Date: 20-05-20 # Chapter 6: PHOTOSYNTHESIS **session 11**

Plants: self food producer

- All living organisms need food
- Animal obtain food from plants(Heterotrophs)
- Plants prepare it for themselves(Autotrophs)

What is process of photosynthesis

- It is an important activity of all green plants
- By this, plants are able to synthesize food from carbon dioxide and water in the presence of chlorophyll and light energy
- The essential chemical steps in this process are the same in all green plants
- Definition- "**Photosynthesis is the process by which living plant cells, containing chlorophyll, produce food substances(glucose and starch), from carbon dioxide and water, by using light energy**"

Importance of photosynthesis

1. Food for all:

- Photosynthesis is ultimately the source of energy and food for all living beings
- Directly for plants and indirectly for animals and humans who eat the plants or the plant eating animals

2. Oxygen supply

- Photosynthesis the only biological process which releases oxygen to the atmosphere
- Oxygen supports all life on the earth
- No living beings can remain alive without oxygen

3. Controls CO_2 concentration

- Photosynthesis helps to keep carbon dioxide concentration in the atmosphere constant
- CO_2 being released during respiration by living organisms is used during photosynthesis

4. Supply of additional plant products

- All useful plant products like timber, fibres, oils, drugs, rubber, resins etc are derived by photosynthesis

Chlorophyll- the vital plant pigment

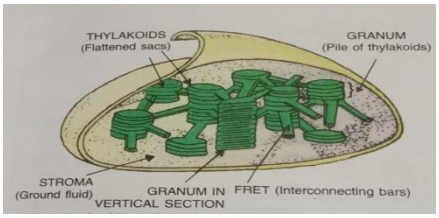
- Green coloring matter found in plants
- Contained in microscopic cells
- There are 9 types of chlorophyll
- Two out of these, chlorophyll- a and chlorophyll-b, are best known and found in abundance
- Chlorophyll absorbs blue and red light at both ends of the visible spectrum
- It reflects green light
- That is why chlorophyll appears green
- The absorbed blue and red lights are most effective for photosynthesis

Too much light destroys chlorophyll

- Chlorophyll is highly sensitive to light
- Too much light destroys it
- The formation of chlorophyll itself depends on the exposure of the plant to light
- The grass growing in the shade under a stone turns yellow due to the non formation of new chlorophyll and disintegration of the older one in the absence of light

Chloroplasts- the site of photosynthesis

- Minute oval bodies bounded by a double membrane
- Their interior contains closely packed flattened sacs(thylakoids)
- They lie in a colourless ground substance called stroma



- There may be 40-50 chloroplasts in a cell.
- The pigment cholorophyll is contained in the walls of thylakoids
- Cholorophyll is a highly complex substance, composed of carbon, hydrogen, oxygen, nitrogen and magnesium
- Chloroplasts are mainly contained in the mesophyll cells located between palisade and spongy cells of leaves
- Also found in the guard cells of stomata and outer layer of green stems
- There may be 5 lakh chloroplasts per sq mm. of leaf surface

Raw materials for photosynthesis

1) Carbon dioxide

- Atmosphere which contains 0.03% CO_2 is the main source of it
- Aquatic plants obtain it from the surrounding water which contains 0.3% or more of it.

2) Water

- Another raw material for the process of photosynthesis
- Absorbed from the soil by the roots by the process of osmosis
- Conducted upward through the stem to the leaves by the xylem tissue
- Transported to all cells of the leaf through veins and their branches

3) Solar energy

- Sun is the ultimate source of energy
- Photosynthesis can take place only in sun light
- Light energy is converted into chemical energy during photosynthesis
- Light energy from sunlight is absorbed by the green pigment, cholorophyll
- 250 molecules of cholorophyll from one quantasome
- This is capable of trapping the smallest unit of solar energy which is converted into chemical energy
- The process of converting solar energy into chemical energy is termed as photochemical act.

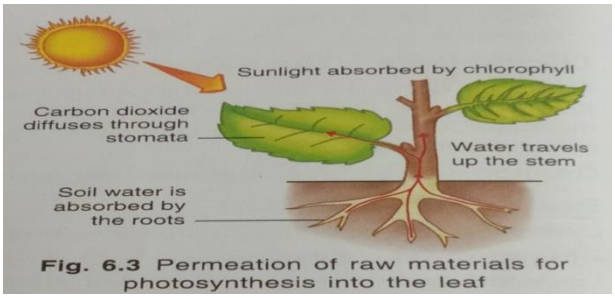


Fig. 6.3 Permeation of raw materials for photosynthesis into the leaf

Regulation of stomatal opening for letting in carbon dioxide

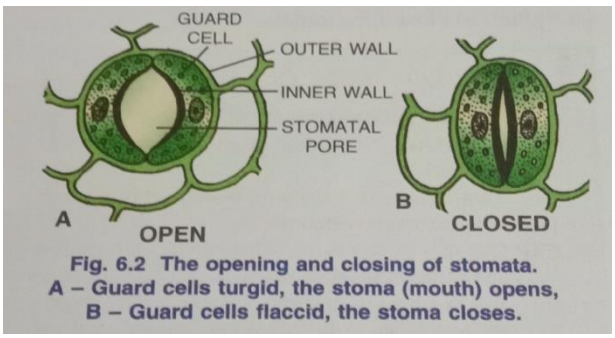


Fig. 6.2 The opening and closing of stomata. A – Guard cells turgid, the stoma (mouth) opens, B – Guard cells flaccid, the stoma closes.

- Stomata are minute opening occurring in large no. the lower surface of leaf
- Its main function is to let in CO_2 from the atmosphere for photosynthesis

- When it is dark, stomata tend to close their opening
- In order to minimize water loss from the leaves through transpiration
- When there is light, as after sunrise, they reopen to allow CO_2 to diffuse in
- Transpiration occurs along with photosynthesis
- Due to this process, one can say that transpiration is the price which the plant pays for photosynthesis
- The closing and opening of stomata are on account of movement of water in and out of the guard cells
- They have thicker inner wall facing the opening
- A thin outer wall on the opposite side
- Their cytoplasm contains chloroplasts

Opening and closing of stomata

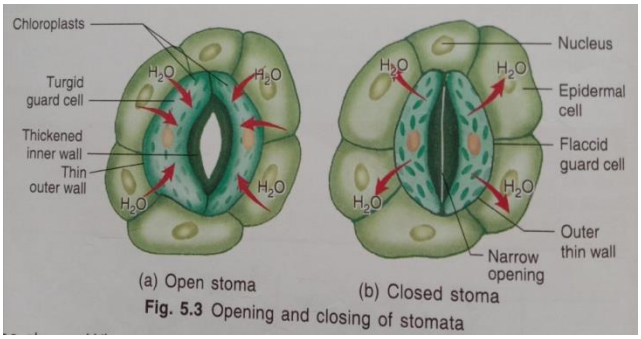


Fig. 5.3 Opening and closing of stomata

- There are two theories about the opening and closing of stomata

1.Sugar concentration Theory

- During day time, the guard cells begin photosynthesis
- Sugar (glucose) produced during the process increases the osmotic pressure
- This draws in water from the adjoining cells due to endosmosis

- Guard cells become turgid and bulge outwards due to their outer wall
- The stomatal opening thus widens
- As the stomata opens, the diffusion of gases in and out begins
- This fulfills the need of CO_2 gas for photosynthesis and for allowing transpiration
- When the water content of the leaf falls down
- The water is drawn out of the guard cells due to exosmosis making them flaccid
- This results in the straightening of their inner thick walls which results in stomatal closure

2. Potassium ion exchange theory

During day

- Stomatal opening and closing depends on the generation of potassium ion (K^+) gradient
- During day time, in the presence of sunlight starch is converted to malic acid
- Malic acid dissociates into malate ions and H^+ ions
- There is an exchange of H^+ and K^+ ions between guard cells and neighbouring epidermal cells
- This is called process of ion exchange
- K^+ ion from the adjacent cells are actively pumped into the guard cells by the usage of ATP
- K^+ ion with malate ions forms potassium malate
- Presence of potassium malate reduces water potential in guard cells and water moves into guard cells
- Diffusion of water in guard cells increases their turgidity and they become fully distended

This helps in opening the stomata

During night

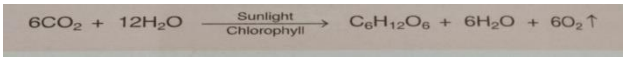
- In the absence of light, efflux of K^+ and influx of H^+ ions takes place
- Water moves out of guard cells

- Guard cells lose turgidity and then kidney shape
- This causes closing of stomata

  Adaptation in leaves for photosynthesis
- Leaves are flat and thin and collectively provide a large surface which helps the plant to absorb maximum light
- Their thinness reduces the distance over which diffusion of CO_2 has to take place
- The leave have dense venation (network of veins)to support rapid transport of raw material as well as the products to and from the mesophyll cells
- Leaves are usually arranged at right angles to each other so as to absorb maximum light
- Large number of stomata present on the leaves also help in gaseous change
- Thin leaves perform better photosynthesis as they are facilitated by rapid transport systems due to lesser distance between them
- The upper part of leaves have palisade cells bearing dense chloroplasts which perform photosynthesis at a faster rate
- **Homework**
- Q1. Why do leaves turn yellowish if they do not get plenty of sunlight ?
- Q2.Why are the cells of epidermis of a leaf thin and transparent ?
- Q3.Does any explain the statement
- " Transpiration is the price which the plant pay for photosynthesis"
- Q4. By which process is solar energy converted into chemical energy?

Date: 23-05-2020 # Chapter 6 Photosynthesis **SESSION – 12**

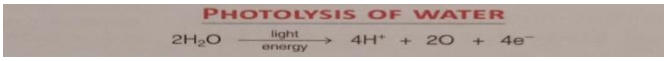
Mechanism of photosynthesis

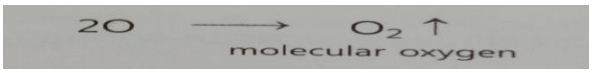
- Mesophyll cells (both palisade and spongy) in a leaf are the principal centres of this activity
- During daytime , sunlight falls on the leaf
- The light energy is trapped by the chlorophyll of the upper layers of mesophyll, specially the palisade cells
- This energy is utilized in chemical processes involved in the manufacture of food
- Carbon dioxide from the atmosphere enters the leaf by diffusion down a concentration gradient through the stomata
- Water from the soil is taken up by the roots, sent up through the stem and finally to the leaves
- The chemical equation to represent this process is 

- The glucose molecule $C_6H_{12}O_6$ is a simple sugar readily soluble in water
- The 6 molecules of H_2O liberated at the end of the process are those that are re-formed during a chain of reactions and not out of the original ones

  Two phases of photosynthesis

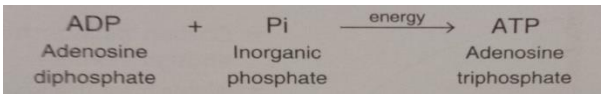
  (A) Light phase or light dependent phase reaction or photochemical phase or Blackman's reaction:
- Light plays a key role in this phase
- Series of chemical reactions occur in very quick succession
- The reaction is initiated by light, therefore the phase is called the photochemical phase
- This reaction takes place in the thylakoids(containing chlorophyll) of the chloroplast
- The reaction is known as photolysis, which means splitting by light
- Definition: " the splitting of H_2O molecules into hydrogen ions and oxygen in the presence of light and grana is called photolysis"
- The main steps involved in this reaction are:
- Step 1: Activation of chlorophyll
- The chlorophyll on the exposure to light energy becomes activated by absorbing photons
- The reaction is known as photolysis, which means splitting by light

- Definition: " the splitting of H_2O molecules into hydrogen ions and oxygen in the presence of light and grana is called photolysis"
- The main steps involved in this reaction are:
- Step 1: Activation of chlorophyll
- The chlorophyll on the exposure to light energy becomes activated by absorbing photons
- Step 2: Splitting of water
- The absorbed energy is used in splitting the water molecule (H_2O) into its two components (Hydrogen and oxygen) and releasing electrons
- 

- The oxygen (o) component is given out as molecular oxygen(O_2)
- 

Step 3: Formation of ATP from ADP

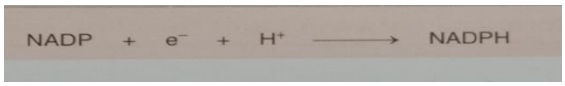
- The electrons (e^-) are used in converting ADP (adenosine diphosphate) into energy rich compound ATP by addition of one phosphate group Pi (inorganic phosphate)



- This process is called phosphorylation (addition of phosphate)
- The energy used in the process comes from light (photon)
- The process is termed as photophosphorylation

Step 4: Formation of NADPH

- The hydrogen ions (H^+) released in the photolysis of water
- It is picked up by a (reducing power) compound NADP(Nicotinamide adenine dinucleotide phosphate) to form NADPH



- NADP is an organic substance
- It accepts hydrogen during photophosphorylation
- It is a coenzyme which works in association with enzyme to catalyse biochemical reaction
- **(B) Dark phase or light independent phase or biosynthetic phase or Calvin Benson cycle**
- The old term " dark phase" did not mean that it occurs when it is dark i.e. at night
- It only meant that the reactions are not dependent on light
- That is why, it is better to call it " light independent phase"
- The reaction in the phase do not require light energy, and occur simultaneously with the light reaction
- The time gap between the two reaction is less than even one thousandth of a second
- During this phase , carbon dioxide fixation occurs by a series of enzyme catalyzed steps and carbohydrate (glucose) is synthesized
- The reaction were discovered by Melvin Calvin and Andy Benson
- Therefore, this phase is also called Calvin- Benson cycle
- Carbon dioxide enters Calvin- Benson cycle through a special carbon dioxide acceptor compound, RuBP (Ribulose bisphosphate)
- Fixation of $CO_2$is catalysed by the enzyme Rubisco (Ribulose bisphosphate carboxylase)
- Molecules of ATP and NADPH produced during light reaction provide energy needed to fix CO_2
- Hydrogen from NADPH combines with CO_2 producing glucose
- Ribulose bisphosphate is regenerated to start Calvin- Benson Cycle again and again

Calvin –Benson Cycle

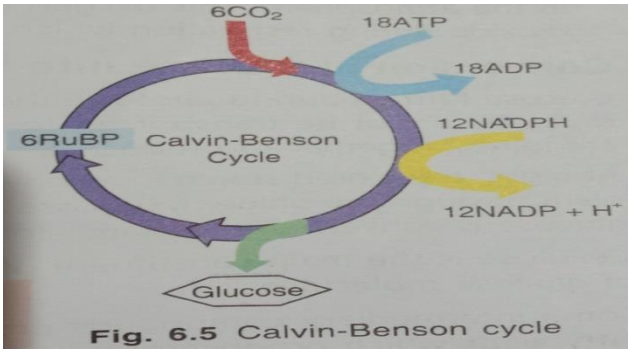
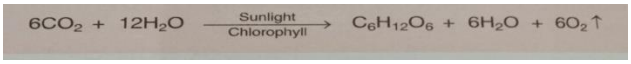


Fig. 6.5 Calvin-Benson cycle

Main events during Photosynthesis

- CO_2 from the atmosphere enters into the leaves through stomata
- water from the soil is taken up by the roots, sent to the leaves where it is distributed to mesophyll cells
- Solar energy splits water molecules (photolysis of water)
- 
- O_2 produced as a by product during the photolysis of water diffuses out into the atmosphere
- Hydrogen ions from NADPH combine CO_2 with and form glucose
- The overall reaction of this process is as follows:
- 

Difference between Light reaction and Dark reaction

- **Light reaction** is light dependent
- **Dark reaction** is light independent
- **Light reaction** involves chlorophyll
- **Dark reaction** does not uses chlorophyll
- **Light reaction** occurs in thylakoid membrane of chloroplast
- **Dark reaction** occurs in the stroma of the chloroplast
- In **Light reaction** light energy is used to form ATP and NADPH and oxygen is released
- In **Dark reaction** ATP and NADPH are used for the fixation of carbon dioxide

End result of the products of photosynthesis

1. **Glucose**

- It is immediately consumed by the plant cells
- Stored in the form of insoluble starch
- Converted into sucrose
- Used in synthesizing fats, proteins etc

2. Water

- the water produced in the process may be reutilized in the continuance of photosynthesis

3. Oxygen

- Some of the oxygen may be used in respiration in the leaf cells (Photorespiration)
- Major portion diffuses out into the atmosphere through stomata
- This oxygen is not a waste, as all organism require it for their existence including the plants which require it at night

Conversion of glucose into starch and other organic compounds

- Glucose formed during photosynthesis is soluble in water
- It is synthesized continuously and rapidly
- It can not be transported to other cells with the same rapidity
- Therefore, several glucose molecules are joined together to produce a molecule of starch
- This process is called polymerisation
- At night, the stored starch is reconverted into soluble glucose which is now transported to all the cells of the plant through the phloem

- Glucose transported to different cells is particularly used in respiration and remaining glucose is converted into starch for storage
- Cellulose is the main constituent of cell walls of plant cells
- It is formed by joining together large number of glucose molecules
- Some intermediary compounds produced during dark reaction are converted into simple amino acids and fatty acids which produce protein and fats

Home work

Q1. What happens during photolysis of water?

Q2. Where does light reaction occur in the chloroplasts?

Q3. What is the source of oxygen produced during photosynthesis?

Q4. Write the overall chemical equation of photosynthesis

Date 27.05. 2020 **Chapter 6. Photosynthesis** **Session -13**

Factors affecting Photosynthesis

- There are four external and three internal factors which affects photosynthesis

A. External factors

(i) Light

(ii) Carbon dioxide concentration

(iii) Temperature

(iv) Water content

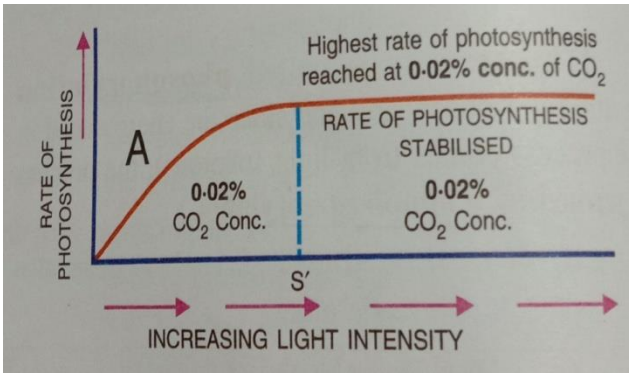
(i) Light

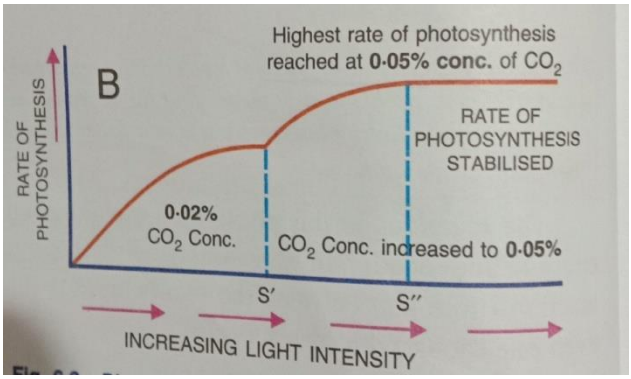
- It is the most important factor for photosynthesis
- Quantity and intensity of light affect the process of photosynthesis

Quality of light

- Highest rate of photosynthesis takes place in red and blue light
- Minimum in green light of the white light
- White light is composed of seven colours
- No photosynthesis takes pLight
- It is the most important factor for photosynthesis
- Quantity and intensity of light affect the process of photosynthesis
- Quality of light
- Highest rate of photosynthesis takes place in red and blue light
- Minimum in green light of the white light
- White light is composed of seven colours
- No photosynthesis takes place in darkness
- It gets stabilized at a point S' (0.02% CO_2)
- If, at this point, the carbondioxide concentration increased, the photosynthesis also increases further
- It gets stabilized at a point S'' (0.05% CO_2)for the two factors together
- Intensity of light
- Photosynthesis increases with an increase in light intensity
- some extent, it is true
- Photosynthesis increases with the light intensity up to a certain limit only

Photosynthesis varies at different light intensities





(ii) Carbon dioxide concentration

- The rate of photosynthesis increases with an increase in CO_2 concentration
- This happens under optimum conditions of temperature and light intensity
- Concentration of CO_2 in the atmosphere is only 0.03%
- Its increase up to 0.1% increases the rate of photosynthesis
- Beyond this, the rate of photosynthesis decreases

(iii) Temperature

- The rate of photosynthesis rises, with the rise in temperature
- This rise occurs up to the optimum temperature of 35^0 C
- This is the maximum suitable temperature when the photosynthesis occurs best
- With the increase of temperature above 35^0 C the rate falls
- Photosynthesis completely stops above 40^0 C
- At this uppermost limit, the enzymes are destroyed
- A rise of 10^0 C upto the maximum optimum temperature (35^0 C) doubles the rate of photosynthesis

(iv) Water Content

- The scarcity of water due to reduced absorption from the soil or due to excessive loss through transpiration reduces the rate of photosynthesis
- Due to the closure of stomata the diffusive capacity (CO_2 intake) decreases the rate of photosynthesis
- Only 1% of water absorbed by the root is utilized in photosynthesis

B. INTERNAL FACTORS

(i) Chlorophyll Content-Nutritional deficiencies of mineral cause loss of chlorophyll

- This brings a drop in trapping solar energy

(ii)Protoplasm

- Dehydration of protoplasm for some reason reduces the rate of photosynthesis
- The accumulation of carbohydrates (sugar and starch) also reduces the rate of photosynthesis

(iii) Structure of leaf

- The thickness of cuticle, the distribution of stomata and the size of the leaf influence the amount of light and the amount of CO_2 entering the leaf

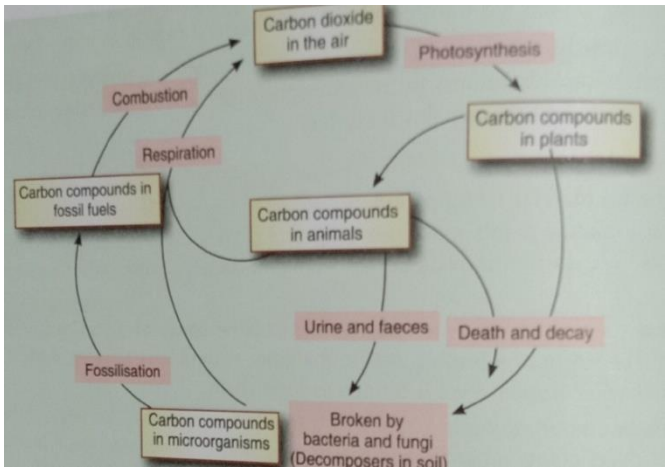
Rate of Photosynthesis

- Photosynthesis is maximum when there is maximum light, more CO_2 and normal temperature(35^0 C)
- The rate of photosynthesis is influenced by the factor which is in short supply
- This factor is called limiting factor
- Less light intensity, enough carbon dioxide and suitable temperature will result in les photosynthesis
- Less carbon dioxide, enough light and suitable temperature will lead to less photosynthesis
- Lower temperature, enough light intensity and suitable carbon dioxide concentration will result in les photosynthesis

Dawn to dusk natural changes in environmental conditions and photosynthesis

- In every period of twenty four hours, plants are subjected to a regular cycle of changes in light intensities
- The rate of photosynthesis increases from dawn to mid day and declines as dusk approaches
- Plants, like other organisms, respire taking in oxygen and giving out carbon dioxide
- In light, the effect of this respiratory activity are masked by those of photosynthesis and there is a net output of oxygen
- In darkness, respiration alone is responsible for changes in the gaseous composition of a plants surrounding atmosphere

Carbon cycle



- It is a series of chemical reactions in which carbon as a chemical element (inCO_2) is removed from the air , used by living organisms in their body processes and is finally returned to the air.
- Carbon is the building material of all the organic compounds found in the living cells e.g. Carbohydrate, lipids, proteins and nucleic acid
  There are three reservoirs of carbon in nature: Atmosphere, Oceans, Petroleum and Coal.
- Atmosphere is the main reservoir of carbon in the form of carbon dioxide.
- Some carbon dioxide is also available dissolved in water.
- Most of the carbon dioxide enters the living world through photosynthesis
- Organic compounds so formed are transferred to herbivores and carnivores in the form of food
- During the process of respiration, decay of dead plants and animals and combustion of fossil fuels and wood, carbon dioxide returns to the atmosphere
- It is because of the carbon cycle, the proportion of carbon dioxide in the atmosphere remains the same

Steps in carbon cycle

(1) Photosynthesis:

- Green plants (producers) use carbon dioxide of the air to produce carbohydrates(sugar, starch etc)

(2) Food chain:

- Through food chain, the food (containing carbon in carbohydrate and other products) passes on from plants to animals (consumers)
- Carbon in an essential element of all body tissues of both plants and animals

(3) Respiration:

- All plants and animals respire by oxidising carbohydrates in their cells to produce energy and give out carbon dioxide into the atmosphere

(4) Decay:

- The dead remains of plants and animals are consumed by bacteria and fungi (decomposers)
- In the process, they breakdown the organic matter, releasing carbon dioxide back into the atmosphere

(5) Combustion:

- When a fuel such as wood, fossil fuel like coal, petroleum or natural gas, is burnt , the carbon contained in it is oxidized to carbon dioxide.
- This CO_2 is given back into the atmosphere

All these fuels named originally comes from living organisms.

(6) Heating and burning of limestone in lime kilns also releases a certain amount of carbon dioxide.

Imbalance of carbon cycle

- These days fossil fuels are being used on a massive scale in home, industries and transport.
- This, steadily increases the carbon dioxide concentration in the atmosphere
- This excess carbon dioxide cannot be consumed by plants during photosynthesis and remains in atmosphere.
- Carbon dioxide traps the sun's radiation energy and does not allow it escapes.
- This may cause global warming and green house effect
- Only a slight rise in temperature may cause the polar ice caps to melt.
- The melting of polar ice caps will raise the sea level
- This may result in submerging a number of cities along the sea coasts all over the world

Home work

- Q1. Name any two factors that affect photosynthesis?
- Q2. What is the optimum temperture for photosynthesis?
- Q3. How do the following favour increased photosynthesis?
  (a) More numerous stomata
  (b) Thinness of leaf
- Q4. Write a short note on imbalance of Carbon cycle

Date: 30. 05.2020 **Chapter 6 Photosynthesis** **Session 14**

Experiments on photosynthesis

- A number of experiments can be performed for proving the various conditions and requirements necessary for photosynthesis

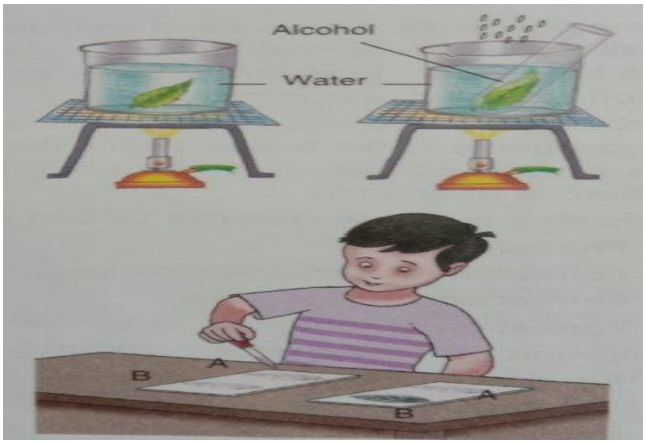
Destarching (Removal of starch)

- a plant used for experiments on photosynthesis should initially be placed in the dark for 24 to 48 hours to destarch the leaves

- During this period all the starch from the leaves will be removed, to the storage organs and the leaves will not show the presence of starch
- A destarched plant is one whose leaves are free from starch
- A plant is destarched by placing it in the dark for 24 to 48 hours

ACTIVITY 1

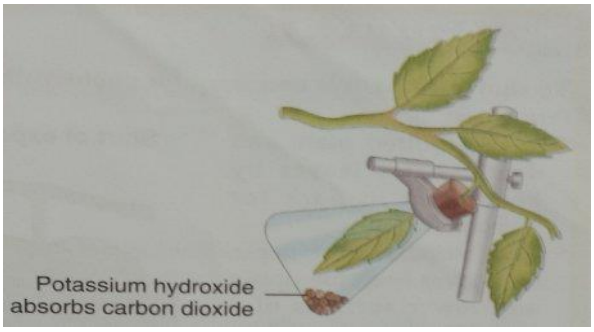
- **To test the leaf for starch (Iodine test)**



- Dip the leaf in boiling water for a minute to kill the cells
- Boil the leaf in methylated spirit over a water bath till it becomes pale white due to the removal of chlorophyll
- The leaves becomes hard and brittle
- Place it again in hot water to soften it
- Spread the leaf in a dish and pour iodine solution on it
- The presence of starch will be indicated by a blue black colour
- A leaf without starch will show brown colouration

Activity 2

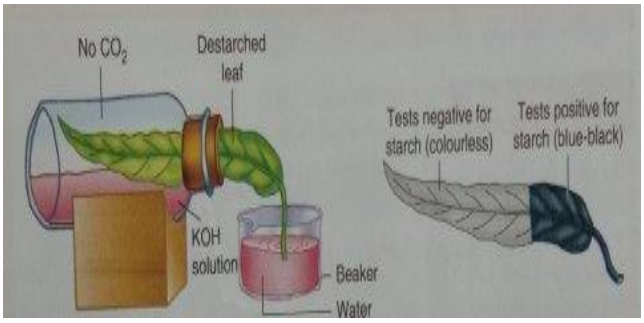
- **To show that carbon dioxide is necessary for photosynthesis**



- Take a plant with destarched leaves
- Insert one of its leaf (through a split cork) into a conical flask containing potassium hydroxide
- Potassium hydroxide absorbs carbon dioxide
- Leave the set up in sunlight
- After a few hours, test the leaf for starch
- The leaf kept in the conical flask, does not blue black while the ones which are exposed to atmosphere air turns blue black

Activity 3

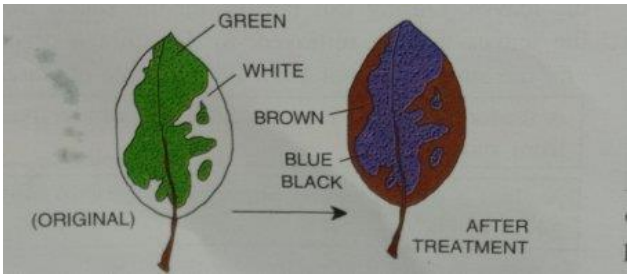
- **To prove that carbon dioxide is necessary for photosynthesis by Moll's half leaf experiment**



- Take a plant with destarched leaves
- Insert half of one of its leaves (through a split cork) into a wide mouthed bottle containing KOH solution
- KOH solution in the bottle absorbs CO_2 from the air present in the bottle
- Leave the plant in sunlight
- After a few hours, test the leaf for starch
- The part of the leaf which was exposed to the atmospheric air becomes blue black
- This shows that carbon dioxide is necessary for photosynthesis
- The part of the leaf outside the bottle becomes the control experiment

Activity 4

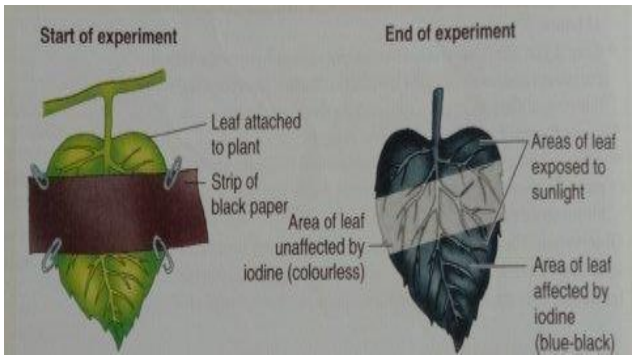
- **To show that chlorophyll is necessary for photosynthesis**



- Take a plant with varigated leaves having some green and some non green areas
- Examples: Coleus, Geranium and Croton
- Destarch the leaves by keeping the plant in a dark room for a few days
- Place the plant in sun
- After a few hours, pluck one leaf
- Make its outline on paper and mark the green and non green areas on the outline
- Test the leaf for starch
- Only the green parts of the leaf turn bluish, showing the presence of starch

Activity 5

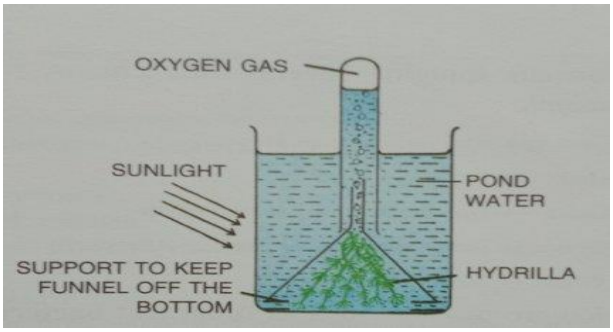
- **To show that light is necessary for photosynthesis**



- Take a potted plant and destarch its leaves by keeping it in dark for 48 hours
- Cover one of its leaf with black paper
- Place the plant in sun
- After a few hours, test the leaf which is covered by black paper for the presence of starch
- It will be observed that the part of the leaf that could get light turns blue black sowing the presence of starch in it

Activity 6

- **To show that oxygen is produced during photosynthesis**



- Place some aquatic plants (Elodea or Hydrilla) in a beaker containing pond water
- Cover them with by a short stemmed funnel
- Invert a test tube full of water over the stem of the funnel
- Ensure that the level of water in the beaker is above the level of stem of the inverted funnel
- Place the apparatus in the sun for a few hours
- Bubbles of the gas will collect in the tube
- Test the gas in the test tube
- A glowing splinter bursts into flame which shows the presence of oxygen

Home work (<u>to be completed in notes register</u>)

- Q1. Describe step by step, how would you test the leaf for the presence of starch
- Q2. "Oxygen is a waste product of photosynthesis" comment
- Q3. Why is it necessary to place a plant in the dark before starting an experiment on photosynthesis? Explain
- Q4. All life owes its existence to chlorophyll. Give reason
- **Exercises from textbook**
- I. Review questions: pg no.85, 86, 87,88, 89
- A. Very short answer type questions

  Q5.(a),(b), (c), (d)

  Q10. (a), (b)

  - B. Short answer type questions

    Q1.(a), Q2. (b), (c)

  - C.Long answer type questions

    Q1 and Q6

  - E. Application / skill- based questions

    Q2, Q9 and Q11