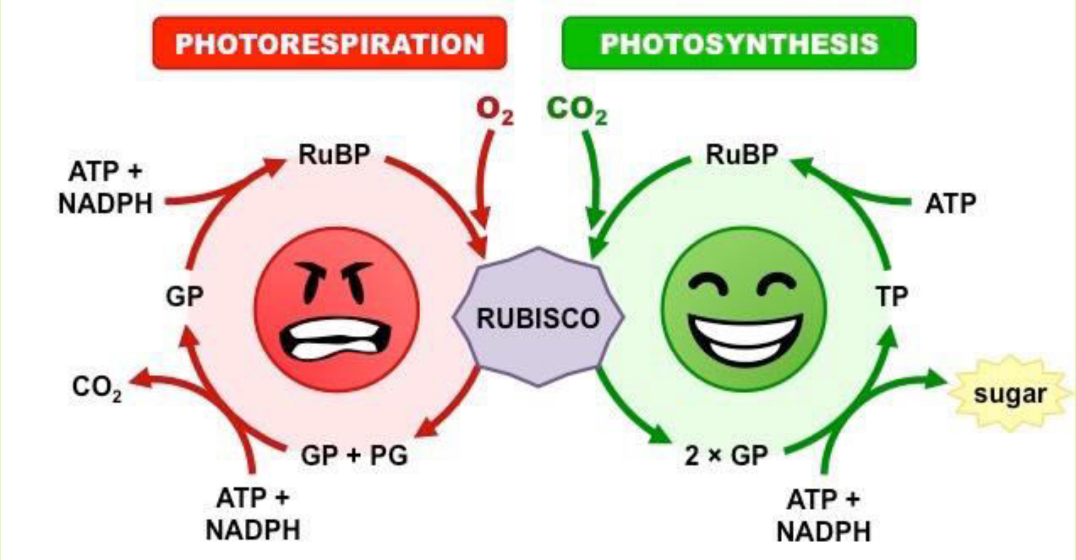
Photorespiration



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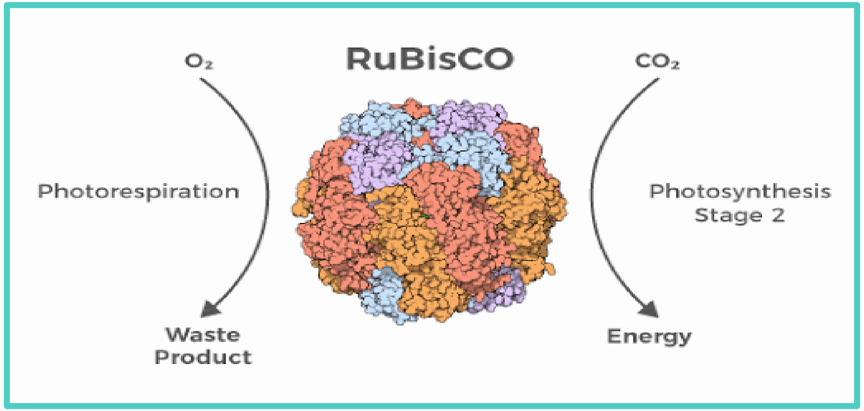
THE C2 OXIDATIVE PHOTOSYNTHETIC CARBON CYCLE

Rubisco is its ability to catalyze by both the carboxylation and the oxygenation of RuBP. Oxygenation is the primary reaction in a process known as photorespiration.

photorespiration results in loss of CO_2 from cells that are simultaneously fixing CO_2 by the Calvin cycle(Ogren1984 leegood et al. 1995).



Photosynthetic CO_2 Fixation and Photorespiratory Oxygenation

Are Competing Reactions

The incorporation of one molecule of O_2 into the 2,3-enediol isomer of ribulose-1,5-bisphosphate generates an **unstable intermediate that rapidly splits into 2-phosphoglyolate and 3-phosphoglycerate.**
As alternative 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 C2 oxidative photosynthetic carbon cycle

scavenger operation

C2 oxidative photosynthetic carbon cycle acts as a scavenger operation to **recover fixed carbon lost during photorespiration by the oxygenase reaction of rubisco**. The 2-phosphoglycolate formed in the chloroplast by oxygenation of ribulose-1,5-bisphosphate is rapidly hydrolyzed to glycolate by a specific chloroplast phosphatase (Figure1).

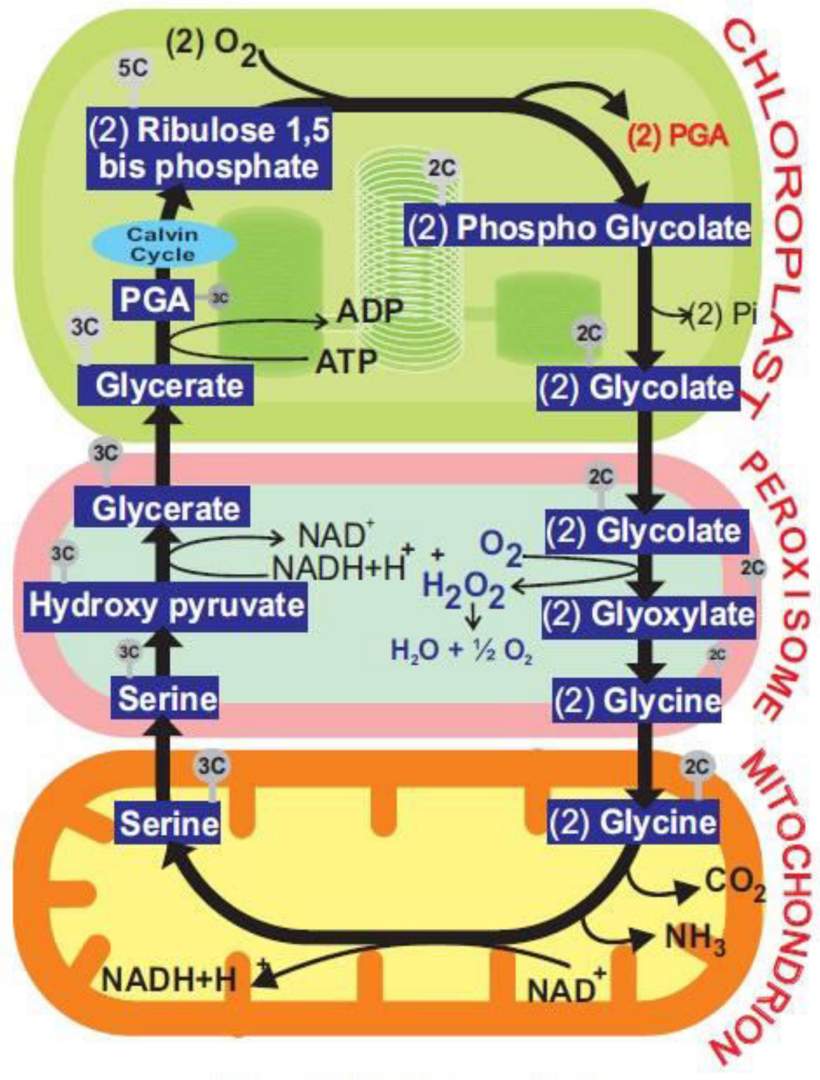
Subsequent metabolism of the glycolate involves the operation of two other organelles peroxisomes and mitochondria (Tollbert 1981).

Glycolate leaves the chloroplast via a specific transporter protein in the envelope membrane and diffuses to the peroxisome. There it is oxidized to glyoxylate and hydrogen peroxide by flavin mononucleotide dependent oxidase.

hydrogen peroxide released in the peroxysomes are destroyed by the action of catalase

while the glyoxcylate undergoes transamination (reaction 5). The amino donor for this use transamination is probably glutamate, and the product is the amino acid glycine.

Figure 1 Photorespiration Cycle



Glycine leaves the peroxisome and enters the mitochondrion (see Figure 1.). there the glycine decarboxylase a 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 NADH-dependent reduction to glycerate .
Finally, glycerate reenters the chloroplast, where it is phosphorylated to yield 3-phosphoglycerate.

PHOTORESPIRATION CONCERT

FACTS

75% of the carbon lost by the oxygenation of ribulose-1,5-bisphosphate is recovered by the , oxidative photosynthetic carbon cycle and returned to the Calvin cycle (Lorimer 1981).

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.

Carboxylation and oxygenation Vs Photosynthetic efficiency

EFFICIENCY OF PHOTOSYNTHESIS

Photorespiration lowers the efficiency of photosynthetic carbon fixation from 90% to approximately 50%. This decreased efficiency can be measured as an increase in the quantum requirement for CO_2 fixation under photorespiratory conditions (air with high O_2 and low CO_2) as opposed to nonphotorespiratory conditions (low O_2 and high CO_2). .

CARBOXYLATION AND OXYGENATION ARE INTERLOCKED IN THE INTACT LEAF

The Calvin cycle can operate independently, but the C2 oxidative photosynthetic carbon cycle depends on the Calvin cycle for a supply of ribulose-1,5-bisphosphate. The balance between the two cycles is determined by three factors: the kinetic properties of rubisco, the concentrations of the substrates CO_2 and O_2, and temperature

TABLE :Reactions of the C2 oxidative photosynthetic carbon cycle

Enzymes	Reactions
Ribulose-1,5-bisphosphate carboxylase/oxygenase	2 Ribulose-1,5-bisphosphate + 2 O_2→2 phosphoglycolate + (chloroplast) 2 3-phosphoglycerate + 4 H^+
Phosphoglycolate phosphatase (chloroplast)	2 Phosphoglycolate + 2 H_2O →2 glycolate + 2 Pi
Glycolate oxidase (peroxisome)	2 Glycolate + 2 O_2→2 glyoxylate + 2 H_2O_2
Catalase (peroxisome)	2 H_2O_2→2 H_2O + O_2
Glyoxylate:glutamate aminotransferase (peroxisome)	2 Glyoxylate + 2 glutamate →2 glycine + 2 α-ketoglutarate

Glycine decarboxylase (mitochondrion)	Glycine + NAD^+ + H^+ + H4-folate →NADH + CO_2 + NH_4^+ + methylene-H4-folate
Serine hydroxymethyltransferase (mitochondrion)	Methylene-H4-folate + H_2O + glycine →serine + H_4-folate
Serine aminotransferase (peroxisome)	Serine + α-ketoglutarate → hydroxypyruvate + glutamate
Hydroxypyruvate reductase (peroxisome)	Hydroxypyruvate + NADH + H^+ →glycerate + NAD^+
Glycerate kinase (chloroplast)	Glycerate + ATP →3-phosphoglycerate + ADP + H^+

Significance of Photorespiration

- ➢Removes Toxic Metabolic Intermediates
- ➢ Photorespiration Protects from Photoinhibition
- ➢ Photorespiration Supports Plant Defense Reactions
- ➢Photorespiration is Intimately Integrated Into Primary Metabolism.
- ➢Photorespiration lower the efficiency of photosynthetic carbon fixation from 90% to 50%. This can be measured as an increased the quantum requirement of CO_2 fixation under photorespiratory condition.
- ➢High temperatures promote oxygenation, and hence the photorespiration

Reference

- Lincoln Taiz and Eduardo Zeiger : Plant Physiology 3rd edition.p-177-181. Publisher: Sinauer Associates; 3 edition (Aug 30 2002).
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Thank You