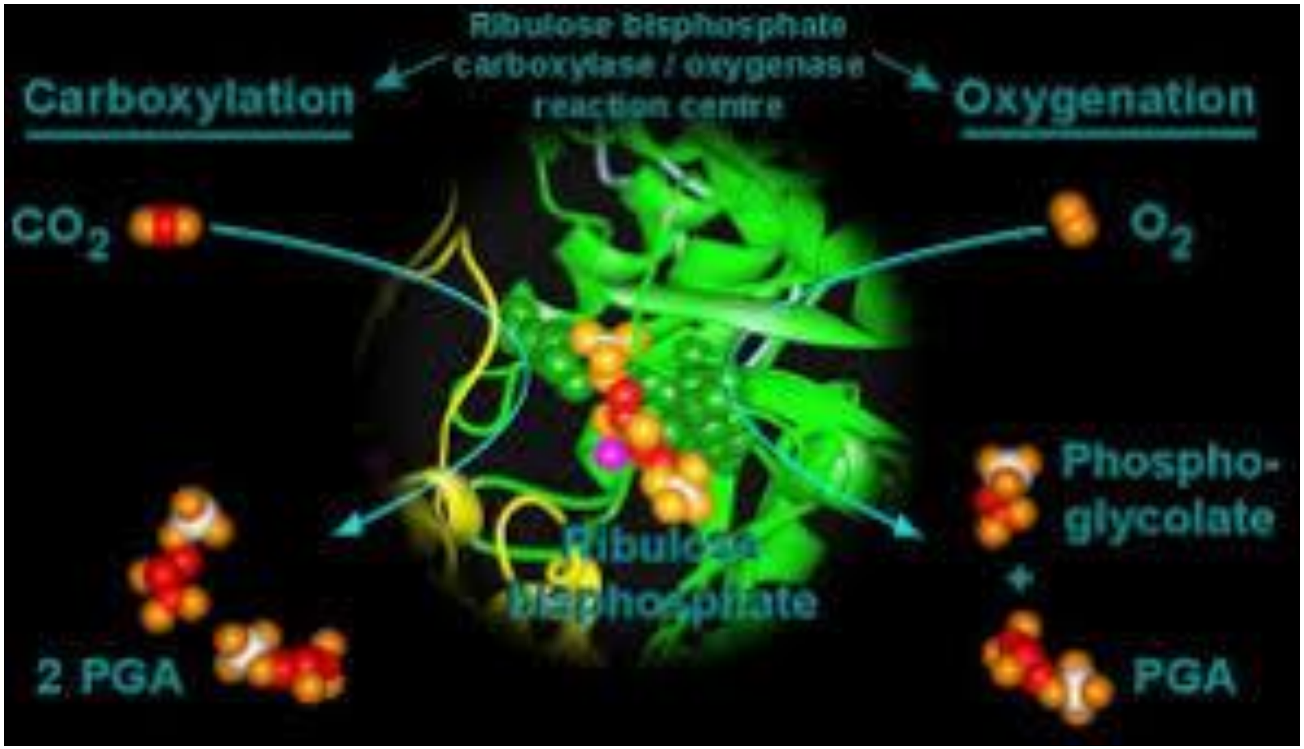
PHOTORESPIRATION/ PHOTOSYNTHETIC CARBON OXIDATION CYCLE /C2 CYCLE

For B.Sc. Part II (Subs) Group C (Plant Physiology)



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Lecture No.07

Photorespiration/ Photosynthetic carbon oxidation cycle /C2 cycle

- An important property of rubisco is its ability to catalyze both the carboxylation and the oxygenation of RuBP. **Oxygenation is the primary reaction in a process known as photorespiration.** Because photosynthesis and photorespiration work in diametrically opposite directions, photorespiration results in loss of CO_2 from cells that are simultaneously fixing CO_2 by the Calvin cycle.

- Decker & Tio discovered photorespiration and clarified that C2-cycle or glycolate pathway operates during day time in C3-plants & Rubisco acts as oxygenase at higher concenration of O_2 and low CO_2 concentration in the C3 – green cells.

During photorespiration, 75 percent of the carbon lost by the oxygenation of RUBP is recovered. Because two molecules of glycine (2C + 2C = 4C) form one molecule of serine (3C).

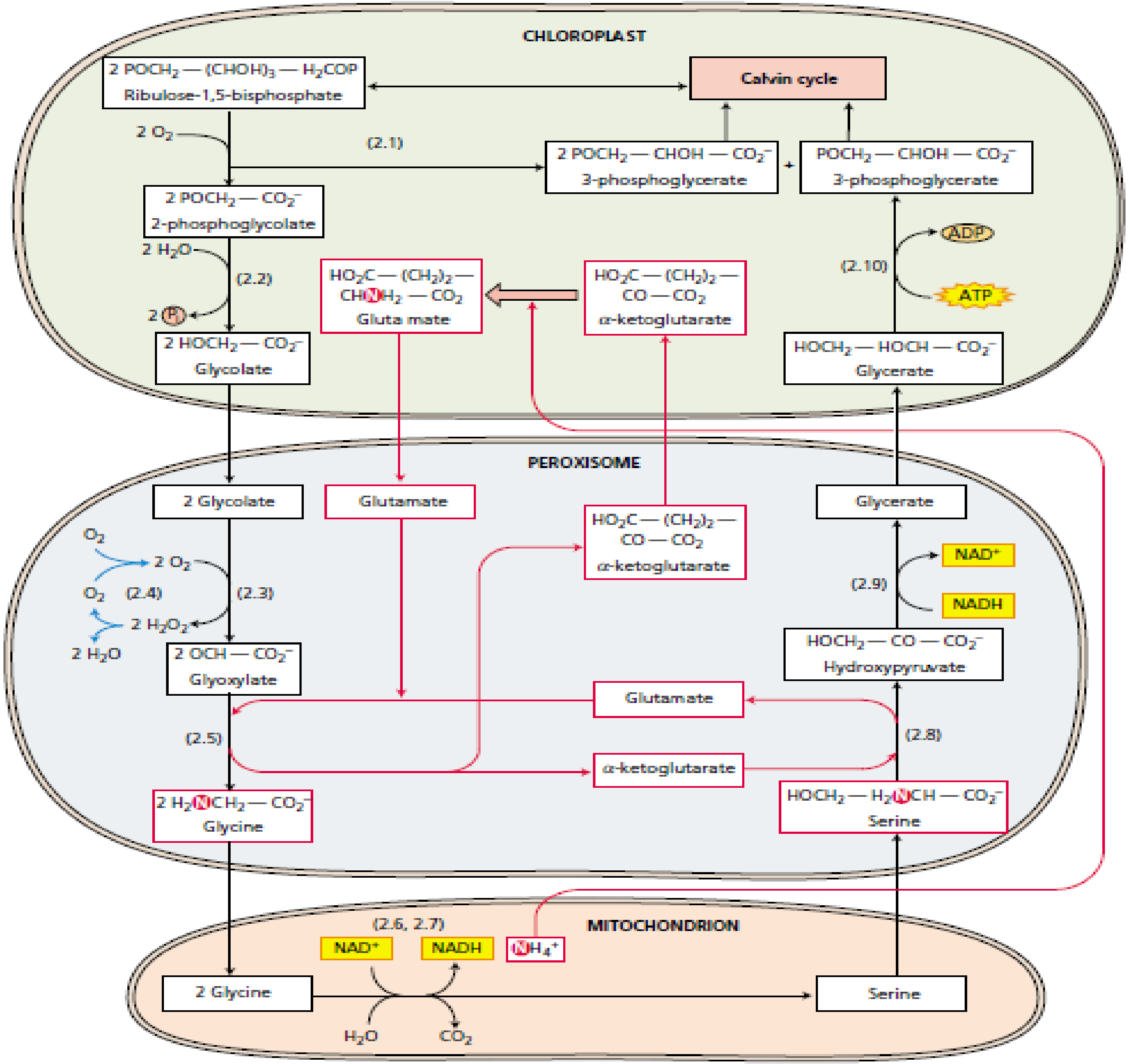

Figure: Reactions of the Photorespiratory cycle

- During this one carbon releases in form of CO_2 in mitochondria thus 25 percent carbon is lost.
- The ability to catalyze the oxygenation of ribulose- 1,5-bisphosphate is a property of all rubiscos.
- Substrates for rubisco, CO_2 and O_2 compete for reaction with ribulose-1,5-bisphosphate because carboxylation and oxygenation occur within the same active site of the enzyme.
- The 2-phosphoglycolate formed in the chloroplast by oxygenation of ribulose-1,5-bisphosphate is rapidly hydrolyzed to glycolate by a specific chloroplast phosphatase.
- Subsequent metabolism of the glycolate involves the cooperation of two other organelles: peroxisomes and mitochondria.
- Glycolate leaves the chloroplast via a specific transporter protein in the envelope membrane and diffuses to the peroxisome.

Glycolate is oxidized to glyoxylate and hydrogen peroxide (H_2O_2) by a flavin mononucleotide dependent oxidase: glycolate oxidase.

- The large amount of hydrogen peroxide released in the peroxisome are destroyed by the action of catalase while the glyoxylate undergoes transamination.
- The amino donor for this transamination is probably glutamate, and the product is the amino acid glycine.
- Glycine leaves the peroxisome and enters the mitochondrion.
- There the glycine decarboxylase multienzyme complex catalyzes the conversion of two molecules of glycine and one of NAD^+ to one molecule each of serine, NADH, NH_4^+ and CO_2.
- The ammonia formed in the oxidation of glycine diffuses rapidly from the matrix of mitochondria to chloroplasts, where glutamine synthetase combines it with carbon skeletons to form amino acids.

- The newly formed serine leaves the mitochondria and enters the peroxisome, where it is converted first by transamination to hydroxypyruvate and then by an NADHdependent reduction to glycerate.
- A malate-oxalo acetate shuttle transfers NADH from the cytoplasm into the peroxisome, thus maintaining an adequate concentration of NADH for this reaction.
- Finally, glycerate reenters the chloroplast, where it is phosphorylated to yield 3-phosphoglycerate.

- In photorespiration, various compounds are circulated in concert through two cycles. In one of the cycles, carbon exits the chloroplast in two molecules of glycolate and returns in one molecule of glycerate. In the other cycle, nitrogen exits the chloroplast in one molecule of glutamate and returns in one molecule of ammonia (together with one molecule of α-ketoglutarate)

- Thus overall, two molecules of phosphoglycolate (four carbon atoms), lost from the Calvin cycle by the oxygenation of RuBP, are converted into one molecule of 3-phosphoglycerate

(three carbon atoms) and one CO_2. In other words, 75% of the carbon lost by the oxygenation of ribulose-1,5-bisphosphate is recovered by the C2 oxidative photosynthetic carbon cycle and returned to the Calvin cycle.

- On the other hand, the total organic nitrogen remains unchanged because the formation of inorganic nitrogen (NH_4^+) in the mitochondrion is balanced by the synthesis of glutamine in the chloroplast. Similarly, the use of NADH in the peroxisome (by hydroxypyruvate reductase) is balanced by the reduction of NAD^+ in the mitochondrion (by glycine decarboxylase).

Reference: Plant Physiology, by Lincoln Taiz and Eduardo Zeiger

Thank You !!