Course- B.Sc. III Hons.

E- content- Online class 2/9/20 &3/9/20

Photorespiration

Krotkov (1963) observed first that in some plants there was outburst of release of CO_2 in light. This was reported only in green cells. He introduced the term photorespiration for the process. He defined photorespiration as the release of carbon dioxide in respiration in presence of light. This was reported in plants such as *Beta, Phaseolus, Gossypium, Pisum, Capsicum, Petunia, Antirrhinum, Glycine, Helianthus, Oryza* and in algae like *Nitella* and *Chlorella*. Photorespiration has been reported in general in the plants of temperate region, but absent in tropical plants.

This has been observed by further researches that photorespiration is associated with high temperature ranging between 25-35^0 C and with high oxygen concentration of the atmosphere.There is consistent enhancement in photorespiration with the increase in O_2.

Studies on tobacco leaves using labelled carbon revealed that first carbon atom of a two carbon compound, glycolate, is liberated as CO_2.Carboxyl group (COOH) group of glycolate is thought to be the donor of CO_2 as photorespiratory release.This was confirmed by Zelitch (1966).

Tregunna *et al*. (1966) and Hew (1968) found that the effects of light on CO_2 release are eliminated by loss of chlorophyll from leaves either due to nutrient deficiency or due to mutation. It is absent in non chlorophyllous or non photosynthesizing cells.

Detailed mechanism of photorespiration could be known only after the work of Bowes, Ogren and Hageman (1971). They found that the enzyme Ribulose 1, 5-biphosphate carboxylase (Rubisco) plays a dual role in the condition of lower and higher concentrations of CO_2.It was observed that under the normal CO_2 level, Rubisco has its carboxylase activity, but under high O_2 or high O_2/CO_2 ratio, Rubisco shows oxygenase activity and catalyses the addition of $O_2$to RuBP to produce a molecule of phosphoglycolic acid and a molecule of phosphoglyceric acid.

Site of photorespiration-

Photorespiration is associated with photosynthesis. Therefore, chloroplast is one of the organelles which is the site of photorespiration. Discovery of peroxisomes (in close association with the chloroplasts) in plants and presence of glycolate metabolism enzymes in peroxisome suggests that peroxisome is another site of photorespiration. Peroxisomes have been found to contain glycolate oxidase, glutamate-glyoxylate transaminase and catalase enzymes. Further studies of Tolbert and Kisaki (1969) indicated that peroxisomes may not be the actual site of CO_2 evolution of photorespiration, but may carry out part of the reaction to produce a substrate for CO_2 evolution.Tolbert (1971) proposed that mitochondria are the site of CO_2 evolution in photorespiration. Experimental evidences confirmed that photorespiration involves three organelles, i.e., chloroplasts, peroxisomes and mitochondria.

Following are different steps of reactions in photorespiration:-

The two reactions may be explained as follows-

In chloroplast--

Carboxylase activity (under normal CO_2 level)

RuBP +CO_2+ H_2O ----------Rubisco-------------→ Phosphoglyceric acid (2 molecules)

Oxygenase activity (Under low CO_2 and high O_2 level)

RuBP + O_2 ------------Rubisco-----------------→ Phosphoglycolic acid + Phosphoglyceric acid

In the process, phosphoglyceric acid is easily converted into glycolic acid by the enzyme phosphatase, by dephosphorylation of phosphoglycolic acid .

Phosphoglycolic acid + H_2O -----------------→ Glycolic acid + Phosphoric acid

Glycolic acid is transported to peroxisome

In Peroxisome

Glycolic acid +O_2 -------Glycolate oxidase-----→ Glyoxylic acid + H_2O_2

In the next step glyoxylate is aminated to form Glycine by the enzyme Glutamate glyoxylate transaminase.

Glyoxylate + Glutamate --------Glutamate glyoxylate transaminase--→ Glycine + α Ketoglutaric acid

Glycine is transported to mitochondria via cytoplasm

In Mitochondria

In mitochondria, two glycine molecules combine to produce one molecule each of Serine, CO_2 and NH_3. This oxidative decarboxylation reaction is complex and involves more than one enzyme. The over all reaction is

2 Glycine + H_2O +NAD^+ ------------------→ Serine + CO_2 + NH_3 + $NADH^+$

NH_3 released by mitochondria, is assimilated by chloroplasts within the same cell. CO_2 released ,is derived from the carboxyl carbon of glycine and hence from the carboxyl carbon of glycolic acid. It is

for this reason that glycolic acid is called the substrate of photorespiration.

In Peroxisome

Serine produced in in the mitochondria, is transported to peroxisome ,where it is converted successively to hydroxypyruvic acid and glyceric acid.

Serine combines with glyoxylic acid and is converted to glycine and hydroxypyruvate. This reaction is catalysed by the enzyme serine-glyoxylic acid aminotransferase. which is further reduced by Hydroxypyruvate reductase to

Glyceric acid.

Serine -------------→. Hydroxypyruvate

Hydroxypyruvate + NADH + H^+---------→ Glyceric acid + NAD^+

Glyceric acid is transported to chloroplast

In chloroplast

In the chloroplast, glyceric acid is phosphorylated by the enzyme Pyruvic kinase involving ATP .

Glyceric acid + ATP---------Pyruvic kinase-------→ Phosphoglyceric acid + ADP

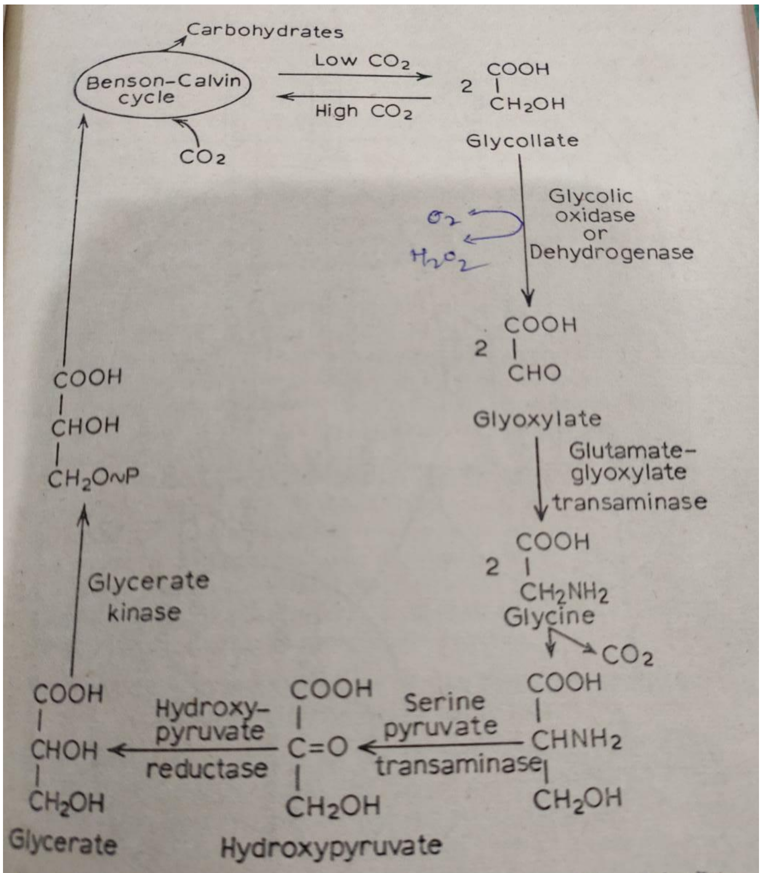
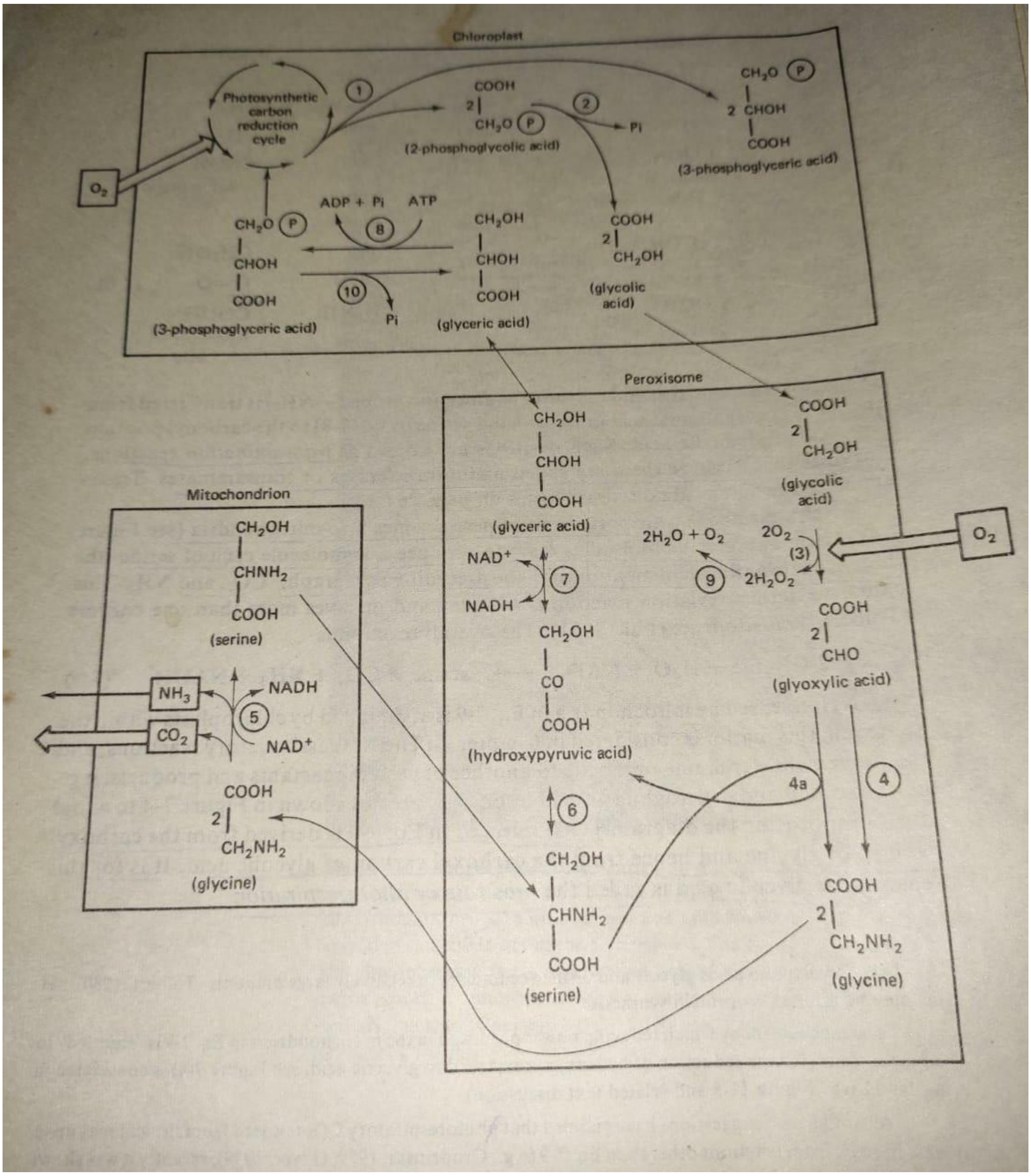


Fig. 9-2 Chemical reactions involved in the formation and metabolism of glycollate.



Schematic diagram; Photorespiration involving chloroplast, peroxisome and mitochondrion

Difference between Dark respiration and Photorespiration

Dark respiration	Photorespiration
1. It is universally present in all the living cells.	1. It is found in green photosynthesizing cells. It is present in plants having Calvin cycle as the CO_2 fixation pathway..
2. Respiratory substrate may be carbohydrate,	2.The substrate is glycolate.

fat or protein.	
3. The process takes place in the cytoplasm and mitochondria.	3. It occurs in between chloroplast, peroxisome cytosol and mitochondria.
4. The substrate may be stored or recently formed.	4. The substrate is always recently formed.
5. In this process ATP molecules are produced.	5. ATP molecules are not produced.
6. H_2O_2 is not produced.	6. H_2O_2 is produced in the process.
7. Found both in C_3 and C_4 plants.	7. Found in C_3 plants.
8.Transamination reaction does not take place.	8. Transamination reaction takes place
9. The process is dependent to O_2 conc. only to a limited extent	9.It shows positive correlation with O_2 Conc.
10. NAD is reduced to $NADH_2$.	10. Here it is reverse, i.e. $NADH_2$ is oxidised.
11. It is light independent and found both in dark and night.	11. It is light dependent process and takes place in light only.

Significance of photorespiration :-

Researches on plants showing photorespiration and lacking it have revealed that photorespiration is found only in the plants having dark reaction as Calvin cycle (C_3 plants), but it is absent in C_4 plants. Plants having photorespiration are generally temperate plants, while tropical plants lack photorespiration. It is apparent in the reaction pathway that there is no generation of ATP. Since this pathway operates in a condition of low CO_2 , so it is believed that this mechanism was common in earler evolution periods when there was very low CO_2 level in atmosphere and it has been suppressed with the increase in CO_2 content in the atmosphere.

The presence of photorespiration process decreases the photosynthetic efficiency of plants. Scientists are keen to develop plants with decreased photorespiration. Genetists are effortful to develop such strains of C_3 plants which have low photorespiration rate. Such efforts are being made in view that this process is surplus and non essential in plants.

However, scientists are of the view that photorespiration has a protective role and as a supportive process which reduces oxygen injury to chloroplast. By consuming O_2, the process helps in maintaining low oxidative state in chloroplast of C_3 plants. Free radicals of oxygen are injurious and may damage the organelles, and photorespiration keeps away free radicals of oxygen.