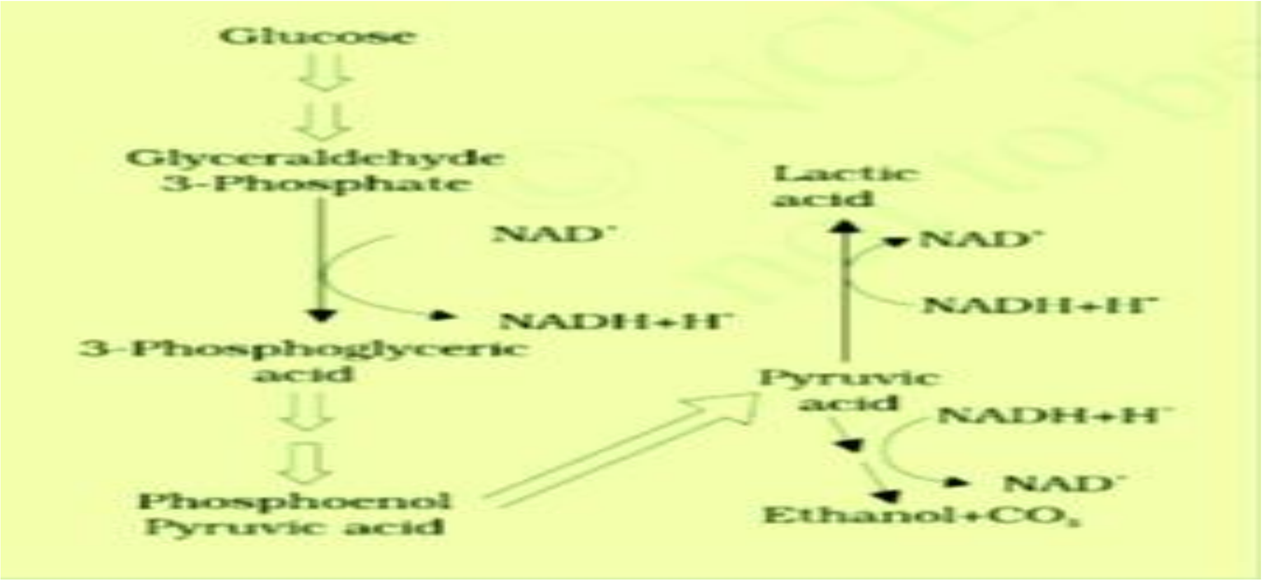
- In plants glucose is derived from sucrose or from storage carbohydrates. Sucrose is converted into glucose and fructose by enzyme *invertase*.
- Glycolysis starts with phosphorylation of glucose in presence of enzyme *hexokinase* to form Glucose-6-phosphate. One molecules of ATP is used in this process.
- In next steps Glucose-6-phosphate is converted into fructose-6-phosphate, catalysed by enzyme *phosphohexose isomerase*.
- Fructose-6-phosphate uses another molecule of ATP to form Fructose-1-6 biphospahte in presence of enzyme *phosphfructokinase*.



- In glycolysis two molecules of ATP are consumed during double phosphorylation of glucose to fructose 1,6 biphosphate. Two molecules of NADPH2 are formed at the time of oxidation of glyceraldehyde 3-phosphate to 1,3 biphosphoglycerate. Each NADH is equivalent to 3ATP, so that **net gain in glycolysis is 8 ATP**.

- Pyruvic acid is the key product of glycolysis, further breakdown of pyruvic acid depends upon the need of the cell.

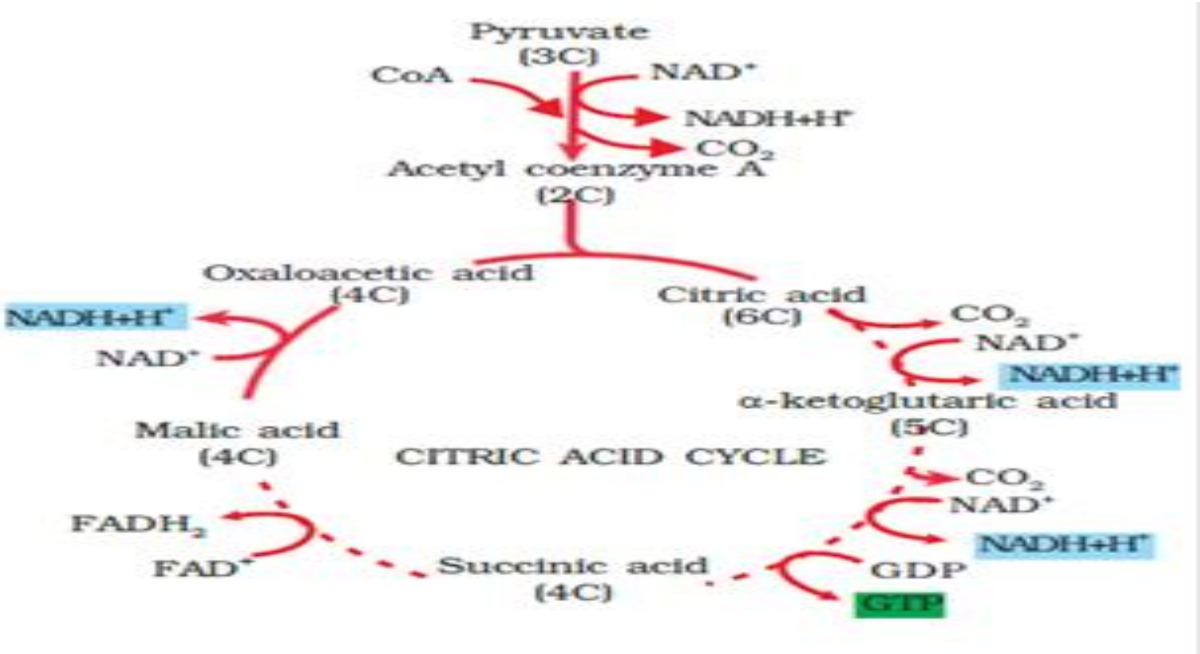
- In animal cells, like muscles during exercise, when oxygen is insufficient for aerobic respiration, pyruvic acid is reduced to **Lactic acid** by enzyme lactate dehydrogenase due to reduction by NADH2.



- In fermentation by yeast, pyruvic acid is converted to ethanol and CO2. The enzyme involved is pyruvic acid decarboxylase and alcohol dehydrogenase catalyse this reaction.
- In both lactic acid fermentation and alcohol fermentation very less amount of energy is released.
- Yeasts poison themselves to death if concentration of alcohol reaches above 13%.
- Final product of glycolysis, pyruvate is transported from the cytoplasm into mitochondria for further breakdown.
- Oxidation of Pyruvate to Acetyl-CoA is done to produce CO2 and NADH. The reaction catalyzed by pyruvic dehydrogenase requires the participation of several Coenzymes including NAD+ .

$$Pyruvic\ acid + CoA + NAD^+ \xrightarrow[Pyruvate\ dehydrogenase]{Mg^{2+}} Acetyl\ CoA + CO_2 + NADH + H^+$$

- The Acetyl CoA enters a cyclic pathway called TCA cycle or **Kreb's cycle**.



Tricarboxylic Acid Cycle/Krebs Cycle

- TCA cycle was discovered by Hans Krebs in 1940. This cycle is called TCA cycle because initial product is citric acid.
- Acetyl CoA combine with OAA (Oxaloacetic acid) and water to yield **citric acid** in presence of enzyme citrate synthase to release CoA.
- Citrate is then isomerised to **isocitrate**. It is followed by two successive steps of decarboxylation, leading to the formation of **α-ketoglutaric acid** and then **succinyl-CoA.**
- In the remaining steps, succinyl-CoA is oxidised to OAA allowing the cycle to continue.
- There are three points in the cycle where NAD + is reduced to NADH2 and one point where FAD + is reduced to FADH2 .
- A molecule of glucose produces two molecules of $NADH_2$, 2ATP and two pyruvate while undergoing glycolysis. The two molecules of pyruvate are completely degraded in Krebs cycle to form two molecules of ATP, $8NADH_2$ and $2FADH_2$.

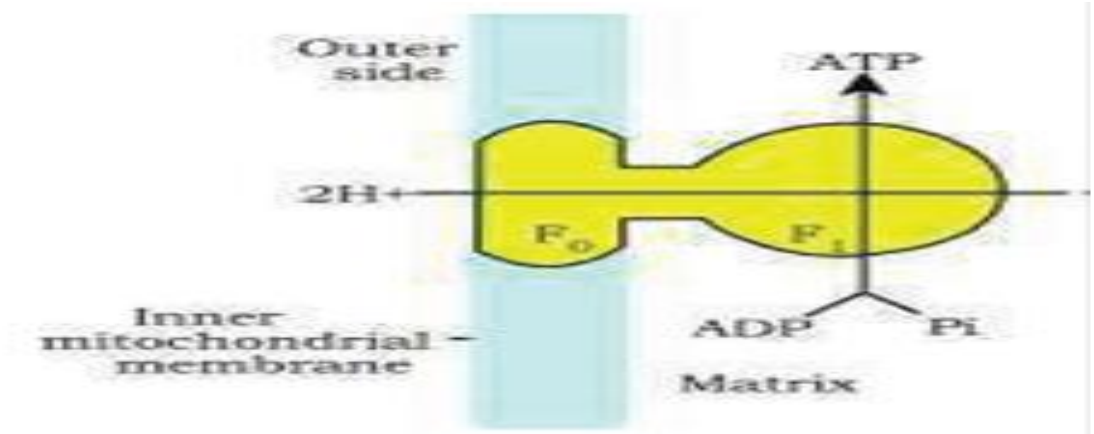
Pyruvic + 4NAD$^+$ + FAD$^+$ + 2H$_2$O + ADP +Pi $\xrightarrow{Mitochondrial\ Matrix}$ 3CO$_2$ $+\underset{FADH_2}{4NADH}+\underset{ATP}{4H^+}$

Terminal Oxidation is the name of oxidation found in aerobic respiration that occurs towards end of catabolic process and involves the passage of both electrons and protons of reduced coenzyme to oxygen to produce water.

Electron Transport Chain

- The metabolic pathway through which the electron passes from one carrier to another inside the inner mitochondrial membrane is called **ETC or mitochondrial respiratory chain.**
- Electrons from NADH produced during citric acid cycle are oxidized by NADH dehydrogenase and electrons are transferred to ubiquinone located within the inner membrane. Ubiquinone also receives electrons from FADH2 which is transferred to *cytochrome c* via *cytochrome bc$_1$* complex.
- When the electrons pass from one carrier to another via electron transport chain, they produce ATP from ADP and inorganic phosphate. The number of ATP molecules synthesized depends upon electron donor.
- Oxidation of one molecule of NADH gives rise to 3 molecules of ATP, while oxidation of one molecule of FAD_2 produce two molecules of ATP.

Oxidative phosphorylation	Photophosphorylation
a) It occurs in respiration process. **b)** Energy of oxidation-reduction is used for production of proton gradient required for phosphorylation.	**a)** It occurs in photosynthesis. **b)** Light energy is utilized for production of proton gradient for phosphorylation.



- The energy released during ETC is used to make ATP with the help of ATP synthase, which consists of two major parts F1 and F0.
- F1 is a peripheral membrane protein complex having site for synthesis of ATP from ADP and inorganic phosphate. F0 is integral membrane protein that form channel for proton.
- For each ATP produced 2H+ passes through F0 from the intermembrane space to the matrix down the electrochemical proton gradient.

Fermentation	Aerobic Respiration
a. It accounts for incomplete oxidation of glucose. **b.** In fermentation, there is net gain of only two molecules of ATP. **c.** NADH is oxidized to NAD+ very slowly.	**a.** It accounts for complete oxidation of glucose. **b.** In aerobic respiration, there is more net gain of ATP. **c.** NADH is oxidized to NAD+ very fast.

Amphibolic Pathway

- Glucose is the favored substrate for respiration. All carbohydrates are usually converted into glucose before used for respiration.
- Fats needs to be broken down into glycerol and fatty acid, which is further broken converted into Acetyl CoA and enter the respiratory pathway.

- Proteins are broken into amino acids and further enter into Krebs cycle.
- Breaking down process within living organism is called catabolism and synthesis process is called anabolism process. So, respiration is an Amphibolic pathway.

CELL DIVISION

What is cell division?

Cell division can be defined as a process by which a cell distributes its genetic material and cytoplasm and gives rise to new daughter cells. It is a part of the larger cell cycle and has a direct role in cell reproduction.

In well-developed organisms, there are two types of cell division observed, mitosis and meiosis. These are very complex processes which are carried out through different phases. However, if simplified, mitosis can be defined as the exact duplication of a cell where the daughter cells will have the same genetic information as the parent cell. In meiosis, the daughter cells will only have half of the genetic information of the original cell. The common end phase in both processes is cytokinesis and the division of the cytoplasm. We will discuss both types of cell division in this topic.

Cell division mitosis and meiosis

The two well-documented types of cell division are:

1. **Mitosis**
2. **Meiosis**

Mitosis

It is the type of cell division where one cell divides to produce two genetically identical daughter cells. A great majority of cell divisions that take place in our body is mitosis. The process is integral to an organism’s body growth and development and it takes place throughout the organism’s lifetime. For some-single-celled organisms such as yeast, mitotic cell division is the only way they can reproduce. In the following, we will learn about the mitotic process of cell division.

The cell division phases of mitosis are:

1. Early and late Prophase
2. Metaphase
3. Anaphase
4. Telophase

Before mitosis begins, the cell is in a state called interphase and it copies its DNA and so the chromosomes in the nucleus consist of two copies which are called sister chromatids. In animals, the centrosome is also copied. Centrosomes control mitosis in animal cells. It should be mentioned here, that as plant cells do not have centrioles and centrosomes, and the microtubule organising centre regulates mitosis.

Early and late prophase

- In the early prophase, the cell initiates cell division by breaking down some cell component and building other components and then the chromosome division starts.
- In this stage, the chromosomes start to condense which helps them to separate easily in later stages
- Afterwards, the mitotic spindle starts to form, a structure made of microtubules. It organises the chromosomes and moves them around during mitosis. The mitotic spindle grows between the centrosomes of the cell as they move towards different poles.
- The nucleolus then disappears which is a sign that the nucleus is getting ready to break down.
- In late prophase which is also called prometaphase, the mitotic spindle starts to organise the chromosomes.
- Once the chromosomes finish condensing, they for a compact structure.
- Then the nuclear envelope breaks down and the chromosomes are released.
- At the end of prophase, the mitotic spindle grows, and some microtubules start to capture and organise chromosomes.

Metaphase

- Metaphase starts when the mitotic spindle organises all chromosomes and lines them up in the middle of the cell to divide.
- All chromosomes align at the metaphase plate

- At this stage of metaphase, the two kinetochores of each chromosome should be attached to microtubules from opposite spindle poles. Before proceeding forward to anaphase, the cell will check if all kinetochores are properly attached to microtubules and it is called spindle checkpoint.
- Spindle checkpoint ensures that the sister chromatids are split equally into two daughter cells.

Anaphase

- In this stage, the sister chromatids separate from each other and move towards the opposite poles of the cell. The protein glue that holds them breaks and it allows them to separate.
- Microtubules which are not attached to chromosomes elongate and push apart. In doing so they separate the poles and makes the cell longer. These processes are controlled by motor proteins and these proteins carry the chromosomes and microtubules as they move.

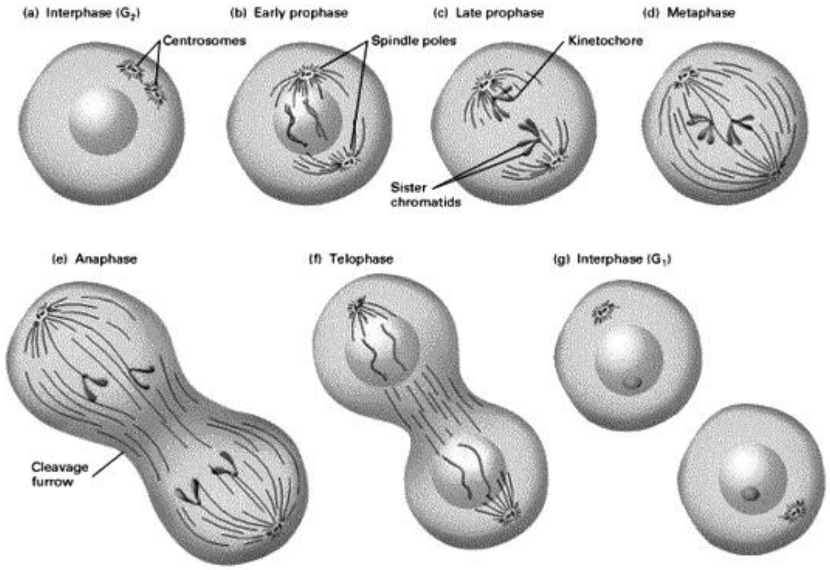
Telophase

- In this stage, the cell is almost divided and starts to re-establish its normal cellular structures as cytokinesis takes place.
- The mitotic spindle breaks down into its building blocks and two new nuclei are formed, one for each set of chromosomes.
- The nuclear membrane and the nucleoli then reappear and the chromosomes begin to de-condense to return to their normal form.

Cytokinesis

- In animal cells, cytokinesis is contractile. There’s a pinch like formation within the cell which divides it in two like a coin purse with a ‘drawstring’. The “drawstring” is a band of actin protein filaments. The pinch crease is called the cleavage furrow.
- Plant cells can’t be divided like this as they have a rigid cell wall and are too stiff. A cell plate forms down the middle of the cell which splits the daughter cells.

Cell Division



Meiosis

In meiosis, a single cell divides twice to produce four cells which contain half of the original amount of genetic material. It can be observed in sperm cells in males and egg cells in females. There are 9 meiotic cell division phases. These are discussed below:

Interphase

- Similar to mitosis the genetic material of the cell is copied and two identical sets of chromosomes are formed.
- The centrosomes and the centrioles are also copied and in this phase, the microtubules extend from centrosomes.

Prophase I

- The two sets of chromosomes condense into an X-shaped formation
- Each chromosome consists of two sister chromatids which contain identical genetic information.
- All chromosomes pair up. For example, both copies of chromosome 1 and both copies of chromosome 2 are together.

- The chromosomes pairs may then exchange parts of DNA through crossing over or recombination.
- In the end, this stage the nuclear membrane dissolves and releases the chromosomes.
- The meiotic spindle which consists of microtubules and other proteins extends across the cell.

Metaphase I

- The chromosome pairs align next to each other along the centre of the cell.
- The centrioles move at the opposite poles of the cell and the meiotic spindles extend from them. Their fibres attach to one chromosome of each pair.

Anaphase I

- The chromosomes pairs are then separated by the meiotic spindle and move one each chromosome to opposite poles of the cell.
- In meiosis I, the sister chromatids of the cell stay together.

Telophase I and cytokinesis

- The chromosomes move to opposite poles of a cell and each pole has a full set of chromosomes.
- A nuclear membrane starts to form around each set of chromosomes to form two new nuclei.
- Cytokinesis takes place and two daughter cells are produced.

Meiosis II

Prophase II

- At the end of meiosis, there are two daughter cells with 23 chromosomes
- The chromosomes condense again and form visible X-shaped structures
- The nuclear membrane will dissolve releasing the chromosomes.
- The centrioles duplicate and the meiotic spindle is formed.

Metaphase II

- Similar to metaphase I, the sister chromatid align along the centre of the cell

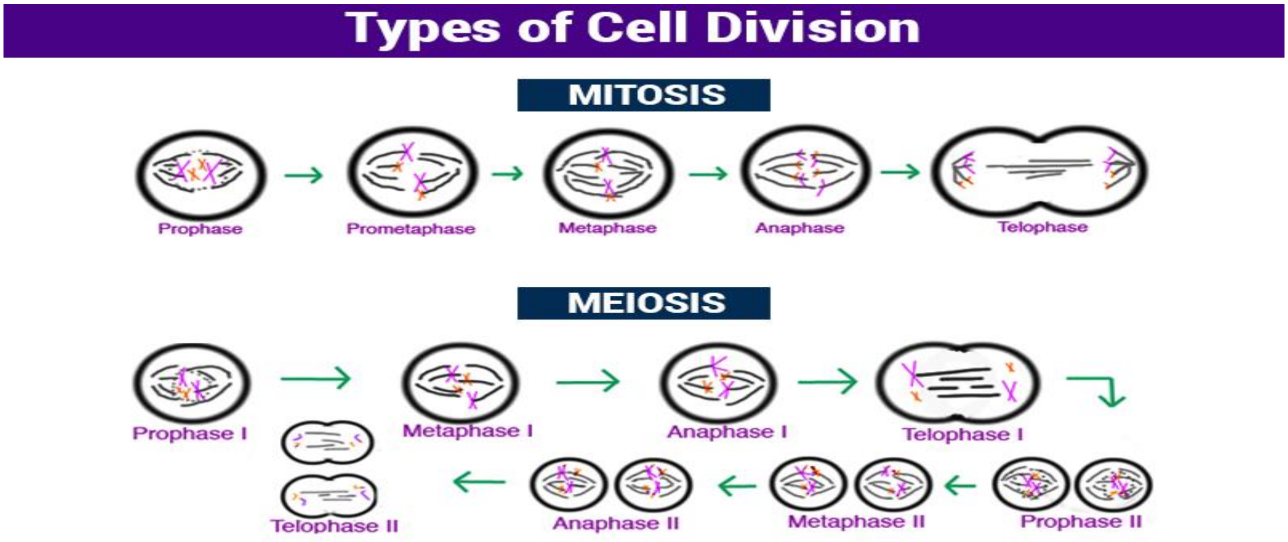
- The centrioles move to opposite poles of the daughter cells.
- Meiotic spindle fibres attach to individual sister chromatids.

Anaphase II

- The sister chromatids separated and moved to opposite poles by the meiotic spindle and they become individual chromosomes.

Telophase II and cytokinesis

- The chromosomes move to opposite poles of the cell and each pole has a full set of chromosome.
- A nuclear membrane starts to form again and two new cell nuclei are formed.
- Cytokinesis takes place.
- Once cytokinesis is completed there are four new cells, with a haploid set of chromosomes
- In males, all four cells are sperm cells
- In females, one new is an egg cell and the others are polar bodies



PLANT TISSUES

Plant Tissues

- Plants are stationary or fixed – they don't move. Most of the tissues they have are supportive, which provides them with structural strength.

- Most of the plant tissues are dead, since dead cells can provide mechanical strength as easily as live ones, and need less maintenance.
- Animals on the other hand move around in search of food, mates and shelter. They consume more energy as compared to plants. Most of the tissues they contain are living.
- Another difference between animals and plants is in the pattern of growth. The growth in plants is limited to certain regions, while this is not so in animals.
- There are some tissues in plants that divide throughout their life. These tissues are localised in certain regions.
- Based on the dividing capacity of the tissues, various plant tissues can be classified as **growing or meristematic tissue** and **permanent tissue**.
- Cell growth in animals is more uniform. So, there is no such demarcation of dividing and non-dividing regions in animals.
- The structural organisation of organs and organ systems is far more specialised and localised in complex animals than even in very complex plants. This fundamental difference reflects the different modes of life pursued by these two major groups of organisms, particularly in their different feeding methods.
- Also, they are differently adapted for a sedentary existence on one hand (plants) and active locomotion on the other (animals), contributing to this difference in organ system design.

Meristematic Tissue

- The growth of plants occurs only in certain specific regions. This is because the **dividing tissue**, also known as meristematic tissue, is located only at these points.
- Depending on the region where they are present, meristematic tissues are classified as **apical, lateral** and **intercalary**.
- New cells produced by meristem are initially like those of meristem itself, but as they grow and mature, their characteristics slowly change and they become differentiated as components of other tissues.

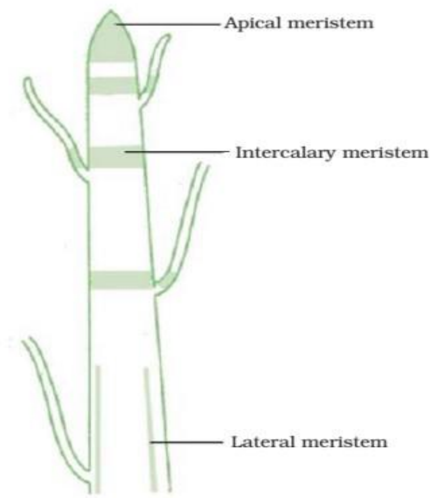


Fig. 6.2: *Location of meristematic tissue in plant body*

1. **Apical meristem** is present at the growing tips of stems and roots and increases the length of the stem and the root.
2. The girth of the stem or root increases due to **lateral meristem (cambium)**.
3. **Intercalary meristem** is the meristem at the base of the leaves or internodes (on either side of the node) on twigs.

- As the cells of this tissue are very active, they have **dense cytoplasm, thin cellulose walls** and **prominent nuclei**. They **lack vacuoles**.

Permanent Tissue

- What happens to the cells formed by meristematic tissue? They take up a specific role and lose the ability to divide. As a result, they form a permanent tissue.
- This process of taking up a permanent shape, size, and a function is called **differentiation**. Cells of meristematic tissue differentiate to form different types of permanent tissue.

Simple Permanent Tissue

Parenchyma

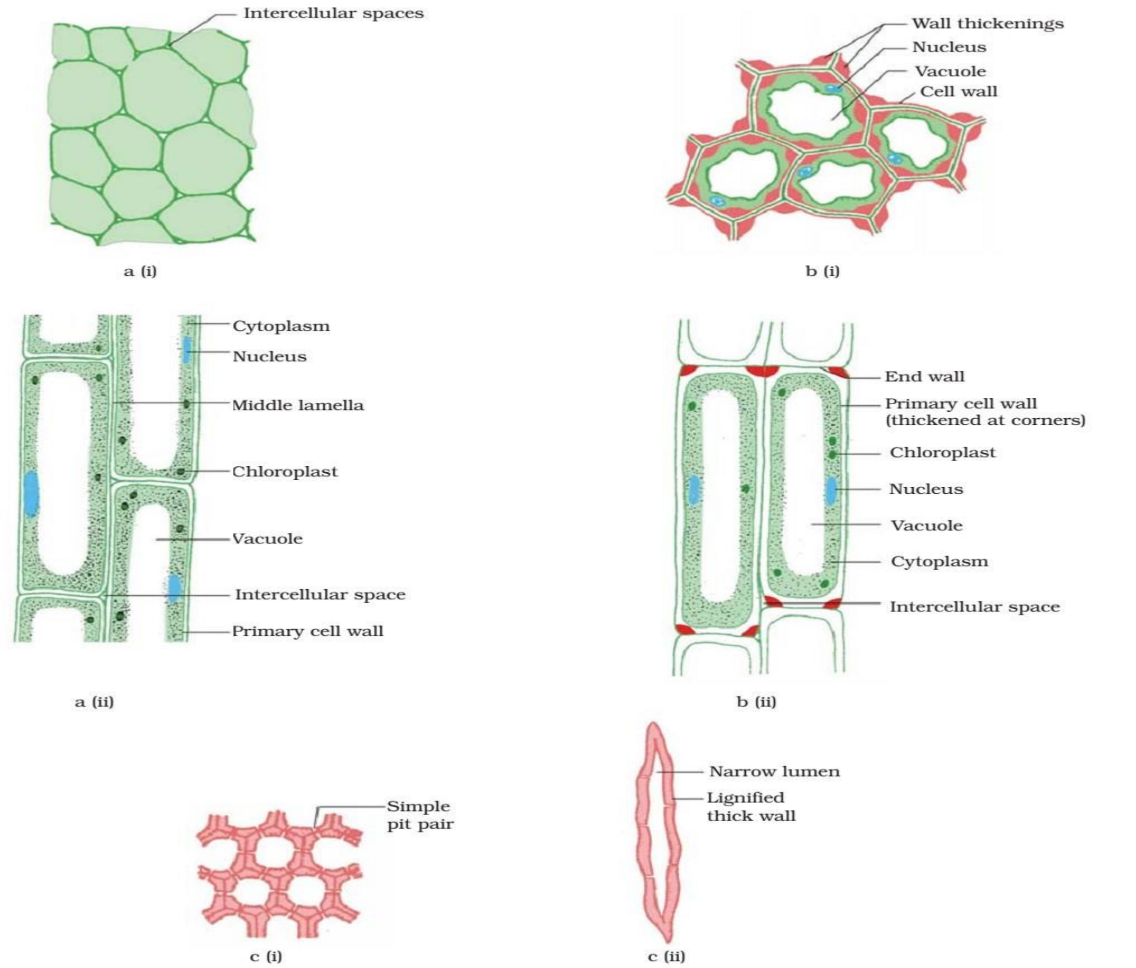
- A few layers of cells form the basic **packing tissue**. This tissue is parenchyma, a type of permanent tissue. It consists of relatively **unspecialised cells with thin cell walls**.
- They are **live cells**. They are usually loosely packed, so that large spaces between cells (intercellular spaces) are found in this tissue.

Chlorenchyma

- This tissue provides support to plants and also **stores food**. In some situations, it contains chlorophyll and performs photosynthesis, and then it is called chlorenchyma.

Aerenchyma

- In aquatic plants, large air cavities are present in parenchyma to give **buoyancy** to the plants to help them float. Such a parenchyma type is called aerenchyma. The parenchyma of stems and roots also stores nutrients and water.



. 6.4: Various types of simple tissues: (a) Parenchyma (i) transverse section, (ii) longitudinal section; (b) Collenchyma (i) transverse section, (ii) longitudinal section; (c) Sclerenchyma (i) transverse section, (ii) longitudinal section.

Collenchyma

- The flexibility in plants is due to another permanent tissue, collenchyma. It allows easy bending in various parts of a plant (leaf, stem) without breaking. It also provides mechanical support to plants. We can find this tissue in leaf stalks below the epidermis. The cells of this tissue are living, elongated and irregularly thickened at the corners. There is **very little intercellular space**.

Sclerenchyma

- Yet another type of permanent tissue is sclerenchyma. It is the tissue which makes the plant **hard and stiff**. We have seen the husk of a coconut. It is made of sclerenchymatous tissue. The cells of this tissue are **dead**. They are long and narrow as the walls are thickened due to **lignin** (a chemical substance which acts as cement and hardens them). Often these walls are so thick that there is **no internal space** inside the cell. This tissue is present in stems, around vascular bundles, in the veins of leaves and in the hard covering of seeds and nuts. It provides strength to the plant parts.

Complex Permanent Tissue

- The different types of tissues we have discussed until now are all made of **one type of cells**, which look like each other. Such tissues are called simple permanent tissue. Yet another type of permanent tissue is complex tissue.
- Complex tissues are made of **more than one type of cells**. All these cells coordinate to perform a common function.
- **Xylem** and **phloem** are examples of such complex tissues. They are both conducting tissues and constitute a vascular bundle.
- Vascular or conductive tissue is a distinctive feature of the complex plants, one that has made possible their survival in the terrestrial environment.

Xylem

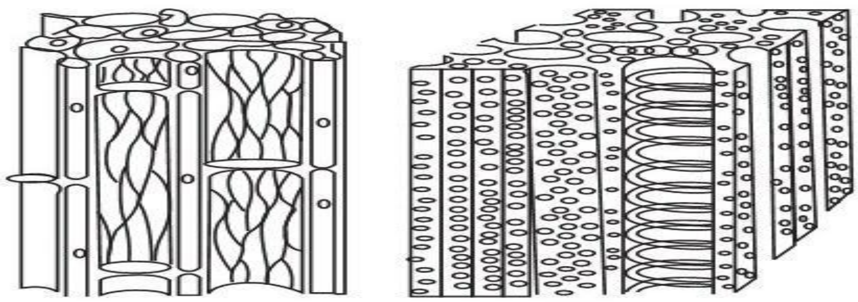
- Xylem consists of **tracheids, vessels, xylem parenchyma** and **xylem fibres**. The cells have thick walls, and many of them are dead cells.
- Tracheids and vessels are tubular structures. This allows them to transport water and minerals vertically.

- The parenchyma **stores food** and helps in the **sideways conduction of water**. Fibres are mainly supportive in function.

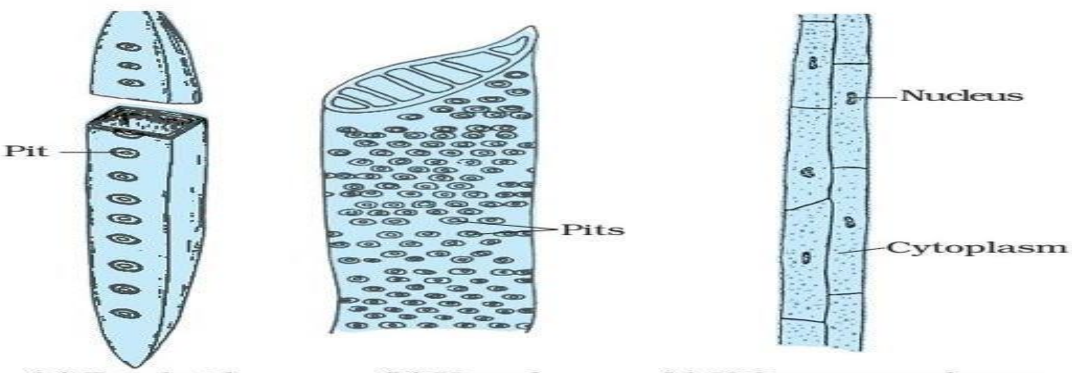
Phloem

- Phloem is made up of four types of elements: **sieve tubes, companion cells, phloem fibres** and the **phloem parenchyma**. Sieve tubes are tubular cells with perforated walls.

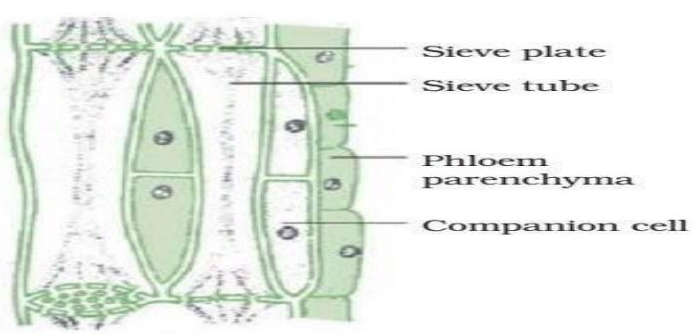
Phloem is unlike xylem in that materials can move in **both directions** in it. Phloem transports **food** from leaves to other Parts of the plant. Except for phloem fibres, phloem cells are living cells.



Phloem Xylem



(a) Tracheid (b) Vessel (c) Xylem parenchyma



(d) Section of phloem

IMPORTANT POINTS TO REMEMBER

1. What is growth, its types, phases and conditions?
2. Explain role of various plant growth regulators.
3. Glycolysis
4. Kreb's cycle
5. Anaerobic respiration
6. Mitosis cell division
7. Meiosis cell division
8. Various plant tissues

References for more learning

NCERT Biology books

Important question

5 marks

1. What is growth, its types, phases and conditions?
2. Discuss Glycolysis and its importance.
3. Discuss Kreb's cycle and its role in respiration.
4. Explain anaerobic respiration.

10 Marks

1. Explain role of various plant growth regulators.
2. Describe various phases of Mitosis cell division with diagram.
3. Describe various phases of Meiosis cell division with diagram.

4. Write a descriptive note on plant tissues.

5. What is plant respiration? Briefly explain aerobic respiration in plants.