Exercise

Short questions

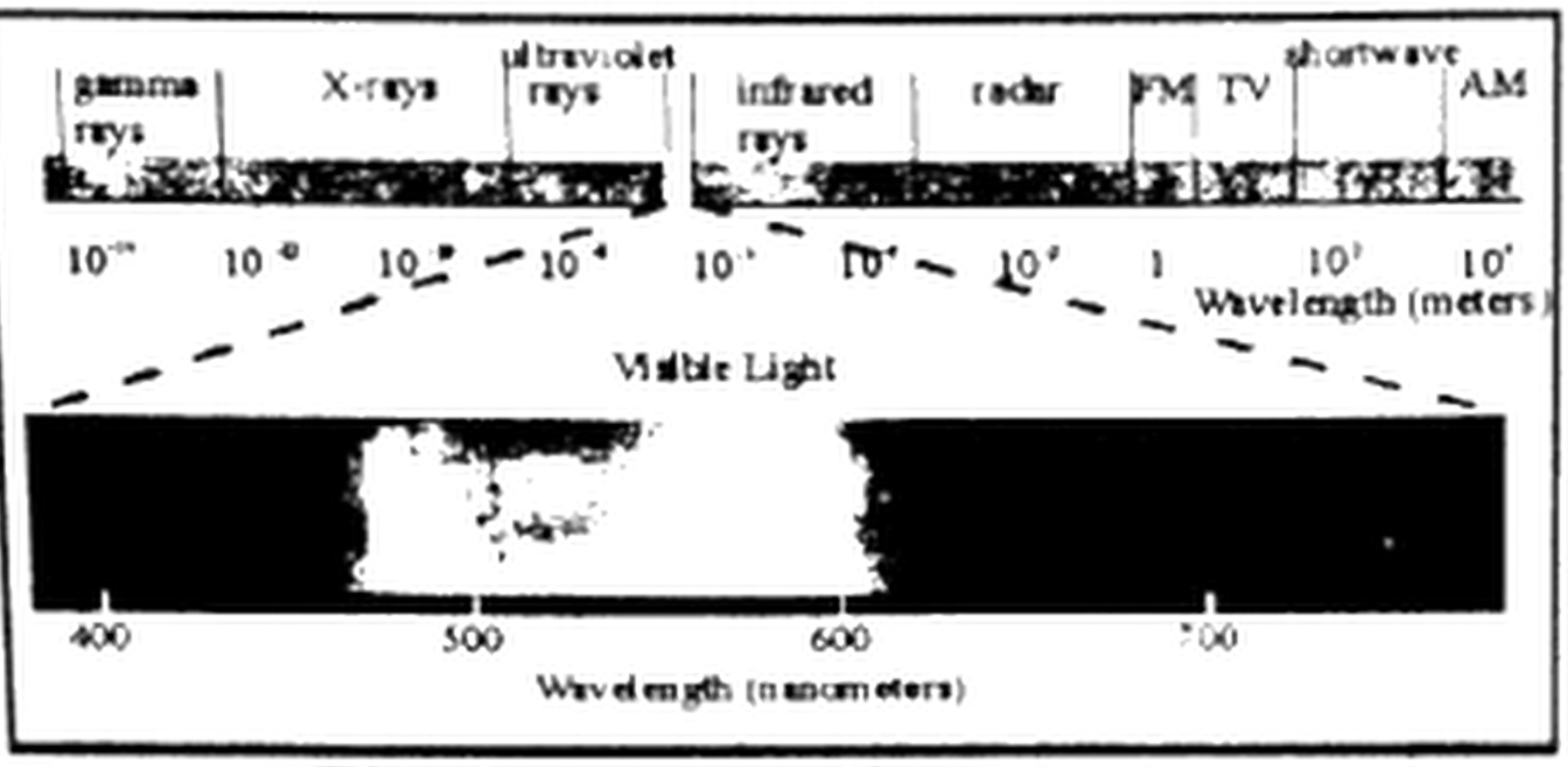
2. What is electromagnetic spectrum?

Ans:

Electromagnetic spectrum:

Sunlight is an electromagnetic or radiant form of energy. The full range of electromagnetic radiation in the universe is called electromagnetic spectrum.

Visible light is only a small part of the spectrum between 380 nm to 750nm which is not only seen by naked eye but is also effective for the process of photosynthesis.



Electromagnetic spectrum

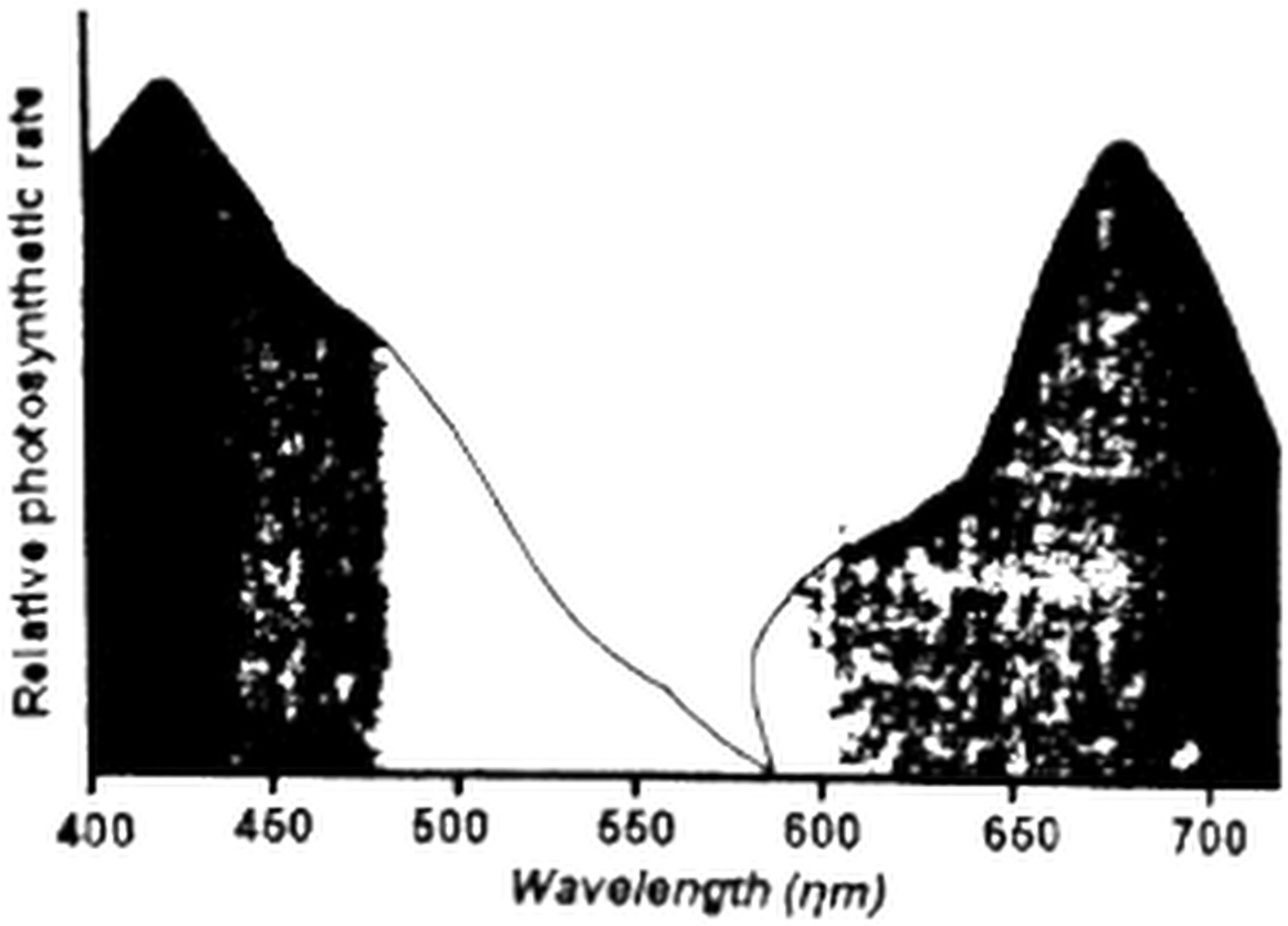
3. Explain "action spectrum" of photosynthesis.

Ans:

Action spectrum:

If a plant is illuminated in different colors of light one by one, the rate of photosynthesis is measured and the data obtained in this way is plotted in a graph, you will see that the rate of photosynthesis will be variable in different colours of light. Such a graph which shows the effectiveness of different wavelength of light for the process of photosynthesis is called action spectrum.

Analysis of action spectrum indicates that blue (430nm) and red (670nm) wavelengths of light are the most effective for the process of photosynthesis.



Action spectrum of photosynthesis

An action spectrum is the rate of a physiological activity plotted against wavelength of light. It shows which wavelength of light is most effectively used in a specific chemical reaction. Some reactants are able to use specific wavelengths of light more effectively to complete their reactions.

4. What are the types of chlorophyll?

Ans:

Types of chlorophyll:

There are two major types of chlorophyll

i- **Chlorophyll-a:**

Chlorophyll-a is a bluish green pigment which is found in all photosynthetic organisms except photosynthetic bacteria.

ii- **Chlorophyll-b:**

Chlorophyll-b is yellowish green pigment which is also found in all photosynthetic organism except brown, red algae and photosynthesis bacteria.

Algae also have some other form of chlorophyll i.e. chl-c, chl-d and chl-e. While, photosynthetic bacteria have yet another type chlorophyll i.e. bacteriochlorophyll.

Molecular formula of chlorophyll a and b:

Chlorophyll-a = $C_{55}H_{72}O_5N_4Mg$

Chlorophyll-b = $C_{55}H_{70}O_6N_4Mg$

5. What is importance of carotene?

Ans:

Importance of carotene:

Carotenoids are terpnoid lipids which are yellow, orange, red or brown pigments. They absorb light strongly in the blue- violet range. They are seen in leaves before leaf fall, present in some flowers and fruits. The carotenoids act as accessory pigment along with chlorophyll-b as they absorb light energy and then transfer it to the chlorophyll-a. Therefore, they protect the chlorophyll-a from excess of light. They also attract insects, birds and other animals for pollination and dispersal.

OR

It gives yellow and orange fruits and vegetables their rich hues. Beta-carotene is also used to color foods such as margarine. In the body, beta carotene converts into vitamin A (retinol). We need vitamin A for good vision and eye health, for a strong immune system, and for healthy skin and mucous membranes.

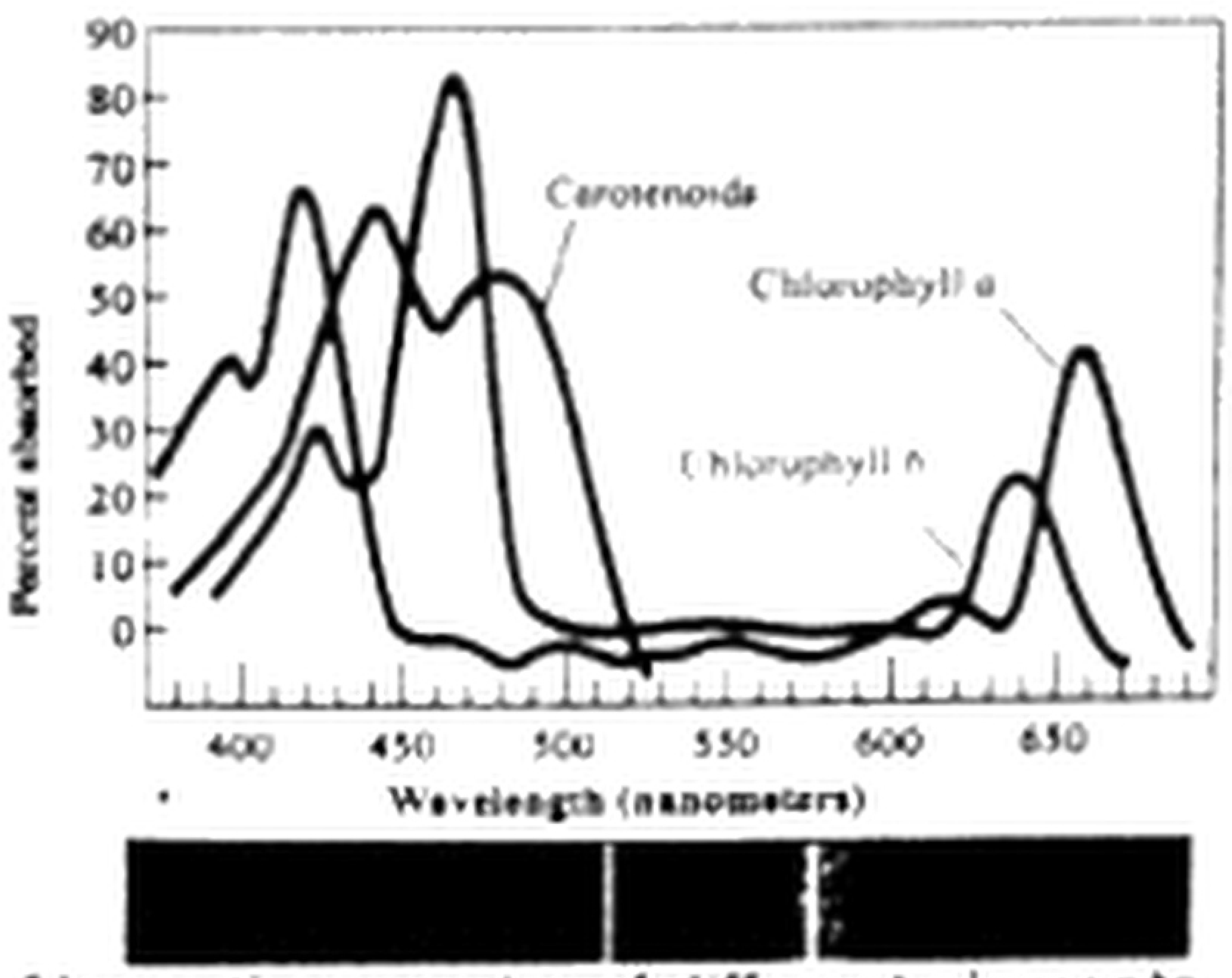
6. Describe "absorption spectrum" in photosynthesis.

Ans:

Absorption spectrum:

The absorption of different colours of light by a particular pigment can be determined by the help of spectrophotometer. The data of spectrophotometer is represented by a graph. Such a graph which shows the absorption of different colours of light by a particular pigment is called absorption spectrum of the pigment.

The absorption spectra of different pigments indicate that they absorb different wavelengths of visible light and these wavelengths are not absorbed at the same rate. The main photoreceptors are chlorophyll a and b and both show more absorption in violet blue (400 nm to 470nm) and orange-red (630nm-660nm) regions of the visible spectrum. On the other hand, carotenoids show more absorption at 430nm to 500nm.



Absorption spectra of different pigments

7. What is photosystem? Explain.

Ans:

Photosystem:

Light is absorbed in the form of photons by the photosystem (a cluster photosynthetic pigments). The absorption of photons causes photoelectric effect i.e. excitation of electrons in the atoms of photosystems and ultimately these excited electrons leaves photosystems. These excited electrons after leaving the photosystems begin to flow through an electron transport chain and their energy is utilized in formation of ATP and $NADPH_2$ by chemiosmosis mechanism.

8. What is the role of Carbon dioxide in photosynthesis?

Ans:

The role of Carbon dioxide in photosynthesis:

Carbon dioxide acts as carbon source for the synthesis of organic compounds in photosynthesis. Plants are therefore known as autotrophs because they use inorganic compounds for the synthesis of their organic compounds. Carbon dioxide is utilized in the dark or light independent reaction (Calvin cycle) of photosynthesis. Air contains about 0.03 to 0.04 percent of carbon dioxide. Land plants use their atmospheric carbon dioxide for photosynthesis. Dissolved carbon dioxide, bicarbonates and carbonates are present in water, which are used by aquatic photosynthetic organisms as carbon dioxide.

9. How it was confirmed that "plants split water as a source of hydrogen releasing hydrogen as a byproduct"?

Ans:

Water is one of the raw materials for photosynthesis. Water acts as hydrogen and electron donor in photosynthesis. It replaces the electron lost by the P680 during photosynthesis. Actually, during light reactions, a chlorophyll-a (P680) in the reaction centre of photosystem-II loses electron due to the absorption of light energy. This event makes the chlorophyll as strong oxidizing agent. When water reacts with chlorophyll in this state, the water molecule is broken down into $2H^+$ ions, 2 electrons ½ O_2. This splitting of water in the presence of sunlight is called photolysis of water.

The electron released from water are used to reduce the oxidized chlorophyll-a so that it can absorb light energy again whereas, $2H^+$ ions are taken up the $NADP^+$ to form NADPH. On the other hand, the oxygen which is produced by photolysis of water is released in atmosphere.

Hypothesis of Van Neil:

This role in photosynthesis was first reported by Van Neil in 1930. He hypothesized that plants split water as a source of hydrogen, releasing oxygen as a byproduct. This observation was based on investigations of photosynthesis in bacteria that make carbohydrates, from carbon dioxide but do not release oxygen.

Neil's hypothesis was confirmed in 1940, when for the first time ^{18}O in biological research was used in first experiment water was made of ^{18}O. The water tagged ^{18}O was added to an alga suspension. The oxygen, evolved during photosynthesis was found to be radioactive. It was separated and identified. In another experiment, carbon dioxide with tagged ^{18}O was added. The oxygen evolved contained none of the isotopes.

Thus, the source of evolved oxygen was proved to be water.

$$6CO_2 + 12H_2O^{18} \xrightarrow[\text{Chlorophyll}]{\text{Light}} C_6H_{12}O_6 + 6H_2O + 6O^{18}_2$$

$$6CO^{18}_2 + 12H_2O \xrightarrow[\text{Chlorophyll}]{\text{Light}} C_6H_{12}O^{18}_6 + 6H_2O + 6O_2$$

10. What is light dependent phase of photosynthesis?

Ans:

Light dependent phase of photosynthesis:

The first phase is called light dependent phase (light reaction) because it can take place only in the presence of light. The light-dependent phase occurs in the thylakoid membranes. In this phase light energy is used to make ATP (Assimilating power) and NADPH (reducing power) whereas, water and oxygen are supposed to be input and output respectively.

11. What is light independent phase of photosynthesis?

Ans:

Light independent phase of photosynthesis:

The second phase is called light independent phase (dark reaction) because it can take place whether light is present or not. This phase actually requires the products of light reaction i.e. ATP and NADPH. Since these products are available in day, therefore dark reaction also occurs in daytime. In this phase, CO_2 acts as input which is converted into glyceraldehyde-3-phosphate (G3P), the output of this phase. The ATP is hydrolyzed to ADP and P_i (H_3PO_4) and its energy is incorporated in this phase, whereas, NADPH provides energized electron and hydrogen for the formation of G3P, which is an energy rich molecule.

12. Explain lactic acid fermentation.

Ans:

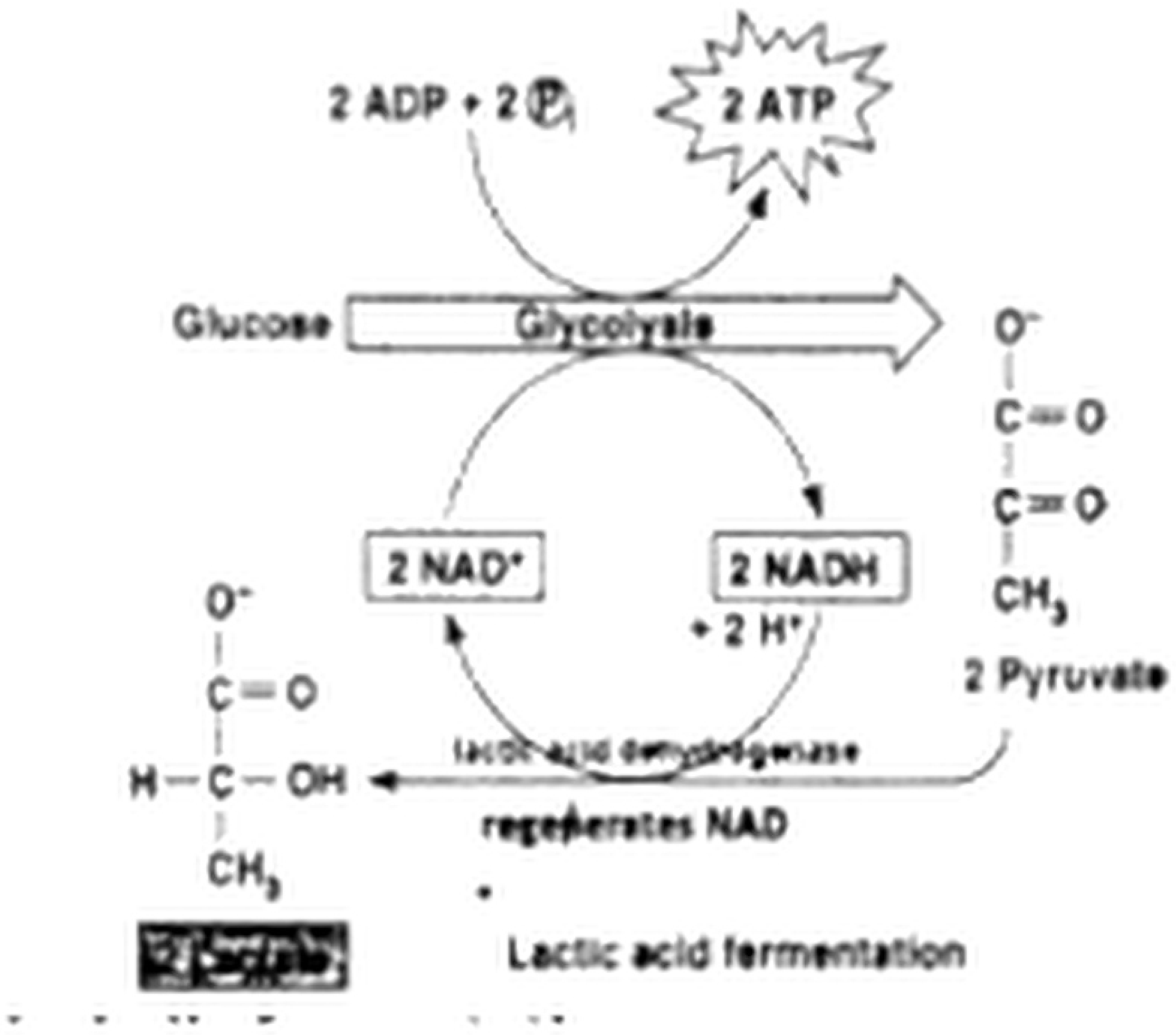
Lactic:

It consists of glycolysis followed by the reduction of pyruvate by NADH to lactic acid. The pathway operates anaerobically because after NADH transfers its electron to the pyruvate, it is free to return and pick up more electrons during the earlier reaction of glycolysis. The overall equation can be represented as

$$C_6H_{12}O_6 + 2NAD^+ \longrightarrow 2C_3H_4O_3 + 2NADH + 2H^+$$

$$2C_3H_4O_3 + 2NADH + 2H^+ \longrightarrow 2C_3H_6O_3 + 2NAD^+$$

Lactic acid fermentation occurs in anaerobic bacteria and in the muscles of mammals as well as human during strenuous exercise when oxygen supply is exhausted. The accumulation of lactic acid causes muscles fatigues i.e. muscles become unable to contract and begin to ache.



Lactic acid fermentation

13. Explain alcoholic fermentation.

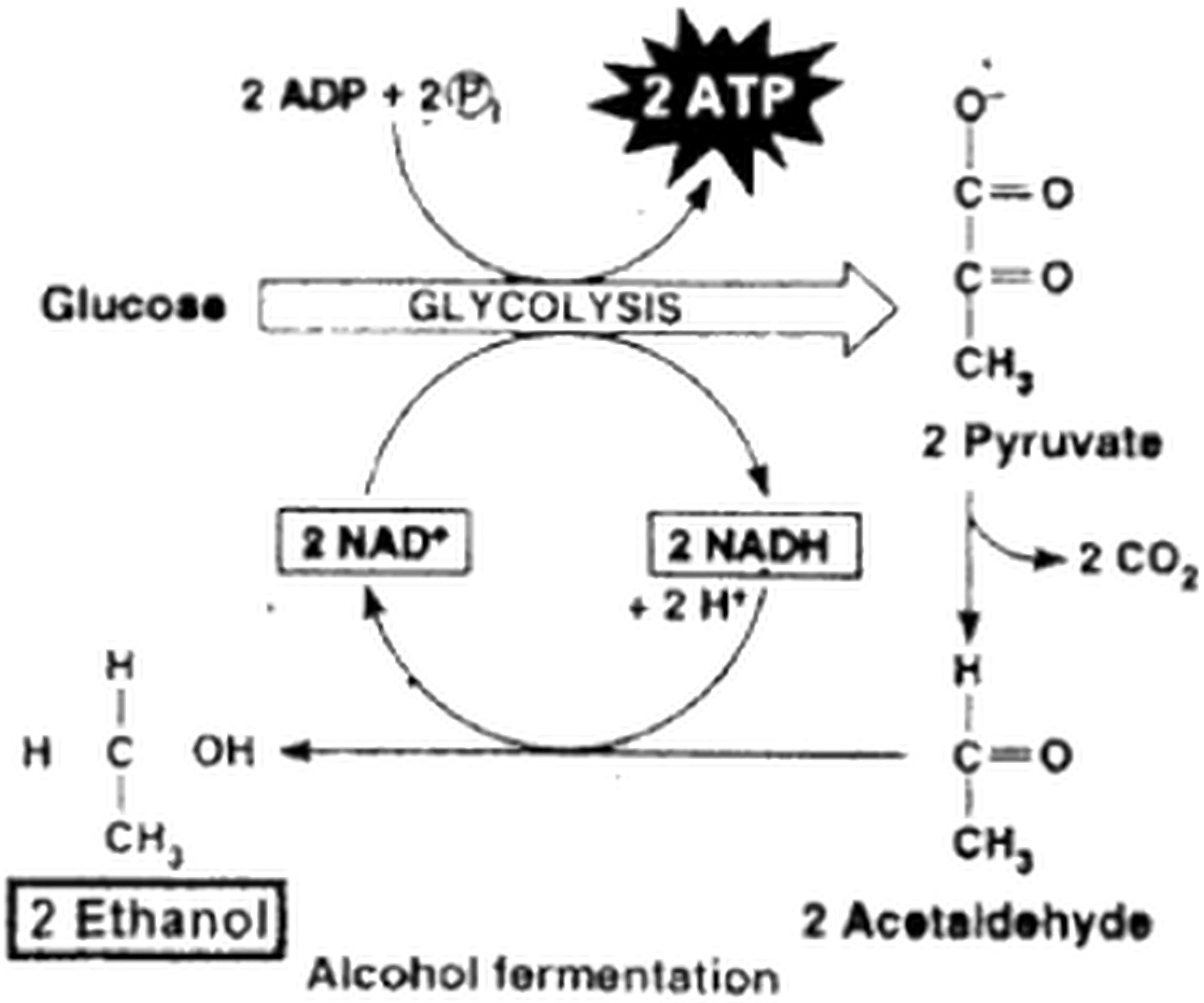
Ans:

Alcoholic fermentation:

Alcoholic fermentation is found in yeast. It consists of glycolysis followed by the decarboxylation of pyruvate to acetaldehyde then reduction of acetaldehyde by NADH to ethyl alcohol or ethanol. This pathway also operates anaerobically because after NADH transfers its electron to the acetaldehyde, it is free to return and pick up more electrons during the earlier reaction of glycolysis. The overall equation can be represented as:

$$C_6H_{12}O_6 + 2NAD^+ \longrightarrow 2C_3H_4O_3 + 2NADH + 2H^+$$

$$2C_3H_4O_3 + 2NADH + 2H^+ \longrightarrow 2C_2H_5-OH + 2NAD^+ + 2CO_2$$



Alcohol fermentation

14. What is importance of PGAL?

Ans:

Importance of PGAL:

Phosphoglyceraldehyde (PGAL) or Glyceraldehydes 3-phosphate (G3P) is an important intermediate of respiration and photosynthesis.

- **i-** In respiration, PGAL appears during glycolysis pathway where its oxidation produces 1,3-bisphosphoglycerate (PGAP) and 2NADH molecules, which leads to the formation of pyruvate.
- **ii-** In the Calvin cycle of photosynthesis, PGAL molecules are converted into glucose phosphate within the chloroplast. Glucose phosphate is then converted to starch. After photosynthesis the fixed carbons leave the chloroplast in the form of dihydroxyacetone phosphate can be used to make the six-carbon sugars, glucose and fructose, which are then joined to form sucrose. It is transported to other parts of the plant.

15: What is the effect of temperature on the activities of RuBisCO?

Ans:

Effect of temperature on the activities of RuBisCO:

Photorespiration is related to the functioning of the enzyme ribulose bisphosphate (RuBisCO) carboxylase/oxygenase. It is often called RuBisCO because it can have an oxygenase activity in addition to carboxylase activity. Its activity depends upon the relative concentration O_2 and CO_2 in leaves. Photorespiration starts when the CO_2 levels inside a leaf become low.

This happens on hot dry days when plant begins to secrete abscisic acid which causes closing of stomata to prevent excess water loss.

If plant continues CO_2 fixation in photosynthesis when its stomata are closed, the CO_2 will be used up and the O_2 released from photosynthesis will be prevented to release out plant body. In this way, the ratio of O_2 in the leaf will increase relative to CO_2 concentrations.

16. What are disadvantages of photorespiration?

Ans:

Disadvantages of photorespiration:

- **i-** Photorespiration costs the plant energy and results in the net loss of CO_2 fixation from the plant. Thus, it reduces the rate of photorespiration process. In most plants, photorespiration reduces the amount of carbon fixed into carbohydrate during photosynthesis by 25 percent.
- **ii-** Photorespiration is not essential for plant. It is also observed that if photorespiration is inhibited chemically, the plant can still grow.
- **iii-** Furthermore, some plants are naturally resistant to photorespiration.

17. What is C4 photosynthesis?

Ans:

C4 photosynthesis:

An Adaption to the problem of photosynthesis:

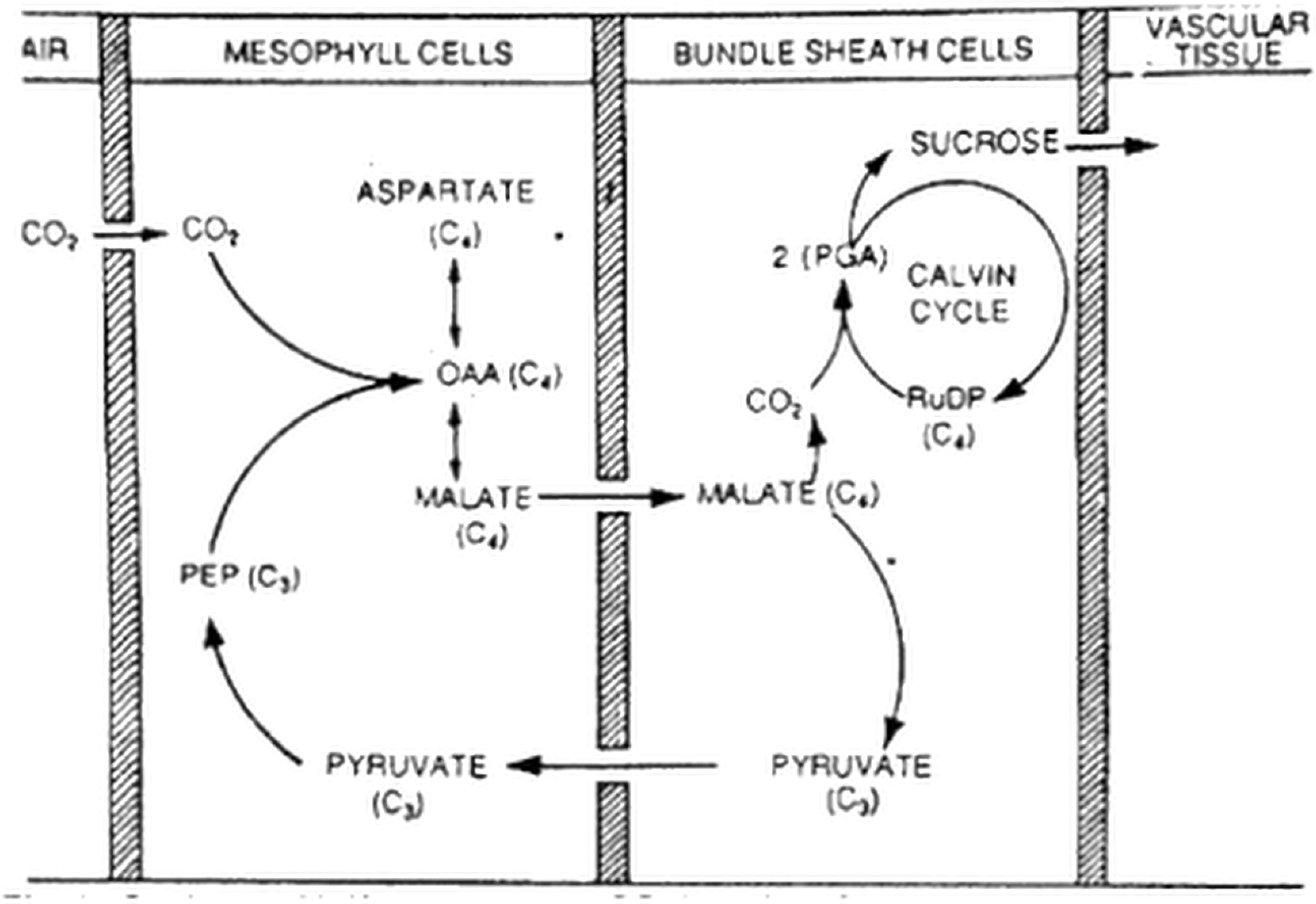
Some plants which grow in tropical climate have an adaption to the problem of photorespiration. They have an additional metabolic pathway in light independent phase of photosynthesis beside Calvin cycle. This metabolic pathway is called Hatch-Slack cycle of C4 pathway in which phosphoenol pyruvate (PEP) carboxylase is used instead of RuBisCO to fix CO_2 to phosphoenol pyruvate (a C3 molecule) and the result is oxaloacetate, a C4 molecule. It takes place in cytoplasm of mesophyll cells.

$$PEP + CO_2 \longrightarrow Oxaloacetate$$

As the first product of CO_2 fixation is a 4-carbon compound oxaloacetate, so that plants are called C4 plants e.g. maize, sugarcane, sorghum etc.

Role of Oxaloacetate:

Oxaloacetate is then transported to the chloroplasts of mesophyll cells. It is then converted to another 4-C compound, the maltate, with the help of NADH, produced in the photochemical phase. The maltate is then transported to the Chloroplast of bundle sheath cells. Here maltate is converted to pyruvate C3 with the release of CO_2 . Thus, concentration of CO_2 increases in the bundle sheath cells. These cells contain enzymes of Calvin cycle. Because of high concentration of CO_2, RuBP carboxylase participates in Calvin cycle and not in photorespiration. Sugar formed in Calvin Cycle is transported into the phloem. Pyruvic acid (pyruvate) generated in the bundle sheath cells re-enters mesophyll cells and regenerates phosphoenol pyruvic acid (PEP) by consuming one ATP (Kranz anatomy see glossary)



18. How photorespiration evolved?

Ans:

Evolution of Photorespiration:

The common simpler answer to this question is that the active site of the RuBsiCO is evolved to bind both carbon dioxide and oxygen. Originally, it was not a problem as there was no oxygen in the atmosphere at that time of establishment of earth so that carbon dioxide binding activity was the only one used. The photorespiration started when the oxygen began to accumulate in the atmosphere.

19. Define/describe/ explain briefly:

(a) Bioenergetics

(b) Photosynthesis

(c) Photosystem

(d) Absorption spectrum

(e) Photophosphorylation

(f) Chemiosmosis

(g) ATP synthase

(h) Cytochrome

(i) Plastoquinone

(j) Plastocyanin

(k) Z-scheme

(l) C4 pathway

(m) Glycolysis

(n) RuBisCO

(o) Krebs cycle

(p) Electron transport chain

(q) Ubiquinone

(r) Stalked particles

(s) Photorespiration

(t) Substrate level phosphorylation

Ans:

(a)Bioenergetics:

Living things cannot grow, reproduce, or exhibits any of the characteristics of life without a ready supply of energy. All metabolic reactions involve energy transformations. So, the quantitative study of energy relationships in biological system is called bioenergetics.

(b)Photosynthesis:

Chemically photosynthesis is a "redox" process in which CO_2 (an oxidized form of carbon) is reduced into glucose (a reduced form of carbon). Water acts as reducing agent which is oxidized into oxygen during this process. Bio-energetically, photosynthesis can be defined as an energy conversion process in which energy poor molecules i.e. CO_2 and Water are transforms into energy rich molecules such as glucose. The extra energy is absorbed in the form of sunlight by the photosynthetic pigments.

The overall reaction of photosynthesis can be summarized as follows:

Reduction

$$6CO_2 + 12H_2O \xrightarrow{\text{light}} C_6H_{12}O_6 + 6O_2 + 6H_2O$$

Oxidation

The above-mentioned main concept of photosynthesis indicated that this process involves the interaction of sunlight, pigments, water and carbon dioxide.

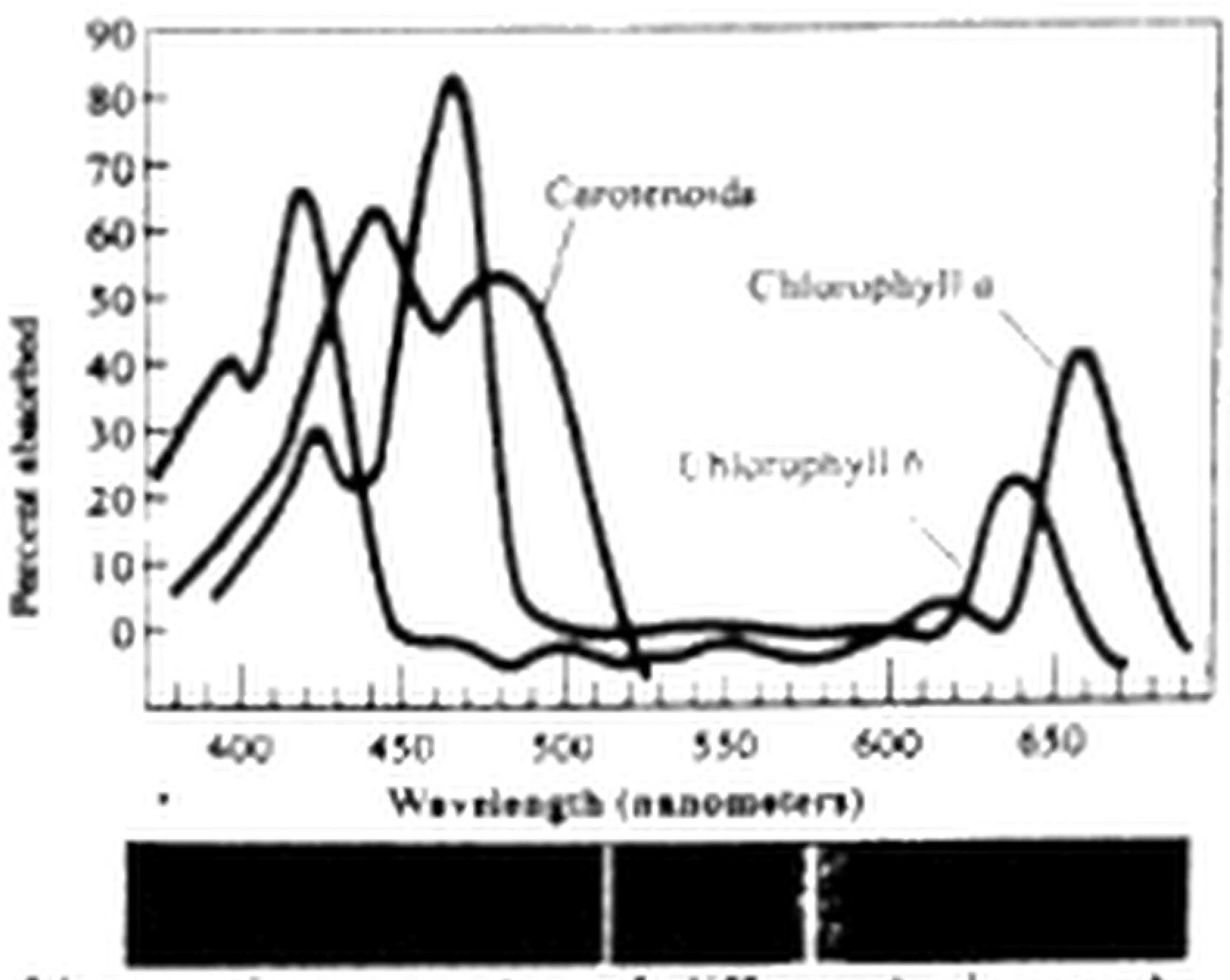
(c)Photosystem:

Light is absorbed in the form of photons by the photosystem (a cluster photosynthetic pigments). The absorption of photons causes photoelectric effect i.e. excitation of electrons in the atoms of photosystems and ultimately these excited electrons leaves photosystems. These excited electrons after leaving the photosystems begin to flow through an electron transport chain and their energy is utilized in formation of ATP and $NADPH_2$ by chemiosmosis mechanism.

(d)Absorption Spectrum:

The absorption of different colours of light by a particular pigment can be determined by the help of spectrophotometer. The data of spectrophotometer is represented by a graph. Such a graph which shows the absorption of different colours of light by a particular pigment is called absorption spectrum of the pigment.

The absorption spectra of different pigments indicate that they absorb different wavelengths of visible light and these wavelengths are not absorbed at the same rate. The main photoreceptors are chlorophyll a and b and both show more absorption in violet blue (400 nm to 470nm) and orange-red (630nm-660nm) regions of the visible spectrum. On the other hand, carotenoids show more absorption at 430nm to 500nm.



Absorption spectra of different pigments

(e)Photophosphorylation:

In non-cyclic electron flow, the excited electrons after leaving a particular photosystem do not comeback, these electrons after losing their energy are incorporated into another molecule. On the other hand, in cyclic electron flow, the excited electrons after leaving a particular photosystem finally come back to their photosystem again. The most important event in light reaction is called photophosphorylation and the mechanism involved in this photophosphorylation is called chemiosmosis.

OR

In the process of photosynthesis, the phosphorylation of ADP to form ATP using energy of sunlight is called photophosphorylation. Only two sources of energy are available to living organisms: sunlight and reduction-oxidation reactions.

(f)Chemiosmosis:

It is the movement of ions across a semipermeable membrane, down their electrochemical gradient. An example of this would be the generation of adenosine triphosphate (ATP) by the movement of hydrogen ions across a membrane during cellular respiration of photosynthesis.

(g)ATP synthase:

The electron flow through the cytochrome complex stimulates it to pump the protons from stroma to the thylakoid inner space. In this way, the energy of flowing electrons is transformed into gradient of protons in the thylakoid inner space. The proton gradient activates an enzyme in thylakoid membrane called ATP synthase which not only moves the protons back into stroma but also catalyzes a reaction in which ADP and P_i are combined to form ATP.

OR

ATP synthase is an enzyme that creates the energy storage molecule adenosine triphosphate. ATP is the most commonly used "energy currency" of cells for most organisms. It is formed from adenosine diphosphate and inorganic phosphate.

(h)Cytochrome:

It is a protein that can transfer electrons with a chemical group called a heme group.

(i)Plastoquinone:

The primary electron acceptor is an iron containing protein, the pastoquinone (PQ). From PQ the electrons flow through a cluster/complex of another iron containing proteins, the cytochromes (Cyt) which consist of Cyt-b_6 and Cyt-f.

(j)Plastocyanin:

Plastocyanin is a copper containing protein involved in electron-transfer. The protein us a monomer, with a molecular weight around 10,500 Daltons, and 99 amino acids in most vascular plants. It is a membrane of the Plastocyanin family of copper-binding proteins.

(k)Z-Scheme:

The path of electron transport through the two photosystems during non—cyclic photophosphorylation is known as Z-scheme due to its conceptual zigzag shape.

(l)C4 pathway:

Dark reactions generally involve a complicated metabolic pathway, the Calvin Cycle or C3 pathway. However, in some plants, in addition to Calvin cycle another metabolic pathway is also involved, called Hatch-Slack cycle or C4 pathway.

(m)Glycolysis:

The initial breakdown of glucose in both aerobic and anaerobic respirations is quite same, in which it is broken down into two molecules of pyruvates. This common step of aerobic and anaerobic respirations is called glycolysis.

(n)RuBsiCO:

Photorespiration is related to functioning of the enzyme ribulose bisphoshate (RuBP) carboxylase/oxygense. It is often called RuBsiCO because it can have an oxygenase activity in addition to carboxylase activity. Its activity depends upon the relative concentration of O_2 and CO_2 in leaves.

(o)Krebs cycle:

Complete oxidation of acetyl coenzyme A into carbon dioxide and water takes places in Krebs cycle. It begins with the binding of Acetyle CoA to 4C compound, the oxaloacetate. The resulting 6C compound is called citrate which passes through a series of electrons yielding oxidation reactions in which NADH and $FADH_2$ are produced that release ATP upon further oxidation in respiratory chain. In addition, ATP is also produced directly by substrate level phosphorylation. Two CO_2 molecules are split off regenerating the 4C compound, the oxaloacetate which is free to bind another acetyle group. In this way, the process become cyclic. In each turn of the cycle a new acetyle group comes into, to replace the two CO_2 molecules that are lost and more electrons are extracted.

Discovery of Krebs cycle:

This cycle was discovered by British scientist Sir Hans Kreb, therefore, called Krebs cycle. It is also called citric acid cycle or tri carboxylic acid (TCA) because the first compound which is formed in the cycle is citerate that contain three carboxylic acid groups.

(p)Electron transport chain:

Inner mitochondrial membrane contains groups of electron and proton transporting enzymes. In each group the enzyme are arranged in a specific series called electrons transport chain or mitochondrial respiratory chain or electron transport system. An electron transport chain or system is a series of electron carriers and some of them work as proton pumps. They take part in the passage of electrons from NADH or $FADH_2$ to its ultimate acceptor i.e. molecular oxygen.

(q)Ubiquinone:

It is not a protein but a small molecule soluble in lipids and insoluble in water cytochromes literally means "cell color". The reduced cytochromes are pink in color. They are protein plus pigment molecules containing iron. They can gain or lose an electron.

(r)Stalked particle:

Oxidative phosphorylation is the synthesis of ATP molecule with the help of energy liberated during oxidation of reduced co-enzymes (NADH, $FADH_2$) produced in respiration. The enzyme required for this synthesis is called ATP synthetase which is also called oxysome or stalked particles.

(s) Photorespiration:

The respiratory activity that occurs in green cells in the presence of light resulting in release of carbon dioxide is termed as photorespiration. It needs oxygen and produce CO_2 and H_2O like aerobic respirations. However, ATP is not produced during photorespiration.

(t) Substrate level phosphorylation:

We are already familiar that the addition of inorganic phosphate to any organic molecule is called phosphorylation but when phosphate is enzymatically transferred from an organic substrate molecule it is called substrate level phosphorylation. However, it accounts for only a small percentage of the ATP that a cell generates.

20. Write the differences between:

(a) Chlorophyll-a and chlorophyll-b

(b) Carotene and xanthophyll

(c) Action spectrum and absorption spectrum

(d) Absorption spectrum and chlorophyll a and b

(e) Antenna complex and reduction centre

(f) Photosystem I and photosystem II

(g) Light dependent reaction and light independent reaction

(h) Phosphorylation and photophosphorylation

(i) Cyclic- photophosphorylation and non-cyclic- photophosphorylation

(k) Lactic acid fermentation and alcoholic fermentation

(l) Calvin cycle and Krebs cycle

(m) Oxidative phosphorylation and substrate level phosphorylation

(n) Photolysis and photorespiration

Ans:

(a) Chlorophyll-a and chlorophyll-b:

Chlorophyll-a	Chlorophyll-b

Chlorophyll-a is a bluish green pigment which is found in all photosynthetic organisms except photosynthetic bacteria.	Chlorophyll-b is yellowish green pigment which is also found in all photosynthetic organism except brown, red algae and photosynthesis bacteria.
Molecular formula	
Chlorophyll-a = $C_{55} H_{72} O_5 N_4 Mg$	Chlorophyll-b = $C_{55} H_{70} O_6 N_4 Mg$

OR

Chlorophyll-a	Chlorophyll-b
It is the principle photosynthetic pigment	It is accessary photosynthetic pigment.
It is present in all phototrophs other than bacteria	It is present in all phototrophs other than diatoms, cyanobacteria, red and brown algae
Blue green in pure state	Olive green in pure state
Empirical formula is $C_{55} H_{72} O_5 N_4 Mg$	Empirical formula is $C_{55} H_{70} O_6 N_4 Mg$
The third carbon of the side group is methyl group ($-CH_3$)	Side group at the third carbon is aldehyde group (-CHO)
Molecular weight is 873	Molecular weight is 907

(b) Carotene and xanthophyll:

Xanthophyll	Carotene
They are yellow in color and are also composed of isoprenoid units Lutein is widely distributed xanthophylls which is responsible for yellow color of foliage in autumn.	The carotenes are orange red pigments composed of isoprenoid units and are found in all photosynthetic eukaryotes. The most widespread and important carotene is beta carotene

(c) Action spectrum and absorption spectrum:

Absorption spectrum	Action spectrum
It is graphic representation of different wavelengths of light absorbed by the different pigments in a leaf during photosynthesis.	It is the graph representation of the effectiveness of different wavelength of light in photosynthesis.
Plot showing the intensity of light absorbing capacity of pigments.	Plot showing relative efficiency of photosynthesis produced by light of different wavelengths
Chlorophyll absorb blue and red light carotenoids absorb violet and blue light.	The maximum photosynthesis occurs in blue and red light
Explains the relationship between quality of light and absorbing capacity of pigments.	Explains relationship between photosynthetic activity in relation to different wavelength of light.

Absorption of different wavelengths of light by pigments can be measured using spectrophotometer.	The rate of photosynthesis is measured as amount of carbon dioxide fixation, oxygen production, NAOP+ reduction etc.

OR

An action spectrum is a graph showing the effectiveness of different wavelengths of light in stimulating the process being investigated. An absorption spectrum is a graph of the relative amounts of light absorbed at different wavelengths by a pigment.

(d) Absorption spectrum of chlorophyll a and b:

Photosynthesis uses two types of chlorophyll, chlorophyll-a and b.

Chlorophyll-a:

It absorbs energy from wavelengths of blue violet and orange red light at675 nm. It reflects green light which give chlorophyll its green appearance. It is very important in the energy phase of photosynthesis because chlorophyll molecules are needed before photosynthesis can proceed. It is the primary photosynthetic pigment. It is the reaction center of the antenna array which is made up of core proteins that bind chlorophyll-a with carotenoids.

Chlorophyll-b:

It absorbs energy from wavelengths of green light at 640nm. This is the accessory pigment that collects energy and passes it on to chlorophyll a. it also regulates the size of antenna and is more absorbable than chlorophyll a. Chlorophyll b complements chlorophyll a.

When there is little light available, plants produce more chlorophyll b than chlorophyll a to increase its photosynthetic ability. This is necessary because chlorophyll a molecule captures a limited wavelength so accessory pigments like chlorophyll b are needed to aid in the capture of wild range of light. It than transfers the light from one pigment to other.

(e) Antenna complex and reduction centre

Antenna complex	**Reaction centre**
The peripheral part of photosystem is called antenna complex which consists of accessory pigments such as chlorophyll-b and carotenoids.	The central part of photosystem is called reaction centre which contains only chlorophyll-a and associated proteins

(f) Photosystem I and photosystem II:

Photosystem-I	**Photosystem-II**
PS I is located at the outer surface of the grana thylakoid membrane (non-appressed granai regions and stroma lamella)	PS I is located at the inner surface of the grana thylakoid membrane (appressed granai regions
The photo Centre or reaction centre is P700	The photocentre or reaction centre is P680
PS I has an iron-sulphur (FeS) type reaction centre (or type 1)	They have a Quinone type reaction also known as Q-type or type-II
The core complex of PS I is composed by a smaller number of proteins approximately 15 subunits than PS II	The core complex of PS I is a multi-subunit complex composed by a approximately 25-30 subunits
Pigments absorb longer wavelengths of light (>680nm)	Pigments absorb shorter wavelengths of light (>680nm)

Rich in chlorophyll a than chlorophyll b	Rich in chlorophyll b than chlorophyll a
Participates in cyclic as well as non-cyclic photophospnorylation	Participates in non-cyclic photophospnorylation
It is not associated with photolysis of water	It is associated with photolysis of water
It generates a strong reducing agent (reducing $NADP^+$ to NADPH) and a weak oxidant	It is the strong oxidant and a weak reductant.

OR

	Photosystem-I	**Photosystem-II**
Light	They absorb light of 700nm wavelengths	Photosystem-II absorb light of 680 nm wavelengths
Active site	It has active center P700	It has active center P689
Photophosphorylation	Participates in cyclic as well as non- cyclic photophosphorylation	Participates in non-cyclic photophosphorylation
Main function	Main function is ATP synthesis	Main function is ATP synthesis and photolysis of water
Located at	PS I is located at the outer surface of the grana thylakoid	PS I is located at the inner surface of the grana thylakoid

	membrane (non-appressed granai regions and stroma lamella	membrane (appressed granai regions
Binding proteins	It has larger binding proteins	It has smaller binding proteins

(g) Light independent and light dependent reaction of photosynthesis:

Basis of distinction	**Light reactions**	**Dark reactions**
Location	Take place in the grana of chloroplast	Always take place in stroma of chloroplast
Process	Use light energy to make two molecules needed for the next stage of photosynthesis; the energy storage molecule ATP and reduced electron carrier NADPH	Make use of these organic energy molecules ATP and NADPH and this response cycle is also called Calvin Benison Cycle
Requirement	Require process such as PS-I and PS-II	They do not have the requirement of process of photosynthesis

Product	The photolysis of water occurs and hence, oxygen gets released	The process of photolysis does not take place and carbon dioxide gets absorbed.

(h) Phosphorylation and Photophosphorylation

Phosphorylation	**Photophosphorlyation**
It takes place during aerobic respiration on cristae of mitochondria	It takes place during photosynthesis in chloroplast
It occurs during terminal oxidation of reduced coenzymes generated in glycolysis and Krebs cycle with molecular oxygen	It occurs during cyclic and non-cyclic electron transport in light reaction of photosynthesis molecular oxygen is not required
It is independent of light	It is dependent on light
It is associated with mitochondrial electron transport system and is of only one type.	It is associated with two pigment systems and electron transport in chloroplast and is of two types cyclic and non-cyclic
Ultimate source of energy is respiratory substrate	Ultimate source of energy is light
It is inhibited by 2, 4-dinitrophenol	Non-cyclic photophosphorylation inhibited by CMU and DCMU

Energy rich ATP molecules produced by this process are used for driving various metabolic process of the cells	Energy rich ATP molecules produced by this process are mainly utilized in dark reaction of photosynthesis for the synthesis of carbohydrates. These may also be used for other synthetic processes within the chloroplast.

(i) Cyclic Photophosphorylation and non-Cyclic Photophosphorylation:

- In cyclic phosphorylation lone PS-I is concerned while both photosystem I and II are used in non-cyclic photophosphorylation.
- The active reaction center of cyclic photophosphorylation is P700 and active reaction center for non-cyclic photophosphorylation is 680.
- In cyclic photophosphorylation electrons travels in a cyclic manner while in non-cyclic photophosphorylation it does not complete the circuit.
- In cyclic photophosphorylation electrons travels back to PS-I but in non-cyclic it does not.
- ATP is produced in cyclic photophosphorylation while ATP and NADPH both are produced in non-cyclic photophosphorylation
- Cyclic photophosphorylation takes place in in isolated chloroplast and bacterial photosynthesis while in non-cyclic green plants are involved.
- Photolysis or water splitting is absent in cyclic Photophosphorylation while it is present non-cyclic Photophosphorylation.
- In cyclic Photophosphorylation oxygen is not evolved while in non-cyclic Photophosphorylation oxygen is produced.
- Cyclic Photophosphorylation is predominantly seen in bacteria while non-cyclic Photophosphorylation is predominantly seen in green plants.

- There is no effect of DCMU on cyclic Photophosphorylation while DCMU inhibits the non-cyclic Photophosphorylation.

Or (Second Answer)

Difference Cyclic and Non-cyclic Photophosphorylation:

Cyclic Photophosphorylation	**Non-cyclic Photophosphorylation**
Cyclic Photophosphorylation refers to the process which produces ATP during the cyclic electron transport chain of light dependent photosynthesis	Non-cyclic Photophosphorylation refers to the process which produces ATP during the noncyclic electron transport chain in light reactions of photosynthesis
Photosystem:	
Only one photosystem (PS I) is involved in cyclic Photophosphorylation.	Photosystem I and II are involved in noncyclic Photophosphorylation.
Nature of the Electron Transport Chain:	
Electrons travel in a cyclic electron transport chain and return to the PS I	Electrons travel in a noncyclic chain.
Products:	
Only ATP is produced in this process.	ATP ,O2 and NADPH are produced in this process.
Water:	
Water is not split during the process.	Water splits or photolysis.
Generation of Oxygen:	

Oxygen is not generated during cyclic Photophosphorylation.	Molecular oxygen is generated during noncyclic Photophosphorylation
First Electron Donor:	
The first electron donor is PS I	Water is the first electron donor
First Electron Acceptor:	
The final electron acceptor is PS I.	The final electron acceptor is NADP+
Organisms:	
Cyclic Photophosphorylation is shown by certain bacteria.	Non-cyclic Photophosphorylation is common in green plants, algae, and cyanobacteria.

Or (Second Answer)

Difference Cyclic and Non-cyclic Photophosphorylation:

	Cyclic Photophosphorylation:		**Non-cyclic Photophosphorylation:**
1	Only the PS I is engaged	**1**	Both PS I and II are engaged
2	ATP molecules are formed	**2**	ATP and NADPH2 are formed
3	It takes place in stroma lamella and grana lamella	**3**	It takes place only in grana lamella

4	Photolysis of water does not occur so oxygen is not released	4	Photolysis of water occurs and oxygen is released
5	The wave length of light required is P700	5	The wave length of light required is P680
6	The Photophosphorylation takes place at two low stages of the cycle	6	The Photophosphorylation takes place at only one stage of the cycle

(j) C4 carbon fixation and C3 carbon fixation:

	C3 cycle (Calvin cycle)	C4 Cycle (Hatch & Slack pathway)
1	C3 cycle is commonly known as Calvin cycle (Melvin Calvin described it first)	C4 cycle is commonly known as hatch and slack pathway (in honor of Marshall Davidson Hatch and C.R slack who elucidated this pathway)
2	Examples of C3 plants Wheat, Rye, Oats, Rice, Cotton, Sunflower, Chlorella.	Example of C4 plants Maize, Sugarcane, Sorghum, Amaranthus.
3	Leaves of C3 plants do not have Krantz anatomy	Leaves of C4 plants possess Krantz anatomy
4	C3 plants are cool season plants, commonly seen in cool and wet areas (temperate areas)	C4 plants are warm season plants, commonly seen in dry areas (tropical areas)
5	The C3 cycle is present in all plants	The C4 cycle is present only in C4 plants

6	First stable product in C3 cycle is a 3carbon (3C, hence the name compound – Phosphoglyceric Acid (PGA)	First stable product in C4 cycle is a 4 carbon (4C, hence the name compound –Oxaloacetic Acid(OAA)
7	The CO2 acceptor in the C3 cycle is RuBP (Ribulose-l,5-bisphosphate). RuBp is a 5 carbon compound	the first CO2 acceptor in the C4 cycle is PEP (Phosphoenolpyruvate). PEP is a 3 carbon compound
8	The first enzyme in C3 cycle is RUBISCO (Ribulose-l,5-bisphosphate carboxylase/oxygen ase)	the first enzyme in C4 cycle PEP carboxylase
9	The first enzyme RUBISCO has high affinity towards oxygen	First enzyme PEP carboxylase does not have any affinity for oxygen
10	Increased oxygen concentration has an inhibitory effect on C3 cycle	Concentration of oxygen does not have any inhibit role in C4 cycle
11	C3 cycle requires 18 ATP molecules to synthesize one molecule of glucose	C4 cycle requires 30 ATP molecules to synthesize one molecule of glucose
12	The complete steps of C3 cycle are executed in the mesophyll cells only	The mesophyll cells will only do the initial steps of C4 cycle, the rest are completed in the bundle sheath cells
13	In C3 cycle, the carbon dioxide fixation tales place only at one place	In C4 cycle, the carbon dioxide fixation tales place twice (first in

		mesophyll cells, seconds in bundle sheath cells)
14	Only a single type of chloroplasts is involved in C3 cycle. All chloroplasts are granal	Two types of chloroplasts are involved in C4 cycle. Granal in mesophyll cells and agranal in bundle sheath cells
15	RuBP is the only CO2 acceptor in C3 cycle	There are two CO2 acceptors in C4 cycle. Phosphoenolpyrdate (PE) is the primary CO2 acceptor in C4 cycle
16	There is no secondary CO2 acceptor in C3 cycle	In C4 plants, there is a secondary CO2 acceptor. RuBP is the secondary CO2 acceptor in C4 plants
17	In C3 plants, the bundle sheath cells do not contain chloroplasts	In C4 plants, the bundle sheath cells contain chloroplasts
18	In C3 plants , the light and dark reactions of photosynthesis occur in a single location	In C4 plants, the light and dark reactions of the photosynthesis are physically separated and completed in two different locations
19	C3 plants can perform photosynthesis only when the stomata are open	C4 plants can do photosynthesis even in the closed condition of stomata

20	The optimum temperature for photosynthesis in C3 plants is very low	The optimum temperature for photosynthesis in C4 plants is high
21	The rate of photorespiration is very high in C3 plants	The photorespiration is altogether absent in C4 plants (if present very little)
22	C3 cycle is less efficient in photosynthetic energy fixation due to the presence of photorespiration	C4 cycle is more efficient than C3 cycle in photosynthesis due to the absence of photorespiration
23	The carbon dioxide compensation point is high in C3 cycle (about 50 ppm)	The carbon dioxide compensation point is low in C4 cycle (2 to 5 or even 0 ppm)
24	In high light intensity, the rate of CO2 evolution is high in C3 plants	In the high light intensity, the rate of CO2 evolution is very low in C4 plants
25	The water loss per g of biomass produced with C3 cycle is high (450 to 950)	The water loss per g of biomass produced with C4 cycle is low (250-350)

Or (Second Answer)

	C3 Pathway	**C4 Pathway**

Definition	Such plants whose first product after the carbon assimilation from sunlight is 3-carbon molecule or 3-phosphoglyceric acid for the production of energy is called C3 plants and the pathway is called as the C3 pathway. It is most commonly used by plants	Plants in the tropical area convert the sunlight energy into C4 carbon molecule or oxaloacetice acid, which takes place before the C3 cycle and then it further convert into the energy, is called C4 plants and pathway is called as the C4 pathway. This is more efficient than the C3 pathway
Cells involved	Mesophyll cells	Mesophyll cell, bundle sheath cells
Example	Sunflower, spinach, beans, Rice, Cotton	Sugarcane, sorghum and Maize
Can be seen in	All photosynthetic plants	In tropical plants
Types of plants using this cycle	Mesophytic, hydrophytic, xerophytic	Mesophytic
Photorespiration	Present in high rate	Not easily detectable
For the production of glucose	12 NADPH and 18 ATPs are required	12 NADPH and 30 ATPs
First stable product	3-phosphoglycerate	Oxaloacetate (OAA)

Calvin cycle operate	Alone	Along with the Hatch and Slack cycle
Optimum temperature for photosynthesis	15-25°C	30-40 °C
Carboxylating enzyme	RuBP carboxylase	In mesophyll: PEP carboxylase. In bundle sheath : RuBP carboxylase
CO2:ATP: NADPH2 ratio	1:3:2	1:5:2
Initial CO2 acceptor	Ribulose-1,5-biphosphate (RuBP)	Phosphoenolpyruvate(PEP)
Kranz Anatomy	absent	absent
CO2 compensation point (ppm)	30-70	6-10

(K) lactic acid fermentation and alcoholic fermentation:

Lactic acid fermentation	**Alcoholic fermentation**
Definition:	
Lactic acid fermentation refers to a metabolic process by which glucose is converted into the metabolite, lactate and cellular energy	Alcoholic fermentation refers to a metabolic process by which glucose is converted into ethanol and carbon dioxide
Occurrence:	

Lactic acid fermentation occurs in lactobacillus spps. yeast, and muscle cells	Alcoholic fermentation occurs in yeast and other microorganisms
Products:	
Lactic acid fermentation produces lactic acid molecules from the pyruvate	Alcoholic fermentation produces ethanol and carbon dioxide from the pyruvate molecules
Enzyme:	
Lactate dehydrogenase and pyruvate decarboxylase are the two enzymes involved in the lactic acid fermentation	Pyruvate decarboxylase and alcohol dehydrogenase are the two enzymes involved in the alcoholic fermentation
In the food industry:	
Lactic acid fermentation is used in the production of yogurt and cheese	Alcoholic fermentation is used in the production of bread, beer, wine and vinegar

Conclusion:

Lactic acid and alcoholic fermentation are two mechanisms involved in the respiration in the absence of oxygen. Both types of fermentation occur in the cytosol. Glycolysis is the first step of both lactic acid and alcoholic fermentation, which produced pyruvate. Lactic acid fermentation produces lactic acid molecules from pyruvate while alcoholic fermentation produces

ethanol and carbon dioxide from pyruvate. The main difference between lactic acid and alcohol fermentation is the products of each fermentation.

(l) Calvin cycle and Krebs cycle:

Krebs Cycle	Calvin Cycle
Part of the aerobic respiration process	Part of the dark reaction of photosynthesis
Takes place in the matrix of the mitochondria	Takes place in the stroma of chloroplast
Leads to synthesize ATP	ATP is spent for the process
Takes place in all the organisms with aerobic respiration	Takes place only in the photosynthetic plants
Carbon dioxide is produced	Carbon dioxide is used
The process does not take place without oxygen	The process does not demand the presence of oxygen

(m) Oxidative phosphorylation and substrate level phosphorylation:

Substrate level phosphorylation	Oxidative phosphorylation
Substrate level phosphorylation directly transfers a phosphate group from the substrate (phosphorylation compound) to ADP to produce ATP.	Oxidative phosphorylation is a process by which energy released by chemical oxidation of nutrients is used for the synthesis of ATP.

Energy used:	
Energy is generated from a coupled reaction for this process.	Energy generated from the reaction of electron transport chain is used for this process.
Redox potential:	
A small difference of redox potential is generated in substrate level phosphorylation.	A large difference in redox potential is generated to power this phosphorylation.
Conditions:	
This occurs under both aerobic and anaerobic conditions.	This occurs under aerobic conditions.
Oxidation of compounds:	
Substrate are partially oxidized.	Electron donors are completely oxidized.
Locations:	
Substrate level phosphorylation occurs in the cytosol and mitochondria.	Oxidative phosphorylation occurs in the mitochondria.
Occurrence:	
This can be seen in glycolysis and Krebs cycle.	This occurs only during the electron transport chain.

Association with electron transport chain and ATP synthesis:	
Substrate level phosphorylation is not associated with electron transport chain or ATP synthase.	This is associated with electron transport chain and ATP synthase.
Involvement of O2 and NADH:	
This does not use O2 or NADH for the formation of ATP.	This uses o2 and NADH to produce ATP.

Or (Second Answer)

Substrate level phosphorylation	**Oxidative phosphorylation**
Substrate level phosphorylation refers to a type of phosphorylation in which a phosphate group is transferred from a substrate to ADP.	Oxidative phosphorylation refers to a type phosphorylation which uses the energy released from the electron transport chain to generate ATP.
Occurs in the cytoplasm and mitochondria matrix	Occurs in the inner membrane of mitochondria
A phosphate group is directly removed from a substrate by a coupled reaction and transferred into ADP.	Phosphate groups are added from the energy released in the electron transport chain.
Direct phosphorylation	indirect phosphorylation

Occurs in the glycolysis and Krebs cycle.	Occurs in the electron transport chain.
NAD and FAD are reduced.	NADH+ and FAD+ are oxidized
Four ATPs are produced.	Thirty-four ATPs are produced.
The change of the redox potential of the substrate is less.	The change of the redox potential of the substrate is more
Partial oxidation of the substrate occurs	Complete oxidation of the electron donors occurs.

(n) photolysis and photorespiration:

Photolysis	Photorespiration
Photolysis is a process whereby molecules of water may have their hydrogen split from the oxygen, because of light energy present on the chlorophyll. This part of photosynthesis occurs in the granum of a chloroplast where the light is absorbed by chlorophyll. **For example,** the photolysis of water molecule in photosynthesis occurred under the influence of light. When photons are absorbed, it causes the	The respiratory activity that occurs in green cells in the presence of the light resulting in release of carbon dioxide is termed as photorespiration. It needs oxygen and produce CO2 and H2O like aerobic respiration. However ATP is not produced during photorespiration.

hydrogen to bind to an acceptor, subsequently releasing the oxygen.	

21. Explain the effect of temperature on the oxidative activity of RuBP carboxylase.

Ans: Effect of temperature on the activities of RuBisCO:

Photorespiration is related to the functioning of the enzyme ribulose biphosphate (RuBP) **carboxylase/oxygenase**. It is often called **RuBisCO** because it can have an oxygenase activity in addition to carboxylase activity. Its activity depends upon the relative concentration of O_2 and CO_2 in leaves. Photorespiration starts when the CO_2 leaves inside a leaf become low. This happens on hot dry days when plant begins to secrete abscisic acid which causes closing of stomata to prevent excess water loss. If the plant continues CO_2 fixation in photosynthesis when its stomata are closed, the CO_2 will be used up and the O_2 released from photosynthesis will be prevented to release out of plant body. In this way, ratio of O_2 in the leaf will increase relative to CO_2 concentrations.

22. Analyze the impact of photorespiration on the agricultural yield in the tropic climates.

Ans: Photorespiration decreases net photosynthesis because a portion of CO_2 fixed in photosynthesis escapes from the leave after it is fixed. Under certain conditions, up to 5% of the photosynthetic potential is lost in photorespiratory metabolism. Thus, photorespiration reduces dry matter production and agricultural yield in tropical climate.