PHOTOSYNTESIS

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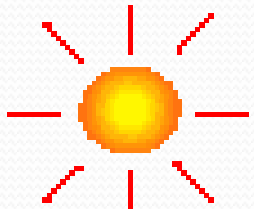
PHOTOSYNTHESIS

The process in green plants and certain other organisms by which carbohydrates are synthesized from carbon dioxide and water using light as an energy source.

Or

The synthesis of complex organic material using carbon dioxide, water, inorganic salts and light energy (from sunlight) captured by light-absorbing pigments such as chlorophyll and other accessory pigments.

Photosynthesis in Brief



$$6(CO_2) + 6(H_2O) \rightarrow C_6(H_2O)_6 + 6(O_2)$$

Overall reaction of Photosynthesis

$$6\ CO_2 + 18\ ATP + 12\ H_2O + 12\ NADPH^+ / 2\ H^+ \rightarrow$$

$$C_6H_{12}O_6 + 18\ Pi + 18\ ADP + 12\ NADP^+ + 6(O_2)$$

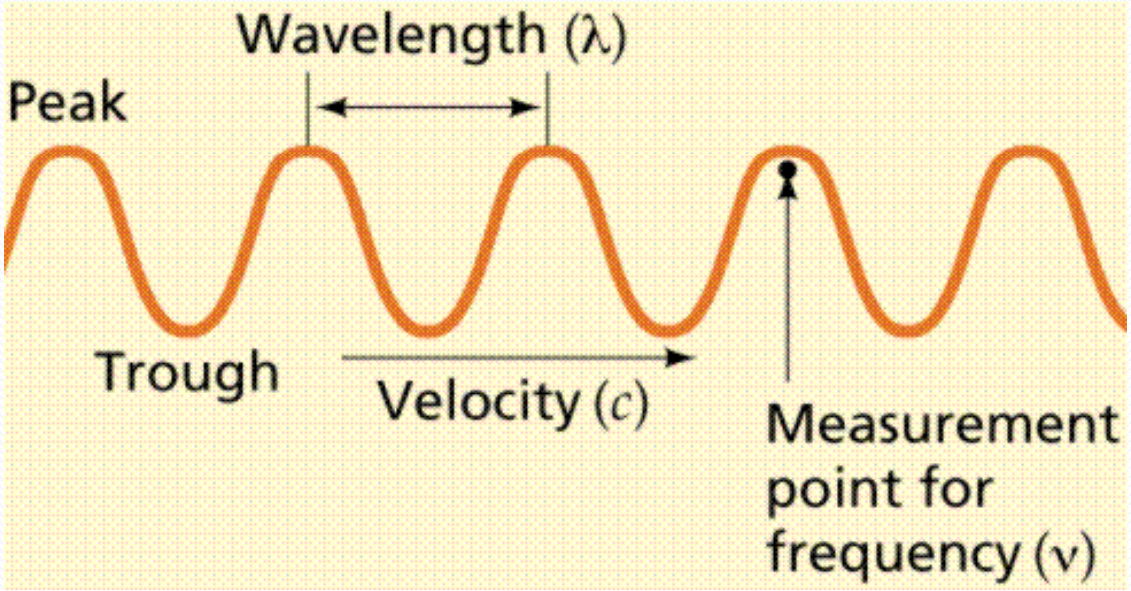
According to Biological Economists

ALL WEAALTH ORIGINATES DIRECTLY OR INDIRECTLY AS A CONSEQUENCE OF PHOTOSYNTHESIS

Photosynthesis is the biggest photochemical & biochemical phenomena acting as a master key for the existance of life on this globe. Inturn solar energy is the chief driver of this reaction

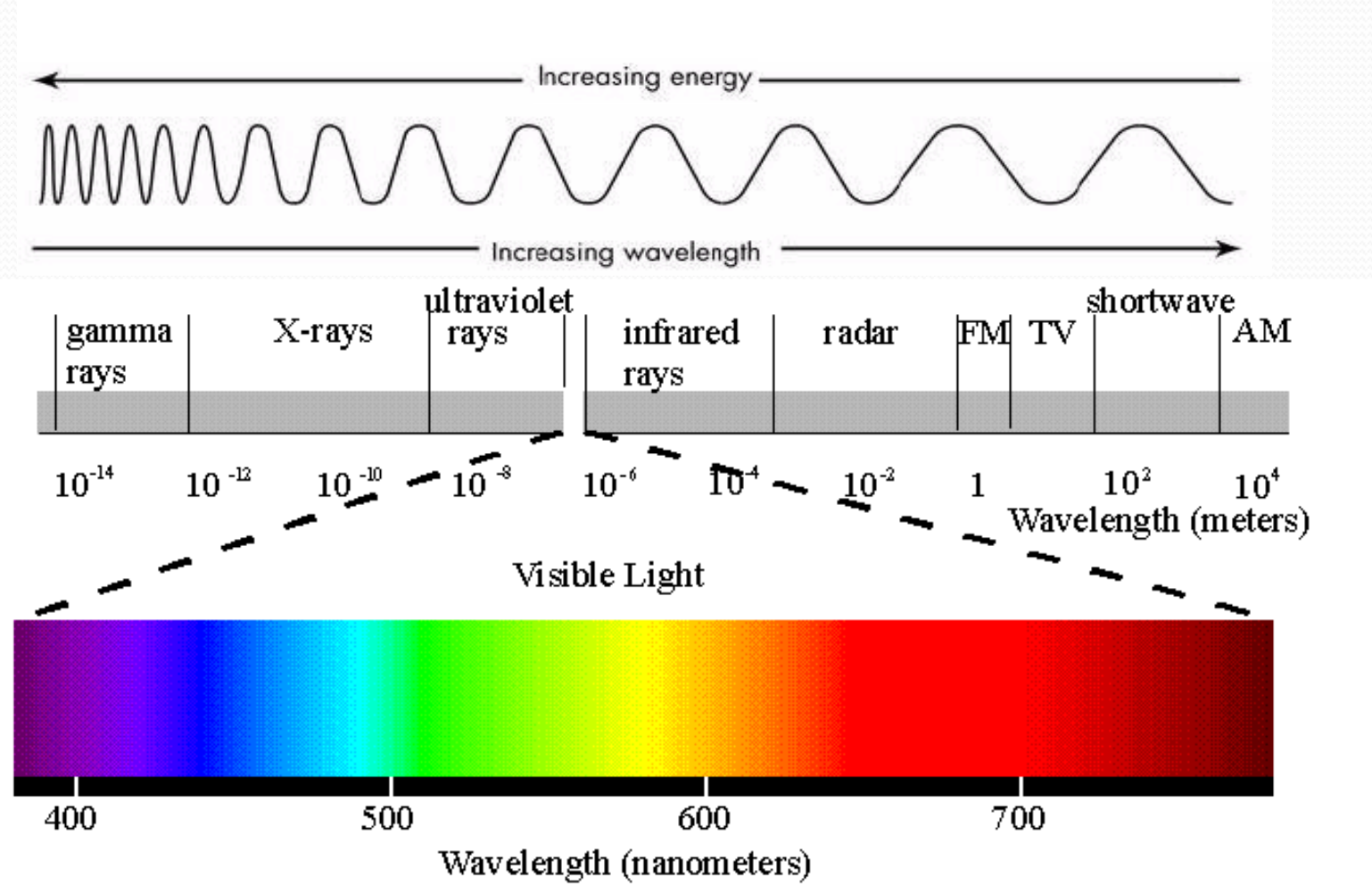
Nature of radiant energy

An elementary knowledge of the physical properties of light and other kinds of radiant energy is essential for proper understanding of photosynthesis and many other photobiological reactions.



Light appears to be propagated across the space as an undulatory waves.

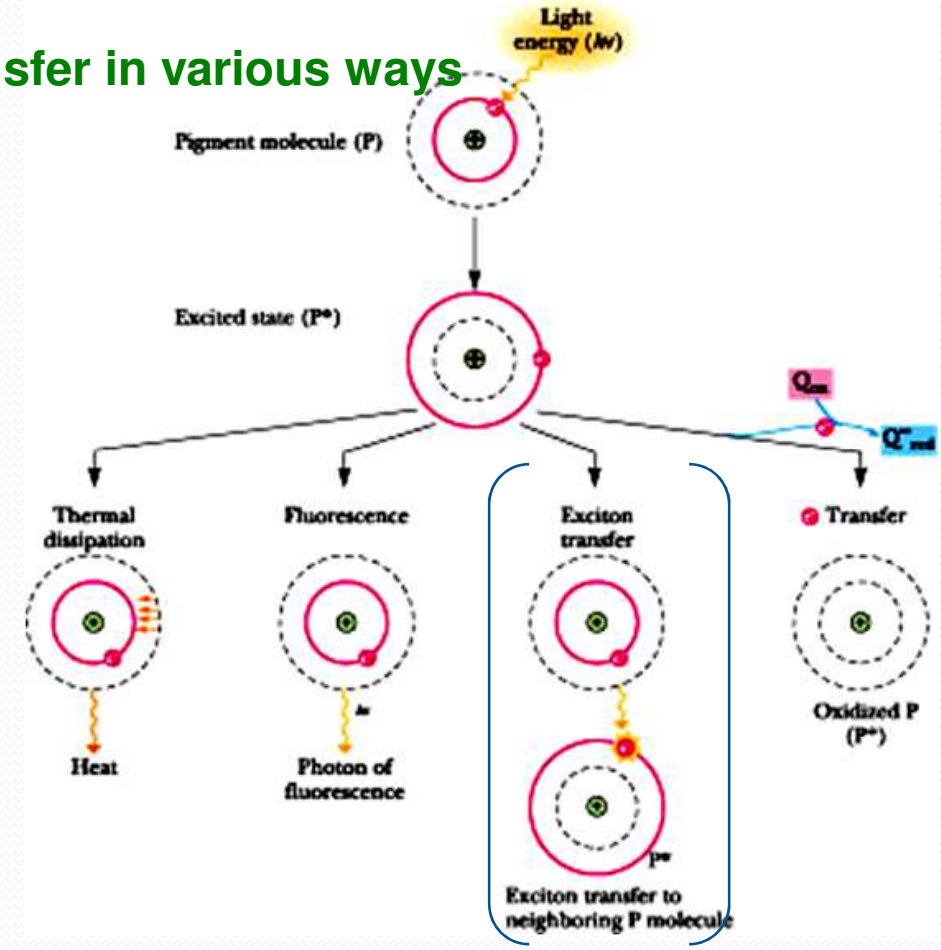
ELECTROMAGNETIC SPECTRUM OF SUN LIGHT



390-760 nm induces sensation in photosynthesis

Photochemical Changes in Chlorophyll

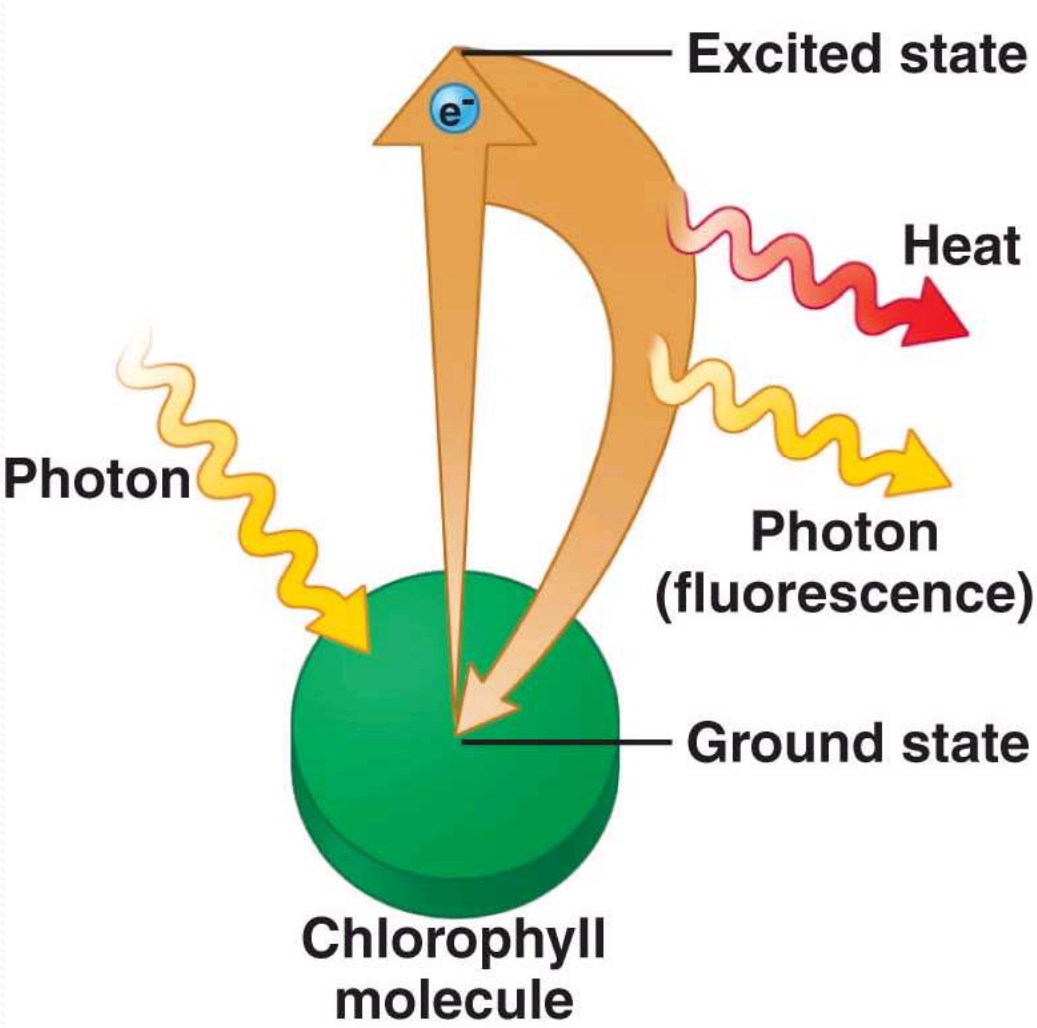
Energy transfer in various ways



A. Loss as heat.
B. Loss of light.
C. Resonance energy transfer.
D. Energy transduction

Mode of Energy Transfer in Photosynthesis

Photochemical Changes in Chlorophyll



Photosynthetic Pigments

The photosynthetic pigments of higher plants fall into two classes, the Chlorophylls and Carotenoids.

These pigments absorb light energy and convert it to chemical energy. They are located on the chloroplast membranes (Thylakoids) and the chloroplasts are usually arranged with in the cells so that the membranes are at right angles to the light source for maximum absorption.

Chlorophylls

There are 6-7 types of chlorophylls known as chlorophyll a, b, c, d, e, bacteriochlorophyll (in bacteria) and chlorobium chlorophyll (in green sulphur bacteria).

Chlorophylls absorb mainly red and blue violet light, reflecting green light. Chlorophyll a is the most abundant photosynthetic pigment and other pigments are accessory or light harvesting antenna molecules.

Carotenoids – β carotene/Orange Carotene

Xanthophylls/ Yellow Xanthophylls

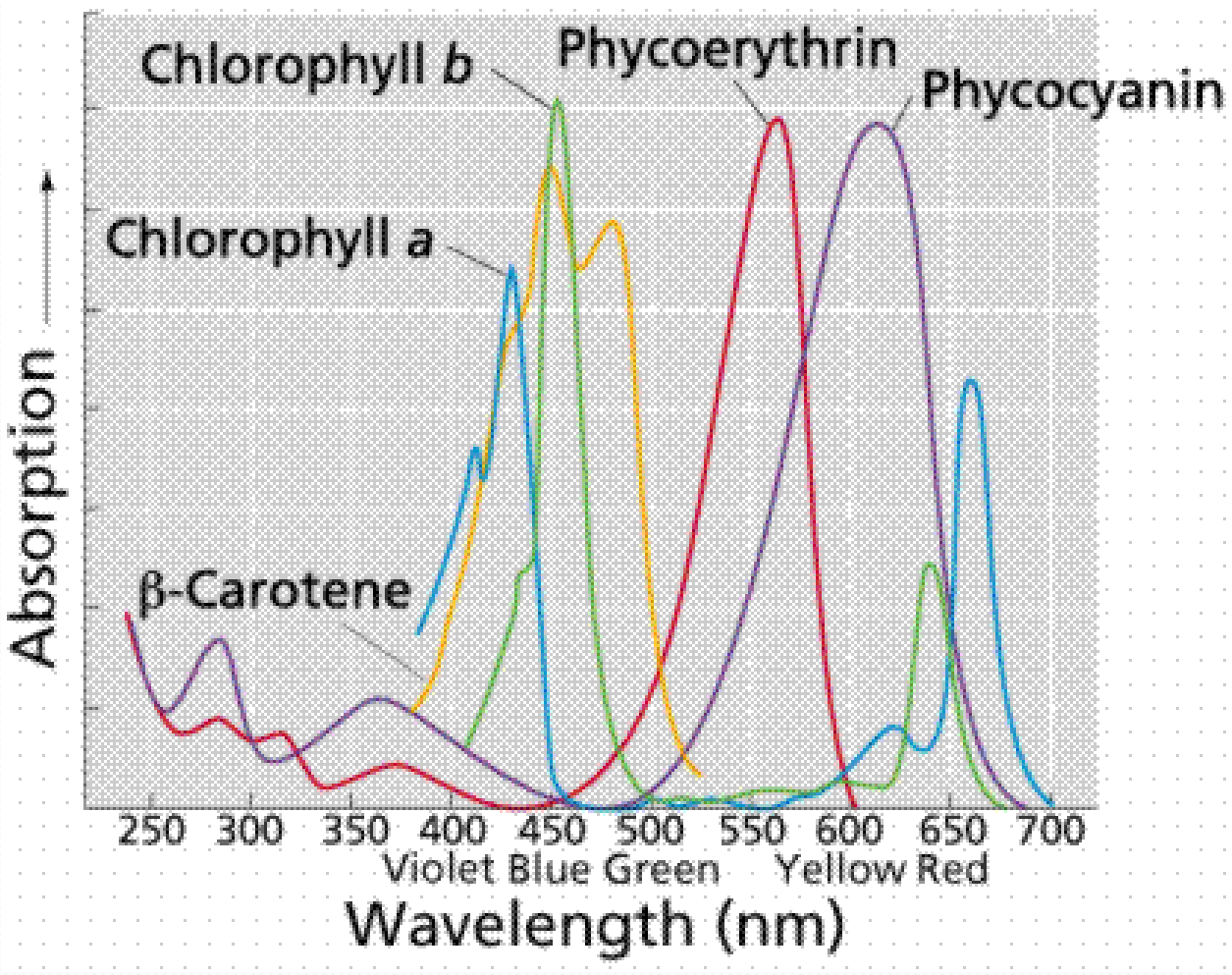
The carotenoids are known to perform two distinct roles.

- **Carotenoids prevents the photo-oxidation of chlorophyll by chlorophyllase.**
- **Carotenoids absorb energy from light and transfer it to chlorophyll a with which they are associated.**

Phycobilins - Phycocyanin-blue pigment

Phycoerythrin-red pigment

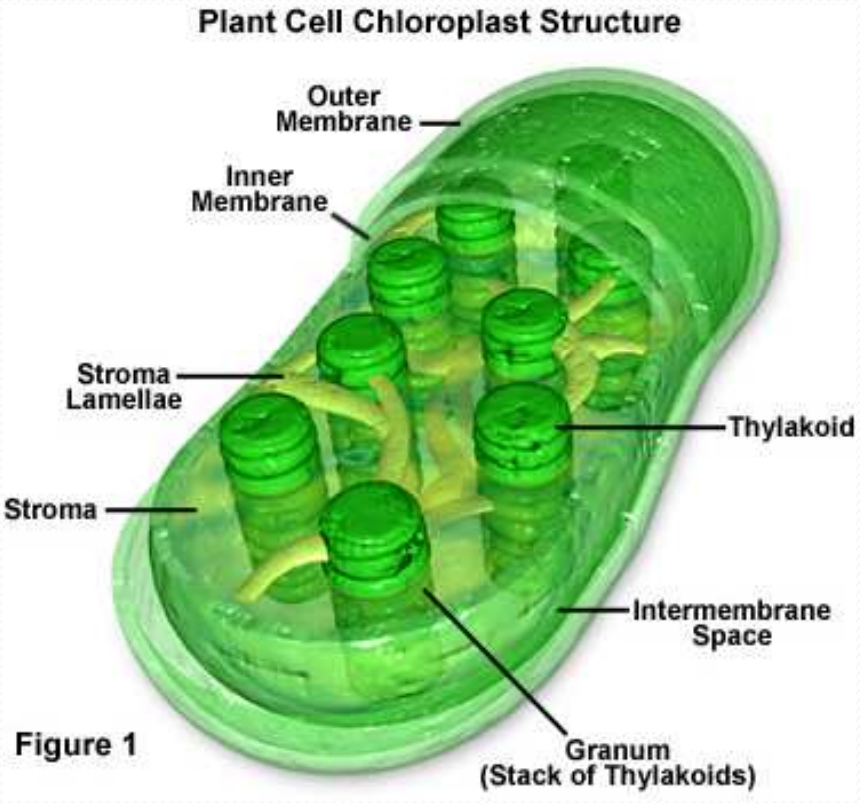
Absorption Spectra of Photosynthetic pigments



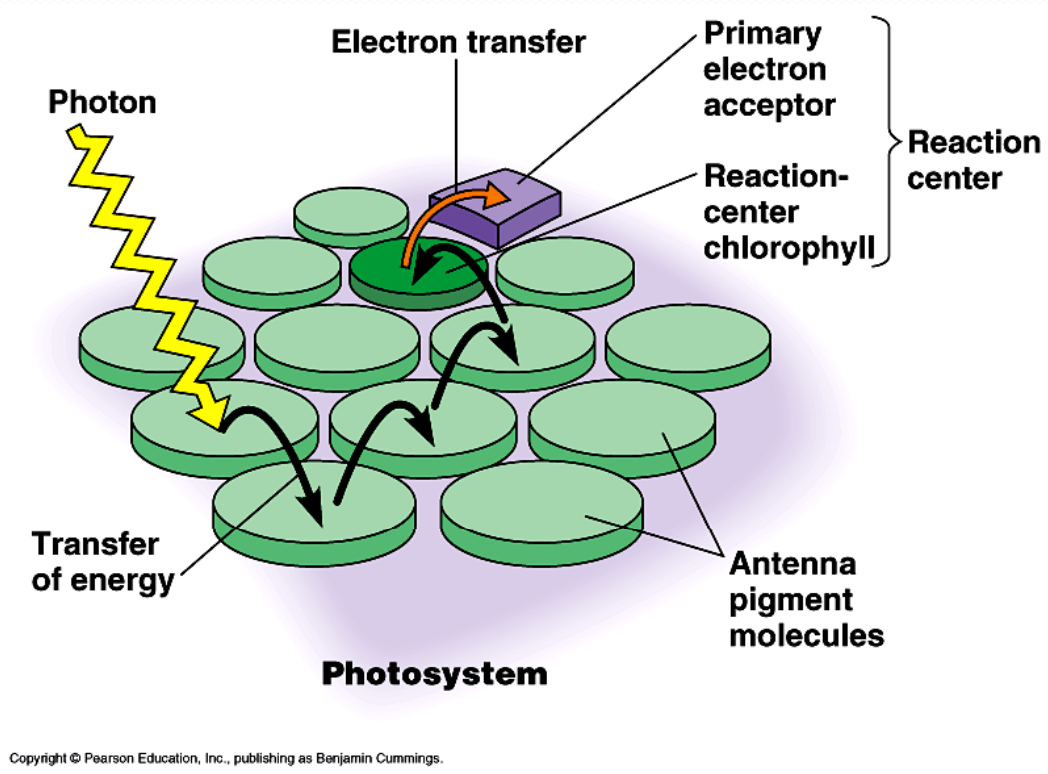
Site of Photosynthesis

The light reactions of photosynthesis, are associated with the thylakoid membranes.

In contrast, the light-independent reactions, or so-called dark reactions, notably CO_2 fixation, are located in the stroma.

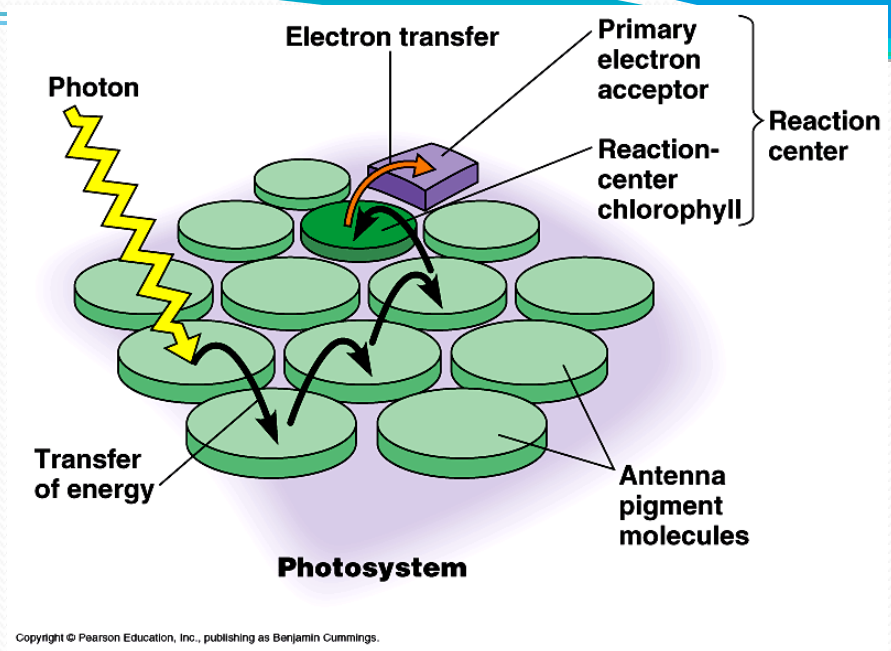


PHOTOSYNTHETIC UNIT AND PHOTOCHEMICAL REACTION CENTRE



A photosynthetic unit is the smallest group of molecules which collaborate together to cause a photochemical act *i.e.* the absorption and migration of light quantum to a trapping center where it brings about the release of an electron.

Photochemical reaction centre:



- **All the pigment molecules in a photosystem can absorb photons but there is only one molecule in each cluster that converts the light energy into chemical energy.**
- **This specialized energy converting pigment molecule consists of a chlorophyll molecule combined with a specific protein and is called the photochemical reaction center.**
- **This chlorophyll complex is associated with a primary electron donor and acceptor.**

Steps/out line of Photosynthesis

Light Reactions of Photosynthesis

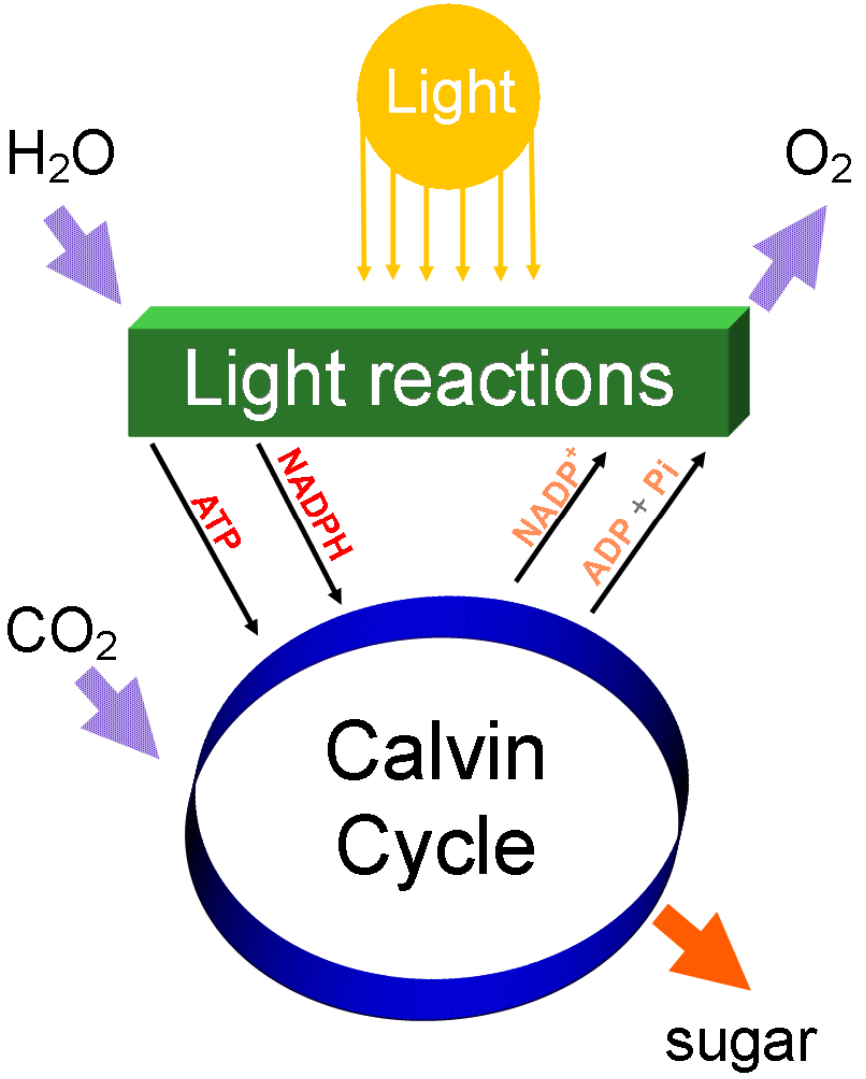
Converts solar energy into potential energy. The light reaction converts ADP and $NADP^+$ into the ATP and NADPH and produces oxygen.

Cyclic Phosphorylation:

Non-cyclic Phosphorylation:

Calvin Benison Cycle of Photosynthesis

The light independent reactions fixes CO_2 in to $C_6H_{12}O_6$ using the products of light reaction



Photosystems

The photochemical phase requires the interaction of 2 photosystems.

<u>Photosystem I:</u> consists ~200 light harvesting chlorophylls, ~50 Carotenoids, a mol. of P700, 1 mol. of an unidentified compound (X), one cytochrome f, one plastocyanin, two cytochrome b 563, Ferredoxin reducing substance and 1/2 membrane bound ferredoxin molecule.

It produces a strong reductant which reduces $NADP^+$ to $NADPH_2^+$.

Photosystems

Photosystem II: consists~200 light harvesting chlorophylls, ~50 Carotenoids, a trapping chlorophyll mol. of P680, one mol. of an unidentified compound (Z), a plastoquinone, ~4 plastoquinone equivalents, 3 mn mole., two cytochrome b 559 and chloride.

The system is concerned with the release of O_2.

In association both I & II produces, ATP and NADPH.

Mechanism of Light Reaction

Photophoshoriyation: **The synthesis of ATP from ADP and phosphate that occurs in a plant using radiant energy absorbed during photosynthesis:**

ADP + pi → ATP

$$NADP^+ + 2H^+ + 2e^- \rightarrow NADPH + H^+$$

Photolysis of Water:

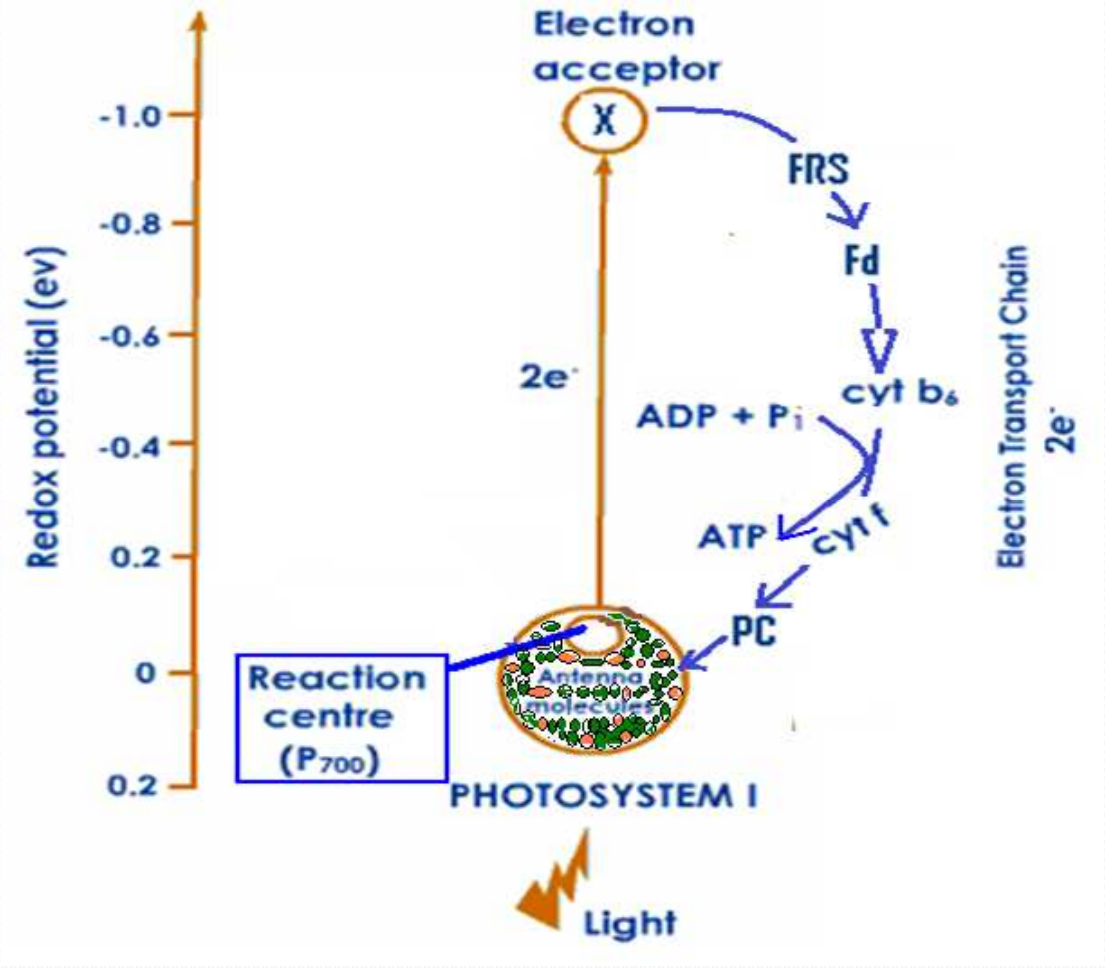
$4H_2O \text{--->} 4H^+ + 4OH^-$

$4OH^- \rightarrow 2H_2O_2 \rightarrow 2H_2O + O_2$

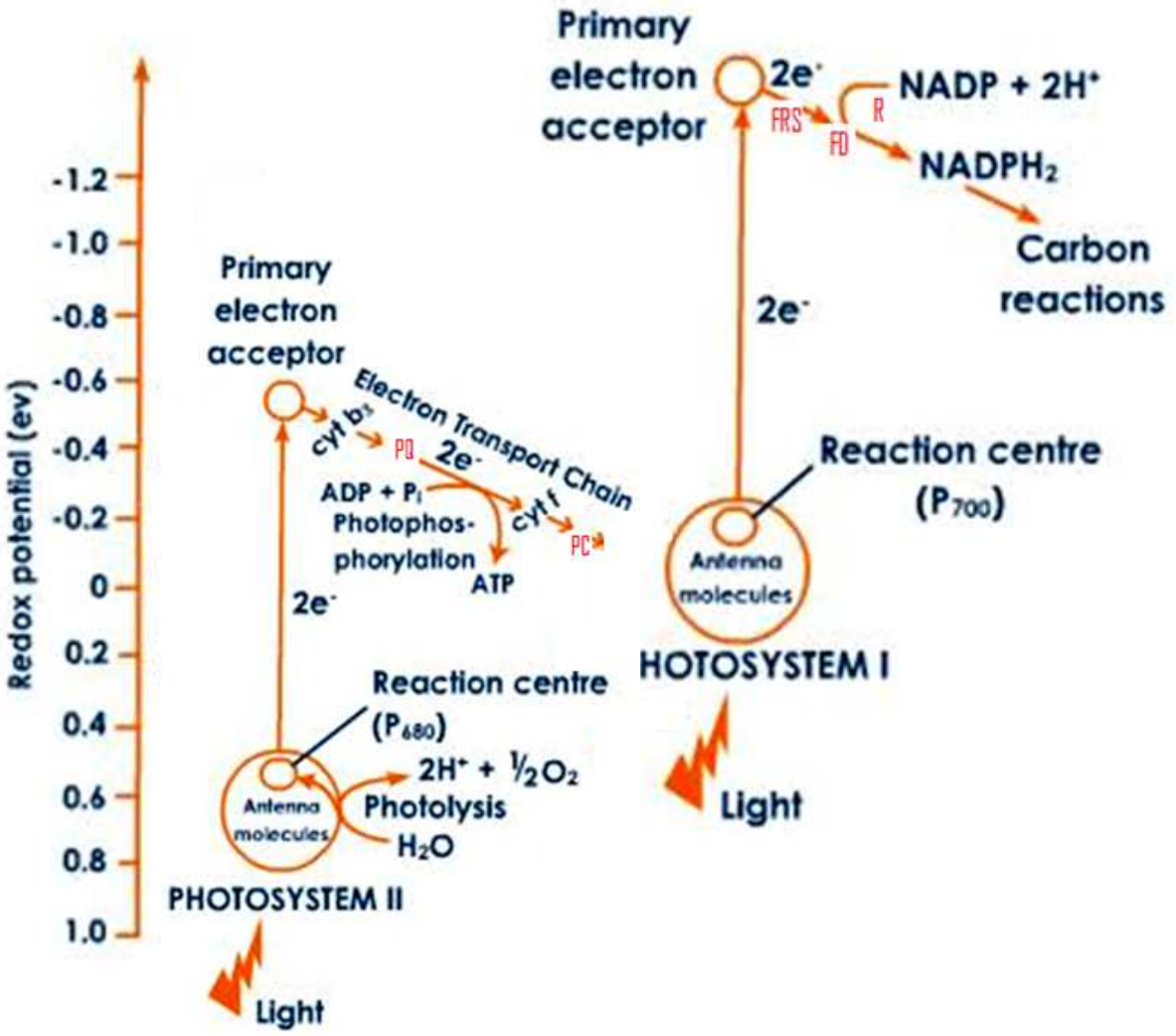
Cyclic Photophosphorylation

Redox potential:
The tendency to release and acceptance of electrons.
Expressed in volts/milivolts.

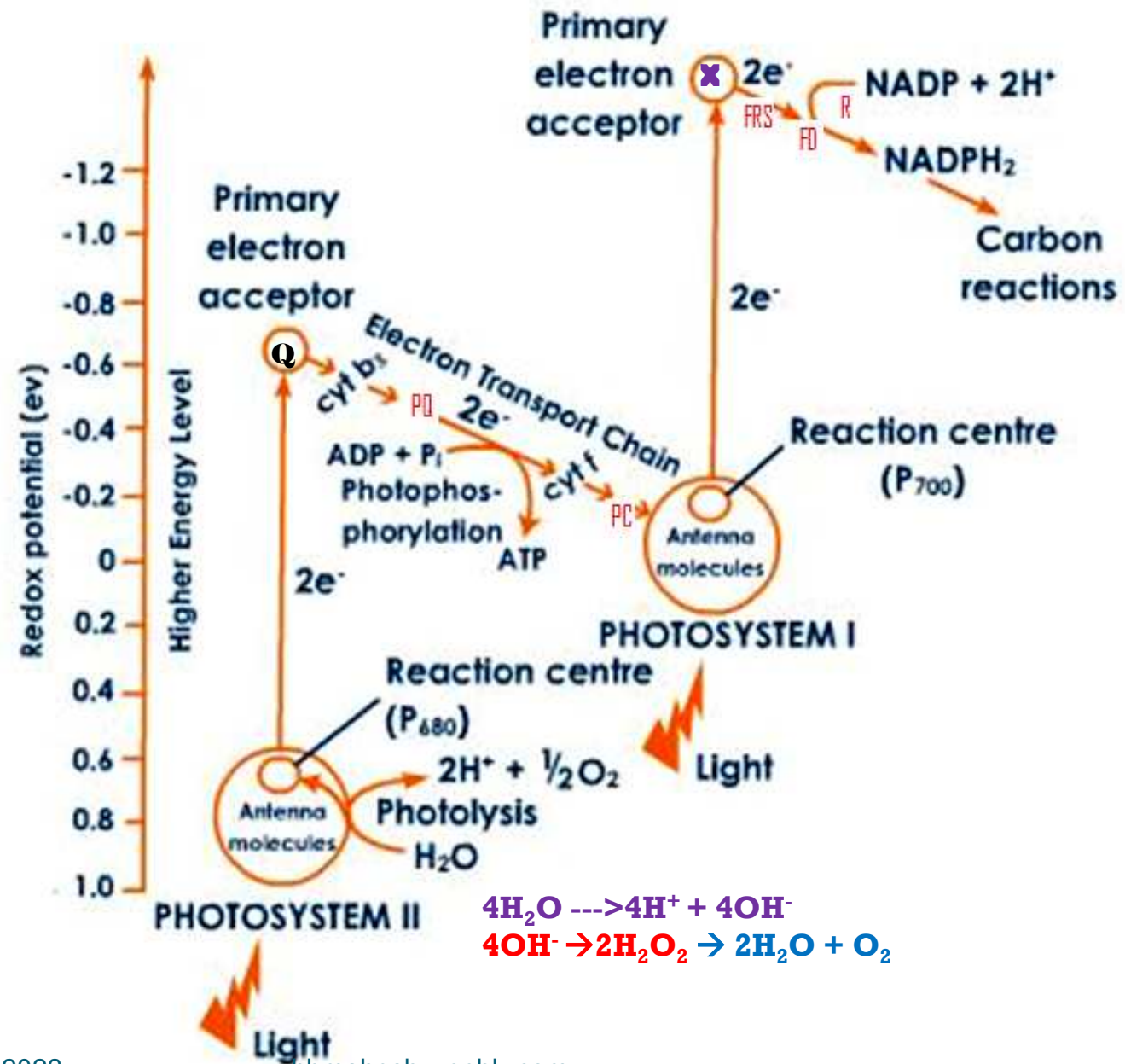
The term Redox has been derived from Reduction-Oxidation.



Non cyclic photophosphorylation

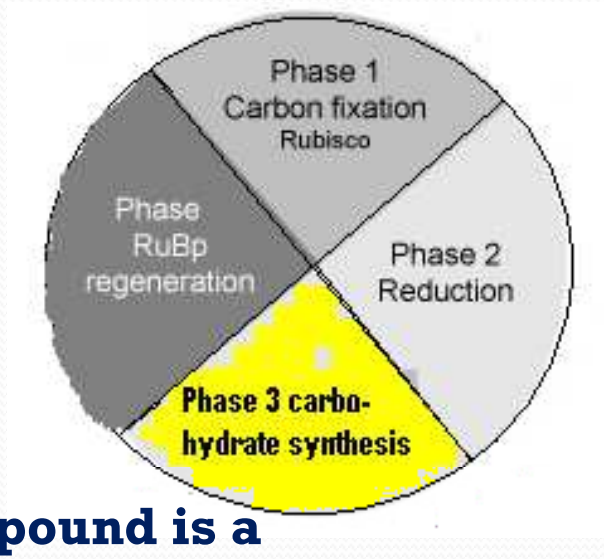


Non-Cyclic Photophosphorylation



Dark Reaction/C3 Cycle/Calvin Benson Reaction/ Blackman Reaction

Melvin Calvin and his colleagues studied photosynthesis using radioactive carbon C^{14} (CO_2) along with paper chromatography and elucidated the reaction of converting CO_2 to carbohydrate.

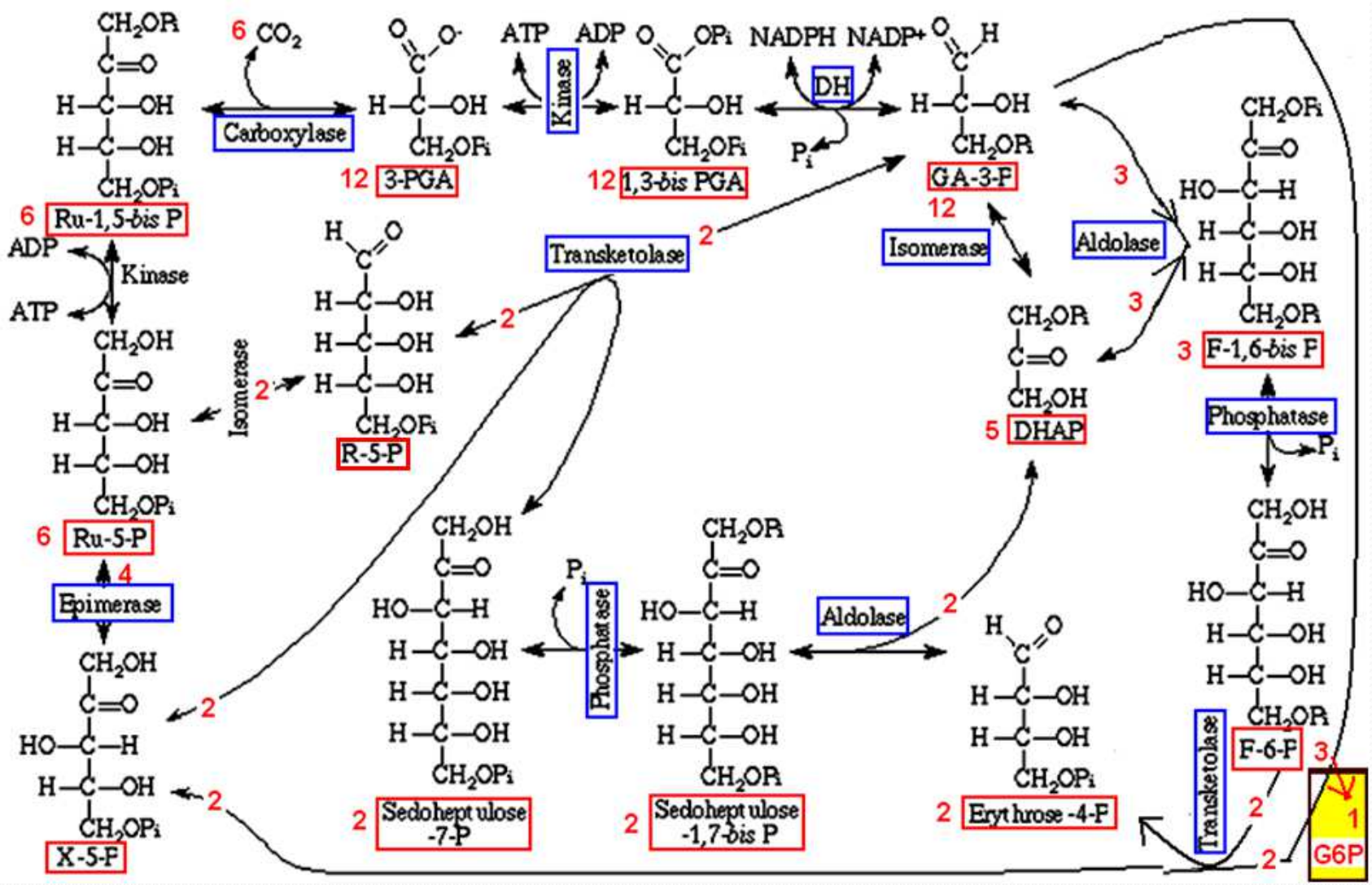


In this reaction first formed stable compound is a three carbon compound PGA and it participates in all reactions. Hence it is called as C-3 cycle.

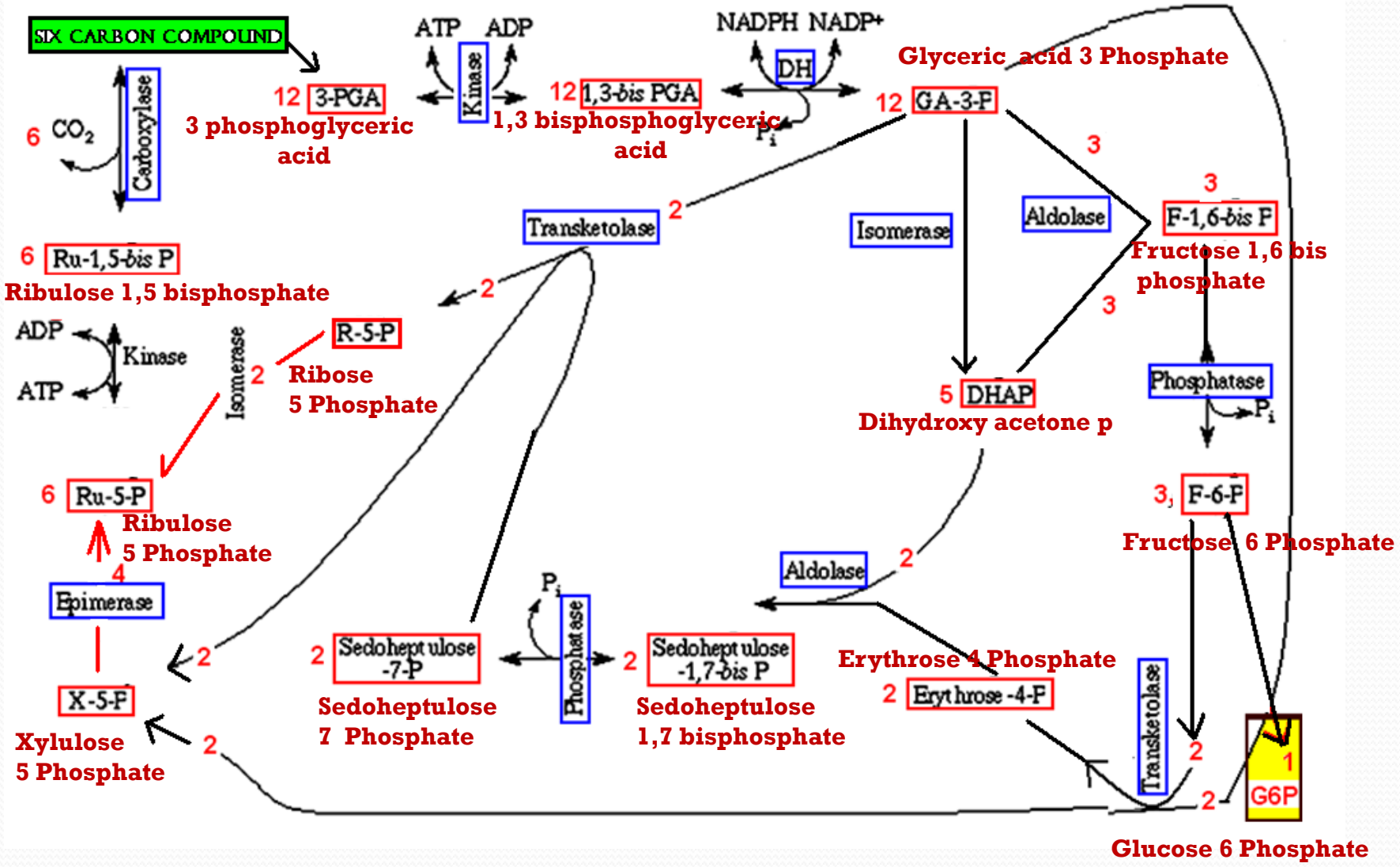
This reaction cycle can be studies in 4 steps.

- **CO_2 fixation.**
- **Carbon reduction**
- **Carbohydrate synthesis and**
- **Regeneration**

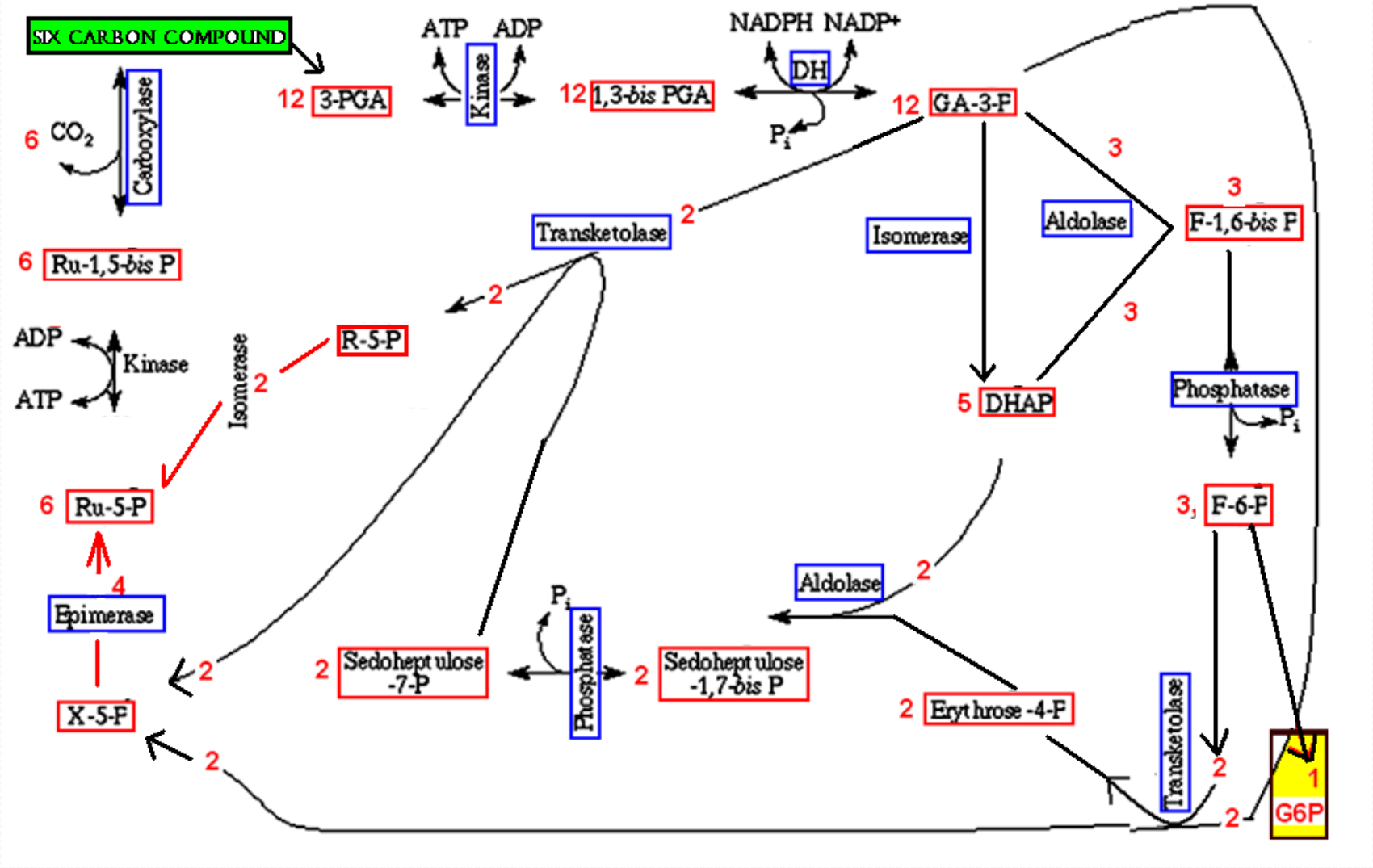
Reaction Steps of C3 Cycle



Out line of C_3 Cycle Reactions



Out line of C_3 Cycle Reactions



THE OVERALL REACTION OF PHOTOSYNTHESIS

$$6\ CO_2 + 18\ ATP + 12\ H_2O + 12\ NADPH^+ / 2\ H^+$$

$$C_6H_{12}O_6 + 18\ Pi + 18\ ADP + 12\ NADP^+ + 6O_2$$

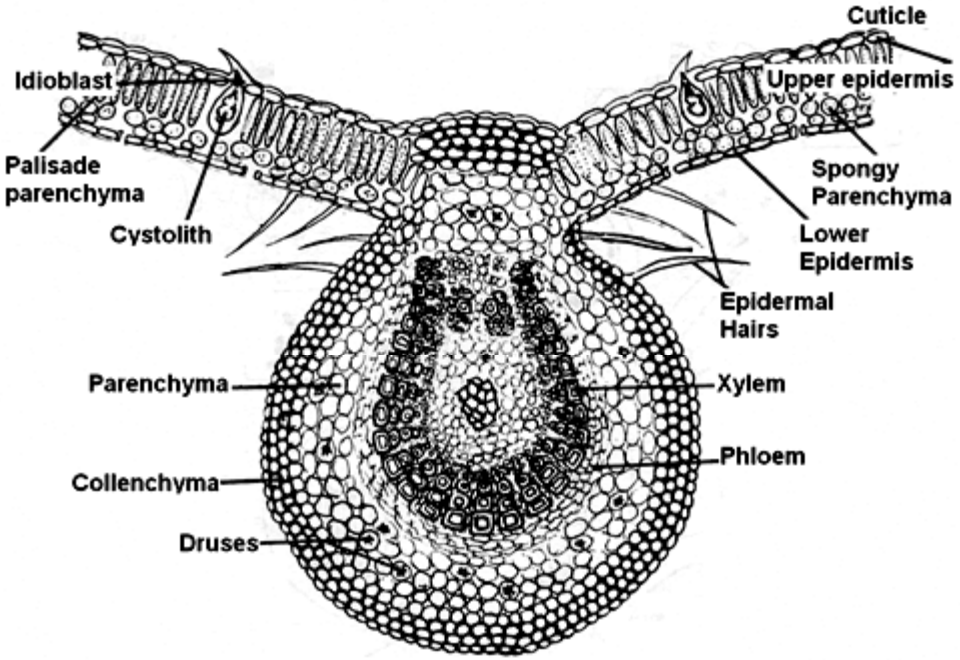
C_3 Plants

A plant that utilizes the C_3 carbon fixation pathway as the sole mechanism to convert CO_2 into an organic compound (i.e. 3-phosphogylycerate).

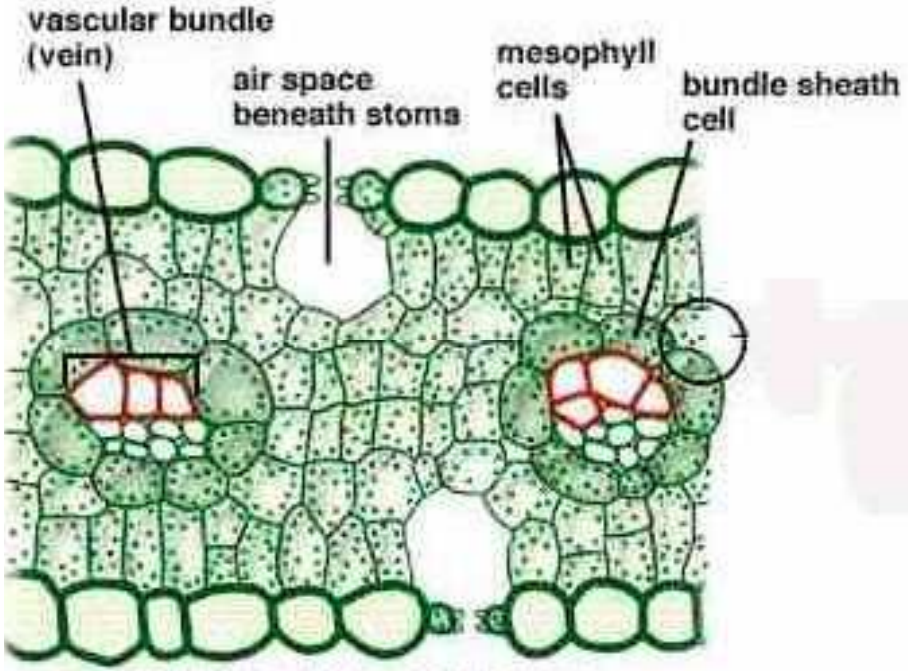
C_4 Plants

A plant that utilizes the C_4 carbon fixation pathway in which the CO_2 is first bound to a phosphoenolpyruvate in mesophyll cell resulting in the formation of four-carbon compound (oxaloacetate) that is shuttled to the bundle sheeth cell where it will be decarboxylated to liberate the CO_2 to be utilized in the C_3 pathway.

Kranz Anatomy



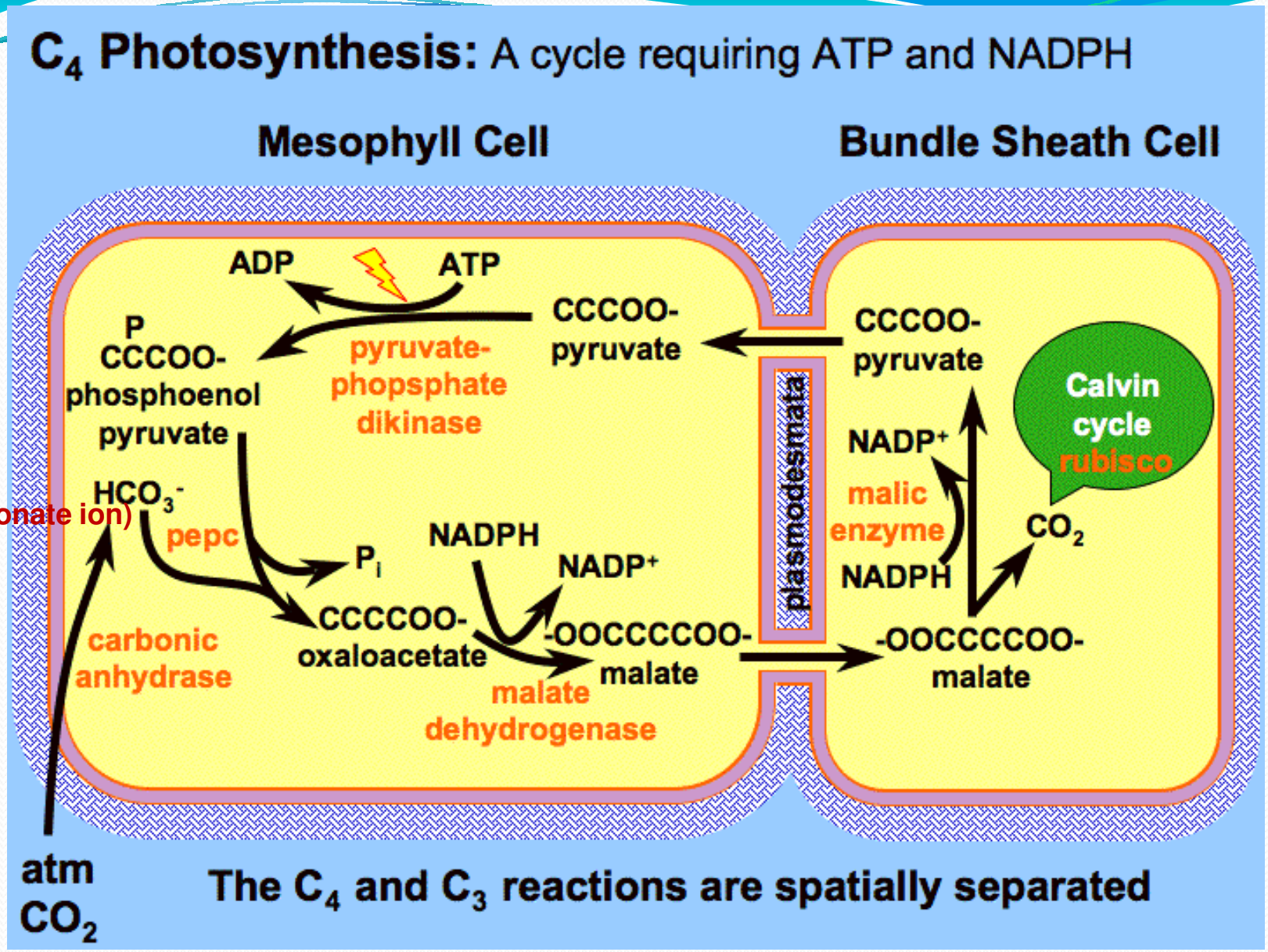
CROSS SECTION OF C3 PLANT



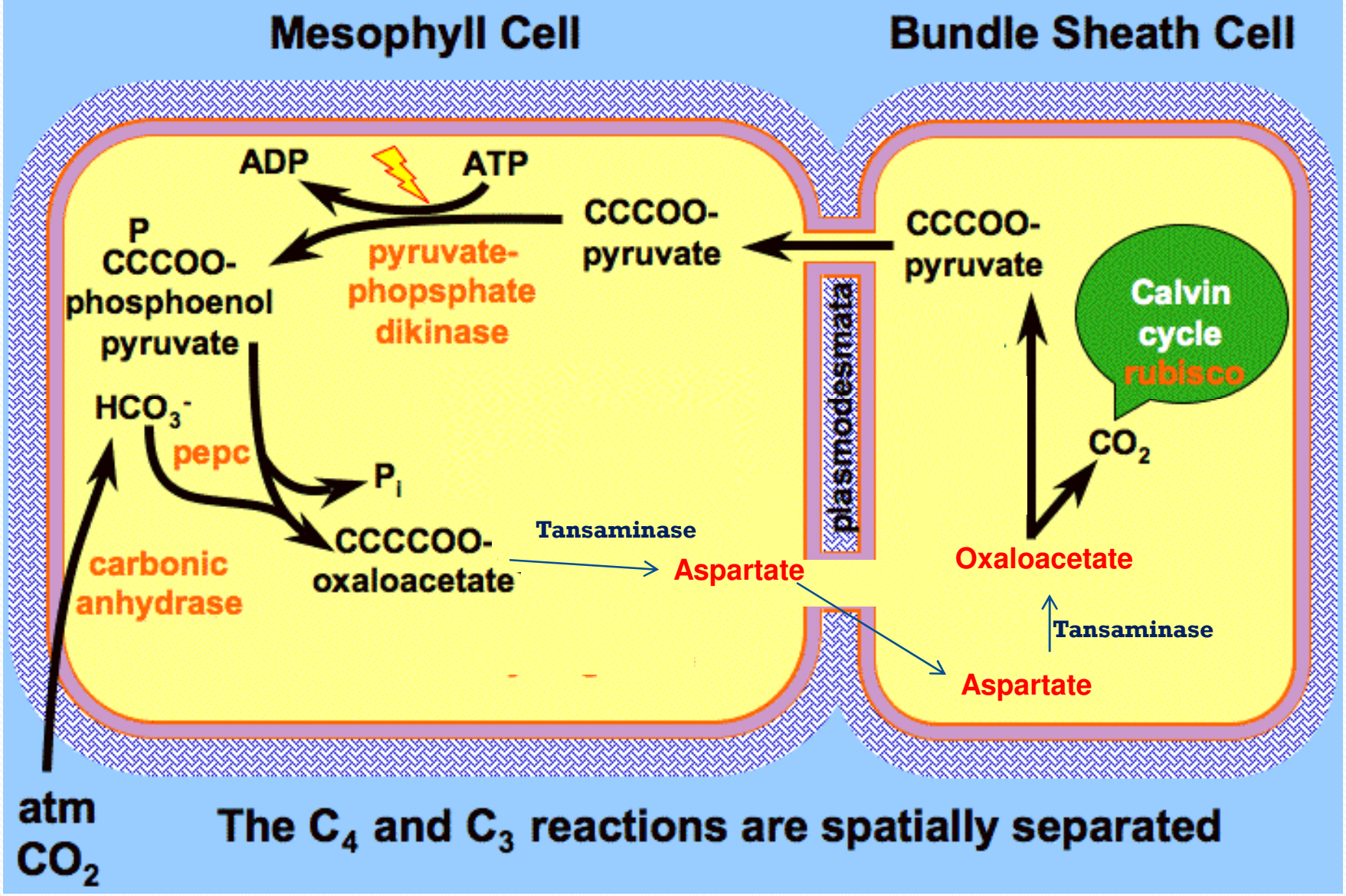
PORTION OF A CROSS SECTION OF A LEAF WITH C_4 PHOTOSYNTHESIS

Differences between C_3 and C_4 plants

C3 Plants	C4 Plants
Non Kranz type anatomy	Kranz type anatomy *i. e.*, has a concentric arrangement of the bundle sheath and mesophyll layer, the bundle sheath is also thicker.
Bundle sheath cells are absent. Carbon fixation and Calvin Cycle reactions occur in mesophyll cells only.	Bundle sheath cells are present and contain chloroplasts. Carbon is fixed in mesophyll cells, then transported to bundle sheath cells where Calvin Cycle reactions occur
A 3 carbon compound phosphoglyceric acid (PGA) is formed as a first stable compound.	Four carbon compounds like oxaloacetate, malate and aspartate are formed during CO_2 fixation as first stable compound
Ribulose 1,5 bisphosphate carboxylase (Rubisco) is the CO_2 accepter	Phosphoenolpyravete (PEP) carboxylase is the CO_2 acepter, and is more efficient than Rubisco.
Only C_3 pathway is present and involves in CO_2 fixation.	Both C_3 and C_4 pathways present and involves in CO_2 fixation. Hence they are called as "Efficient Plants"


C4 Photosynthesis: A cycle requiring ATP and NADPH
Mesophyll Cell
Bundle Sheath Cell
ADP
ATP
P
CCCOO-
phosphoenol
pyruvate
pyruvate-
phopsphate
dikinase
CCCOO-
pyruvate
CCCOO-
pyruvate
plasmodesmata
Calvin
cycle
rubisco
NADP+
malic
enzyme
NADPH
CO2
HCO3-
(Bicarbonate ion)
pepc
Pi
NADPH
NADP+
CCCCOO-
oxaloacetate
-OOCCCCOO-
malate
-OOCCCCOO-
malate
carbonic
anhydrase
malate
dehydrogenase
atm
CO2
The C4 and C3 reactions are spatially separated

C_4 Photosynthesis: A cycle requiring ATP and NADPH

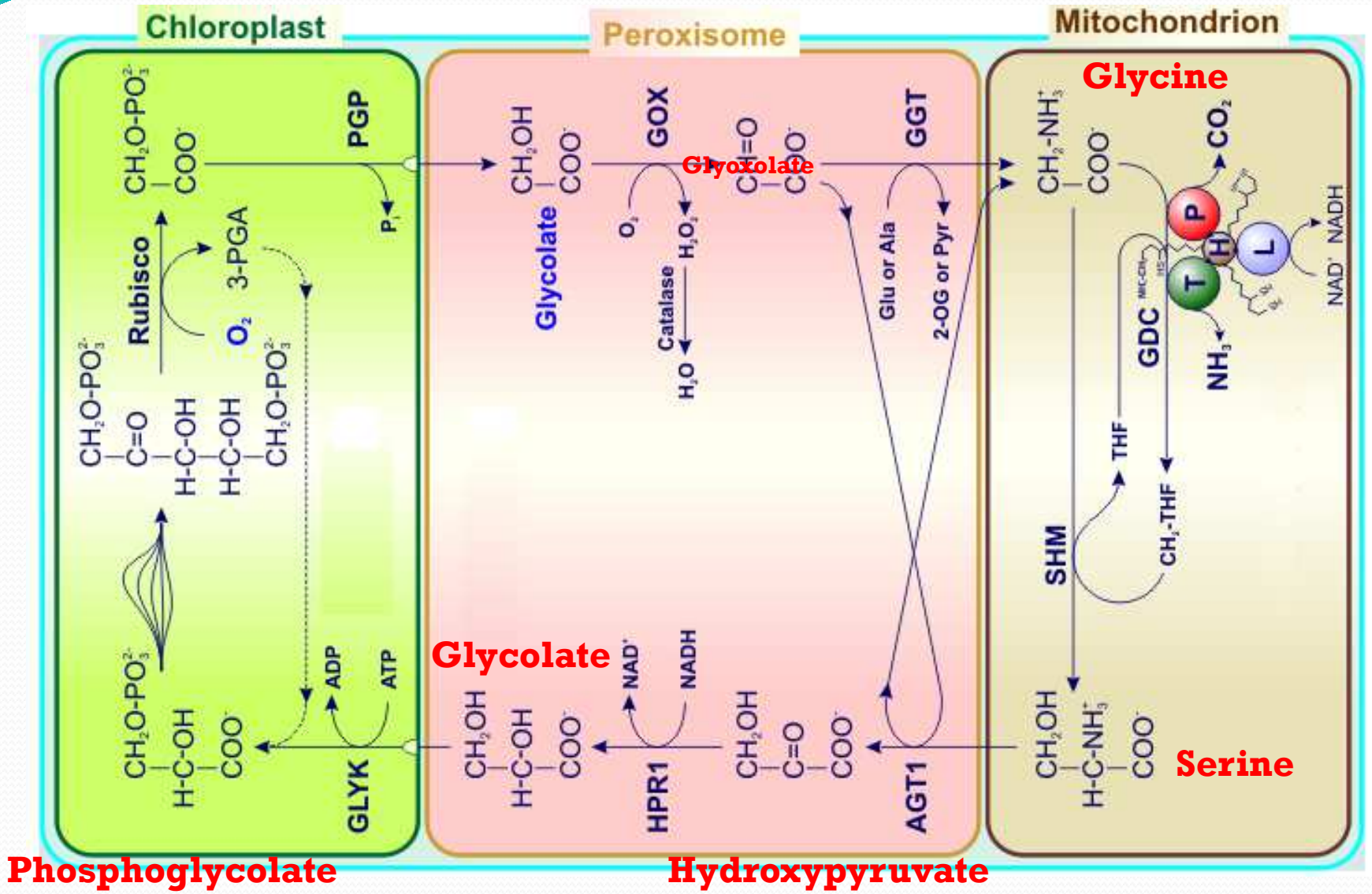


The C_4 and C_3 reactions are spatially separated

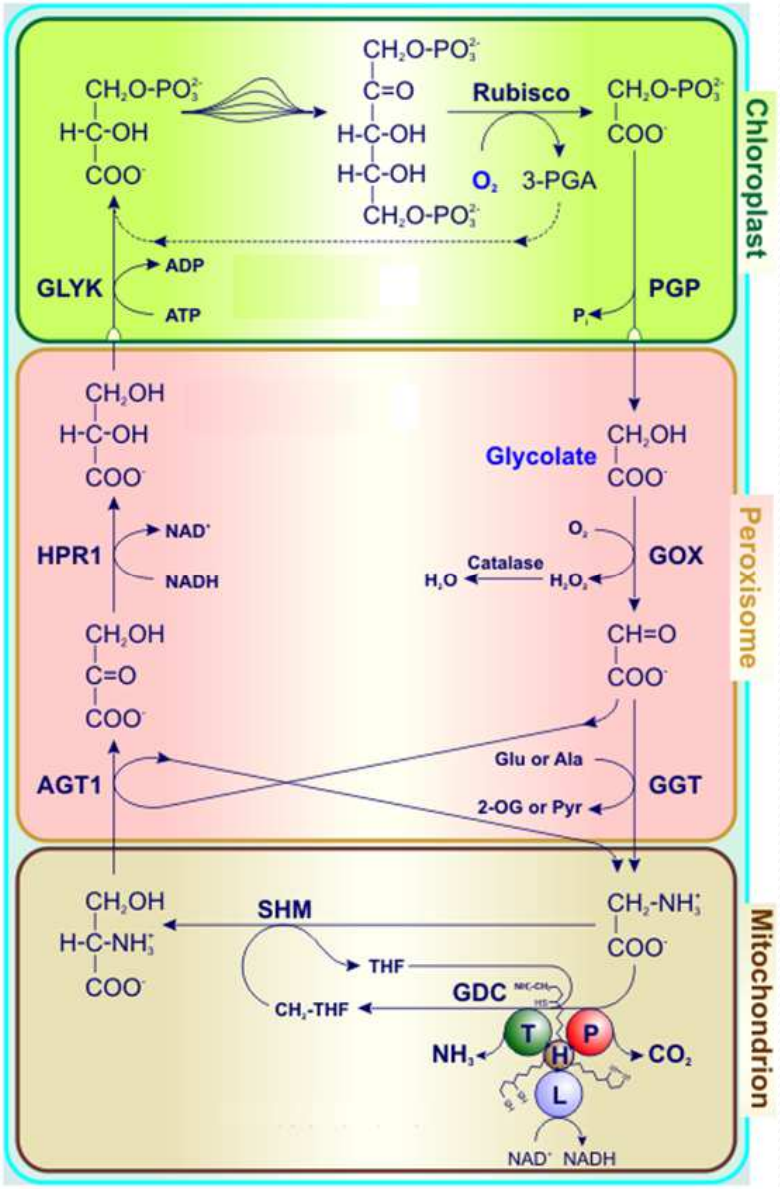
Photorespiration

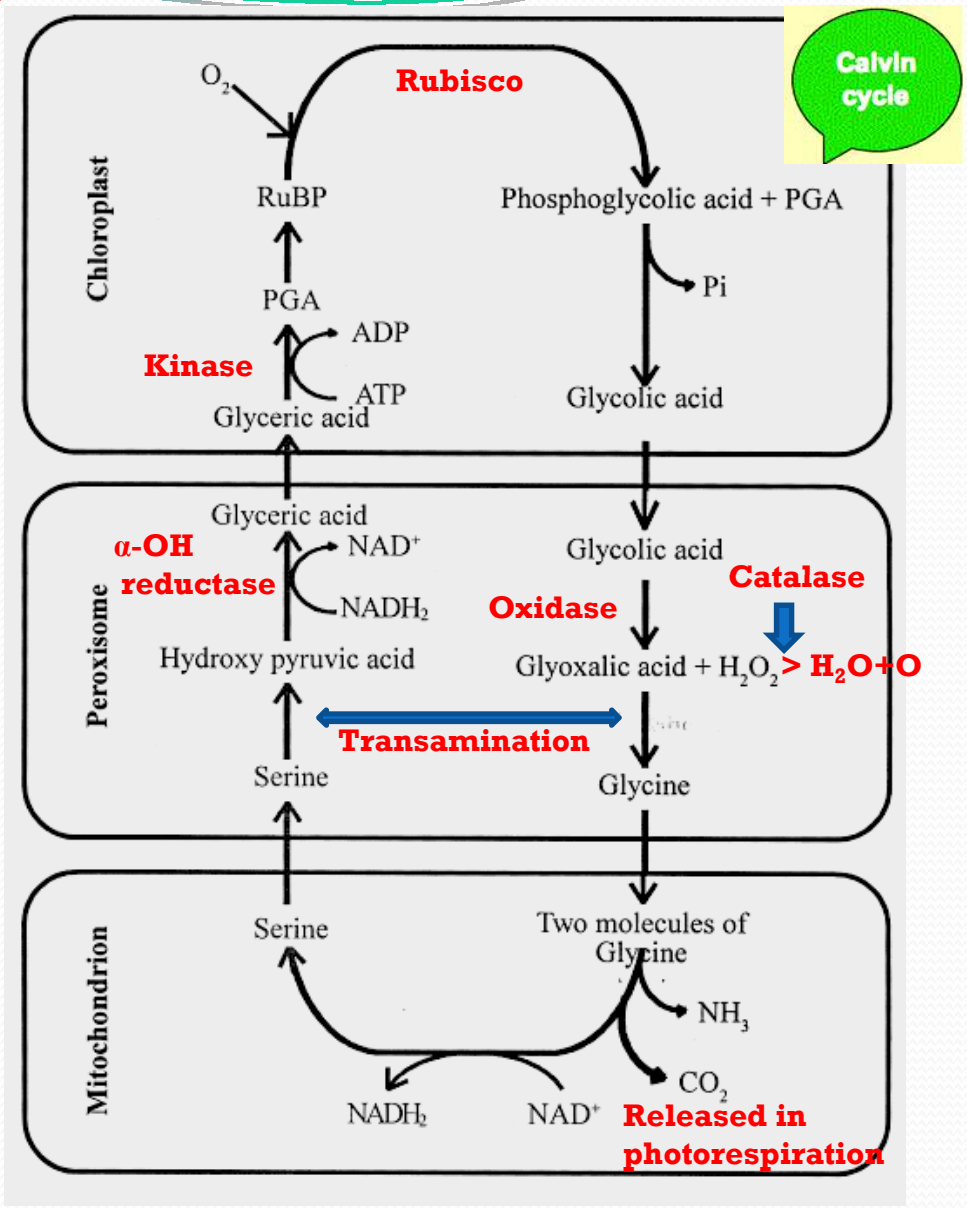
The process by which in the presence of light plant consumes oxygen and releases carbon dioxide (in stead of fixing (CO_2) during Photosynthesis, resulting in a decrease in Photosynthetic output.

Photorespiration Pathway



Photorespiration Pathway





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