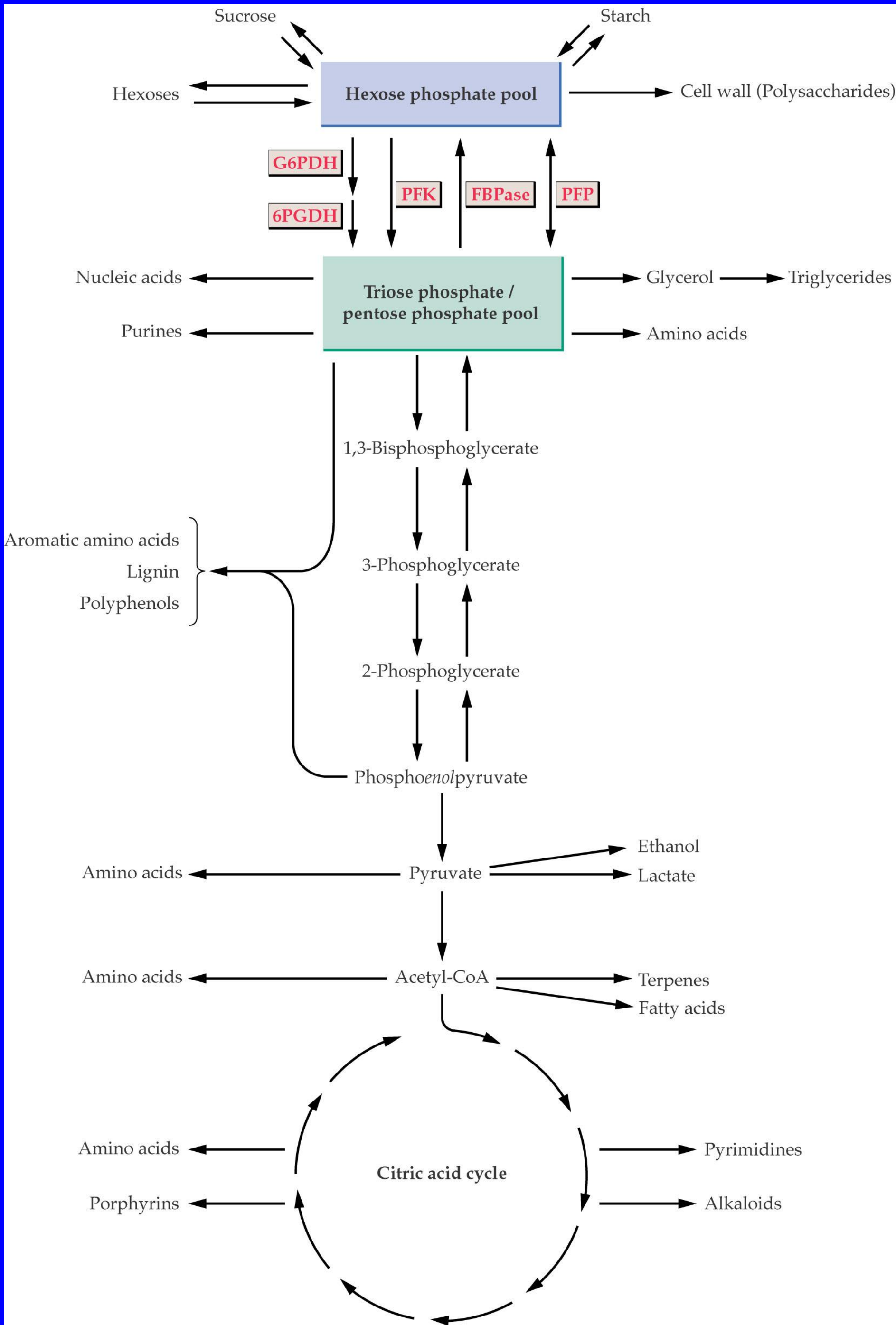
Chapter VII Photosynthesis - Photosynthetic Process

VII. Products of Photosynthesis

(I) Types of products

1. Mainly starch, also including glucose and fructose;
2. Protein, fat, organic acid and glycolic acid are also direct products of photosynthesis;
3. Phosphotriose is an important intermediate product of photosynthetic products.



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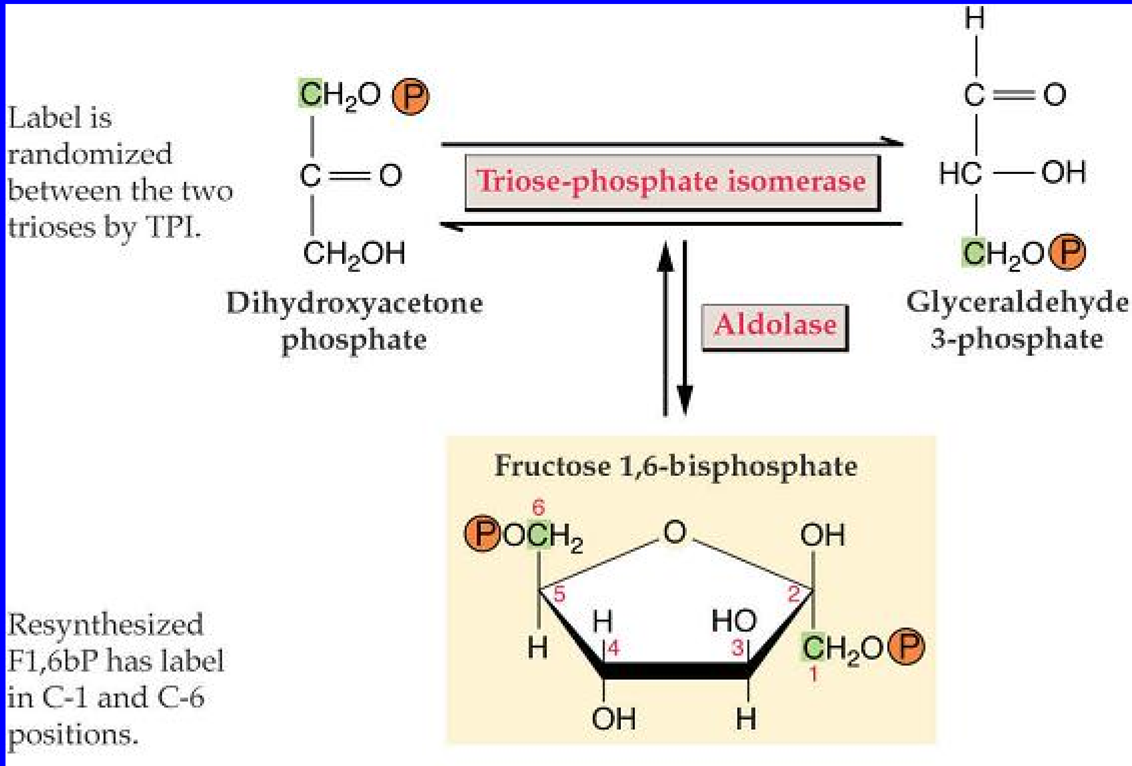
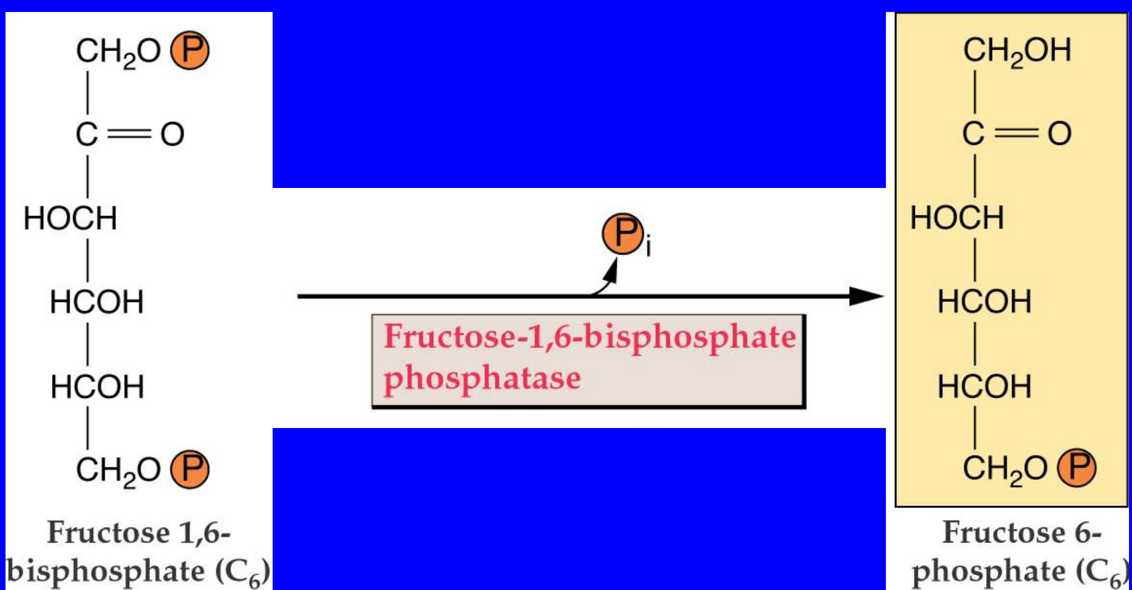
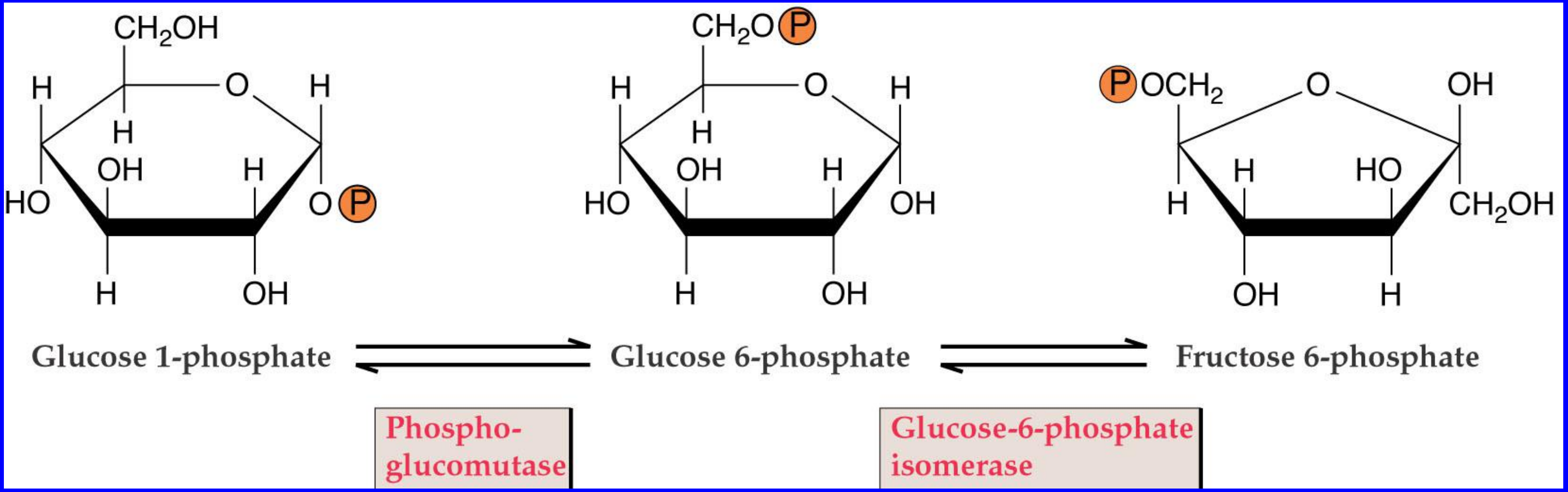
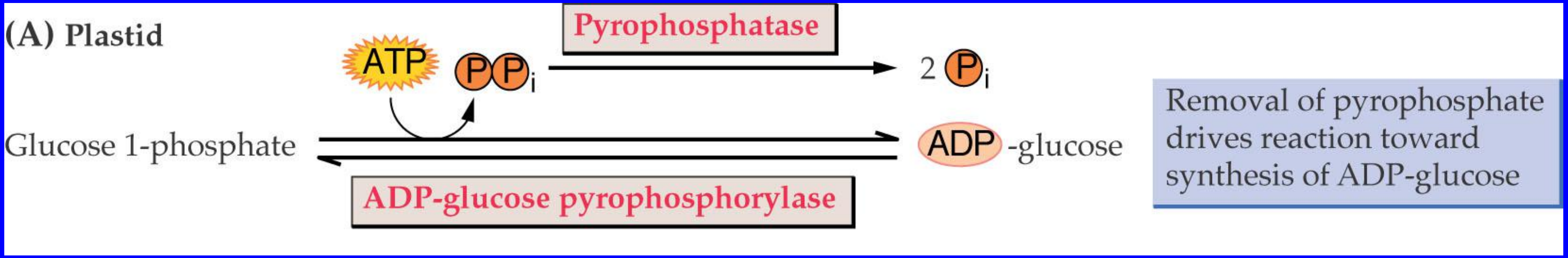


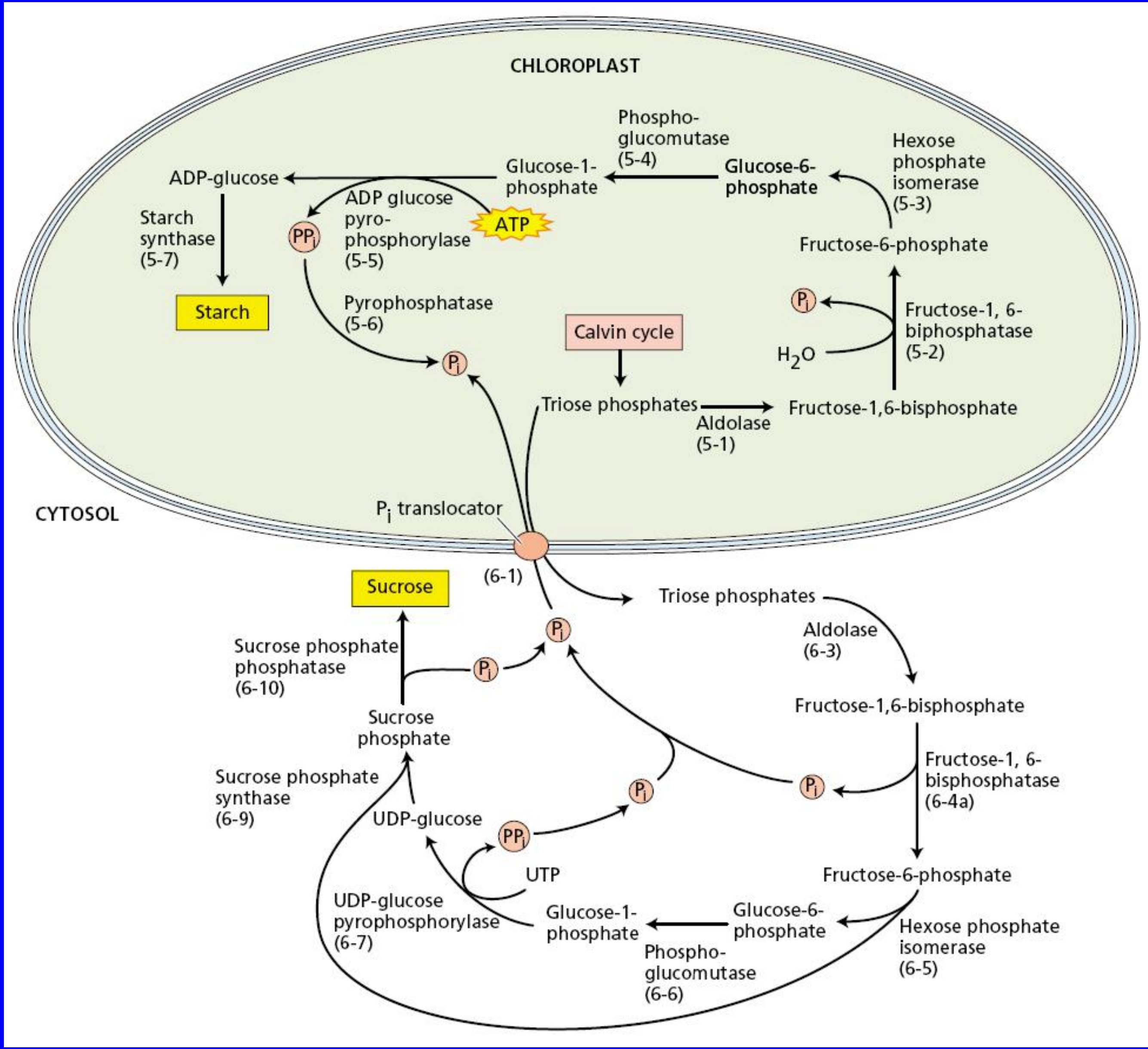


(II) Synthesis of starch in chloroplast

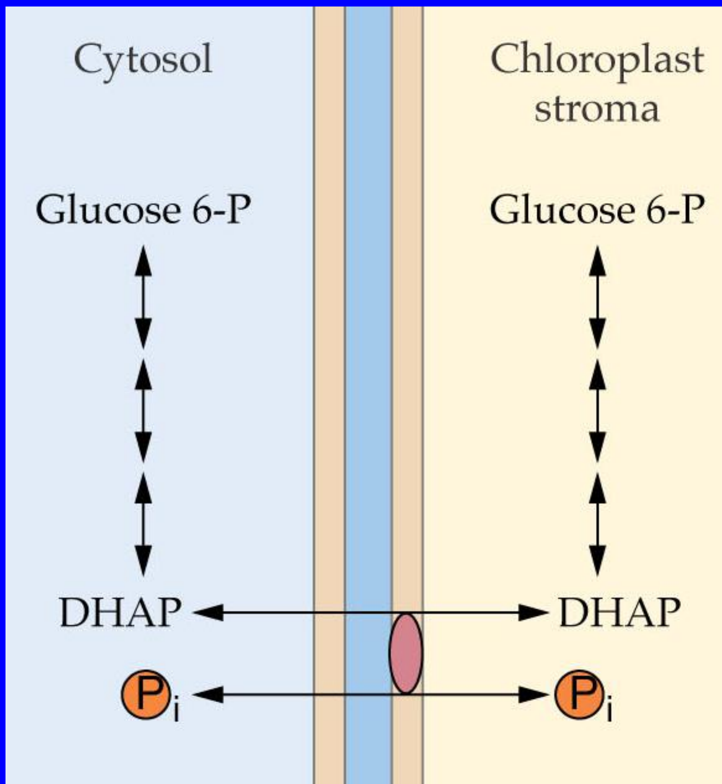

CH2OH
H
O
H
H
OH
H
HO
O P
H
OH
CH2O P
OH
P OCH2
CH2OH
HO
Glucose 1-phosphate
Glucose 6-phosphate
Fructose 6-phosphate
Phospho-
glucomutase
Glucose-6-phosphate
isomerase

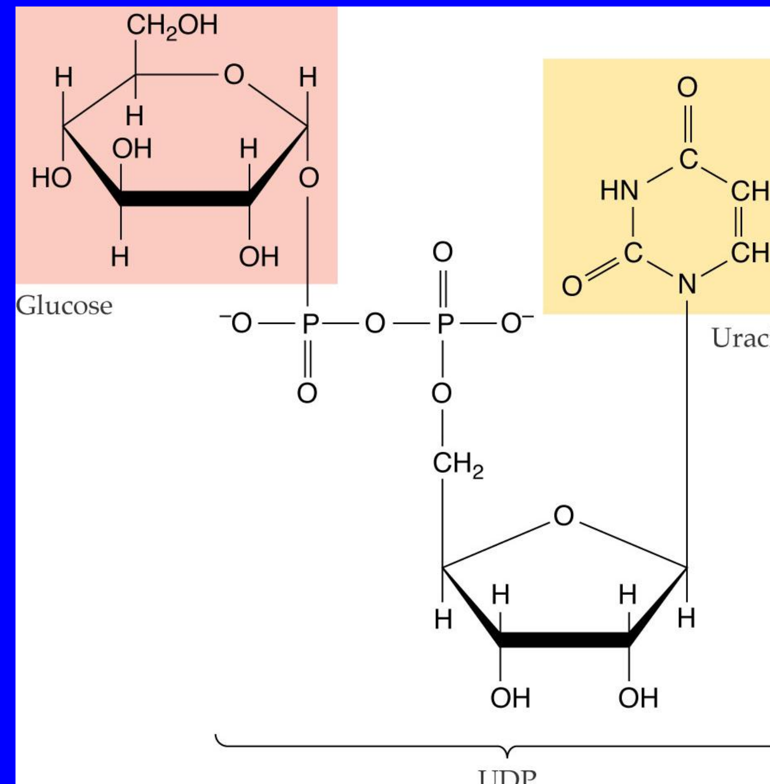

(A) Plastid
Pyrophosphatase
ATP
PPi
2 Pi
Glucose 1-phosphate
ADP -glucose
ADP-glucose pyrophosphorylase
Removal of pyrophosphate
drives reaction toward
synthesis of ADP-glucose

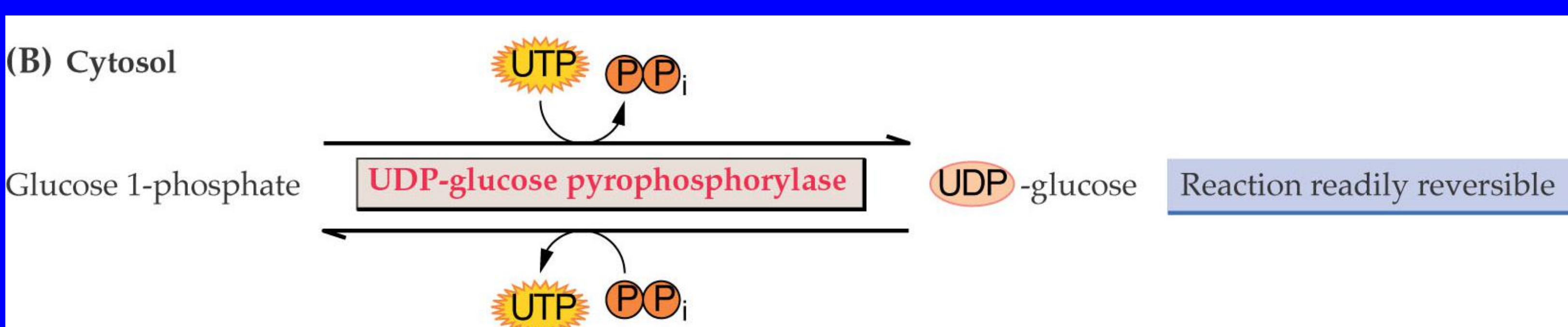
The syntheses of starch and sucrose are competing processes that occur in the chloroplast and the cytosol, respectively. When the cytosolic P_i concentration is high, chloroplast triose phosphate is exported to the cytosol via the P_i in exchange for P_i, and sucrose is synthesized. When the cytosolic P_i concentration is low, triose phosphate is retained within the chloroplast, and starch is synthesized.



(III) Synthesis of sucrose in cytosol







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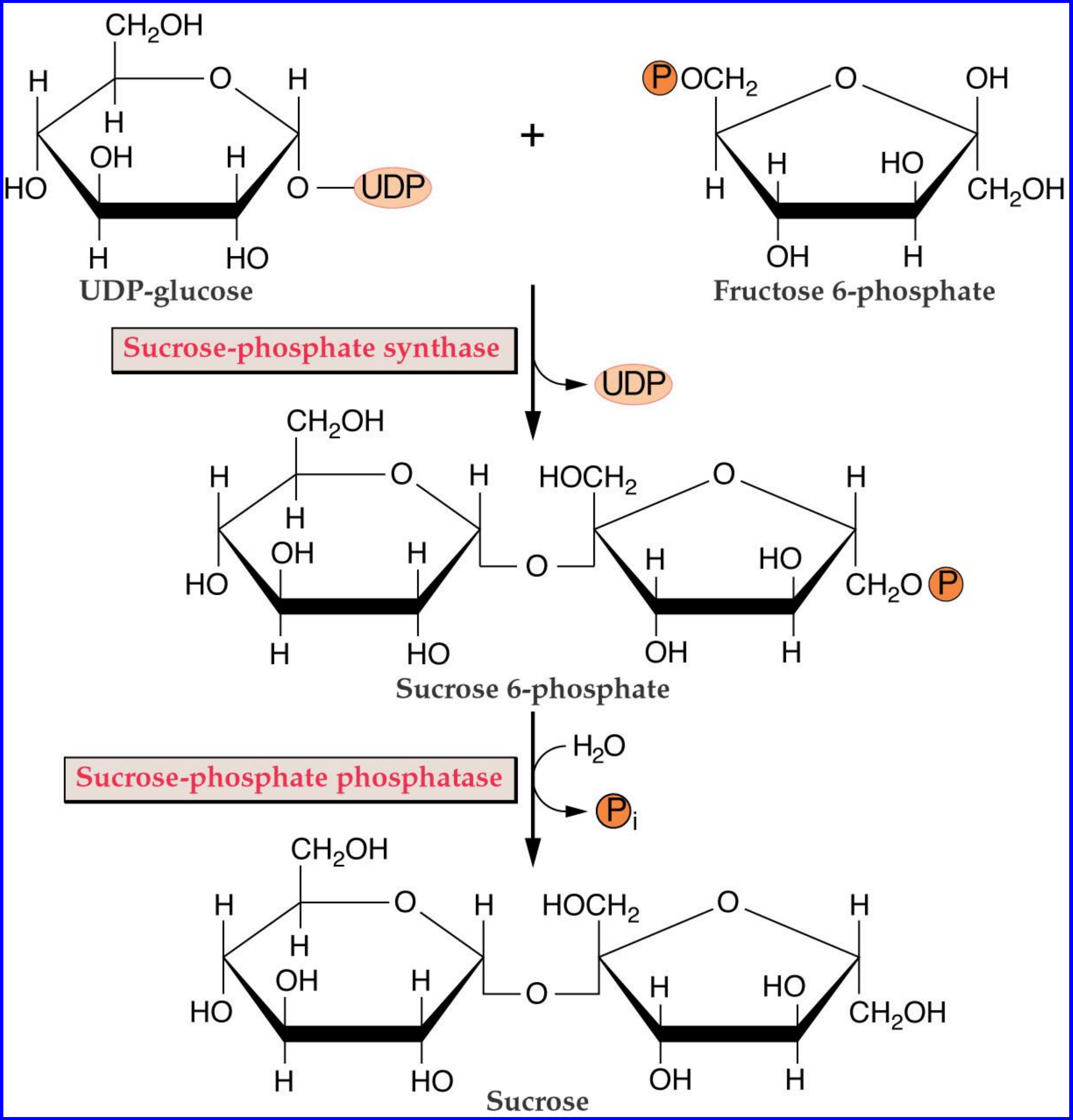
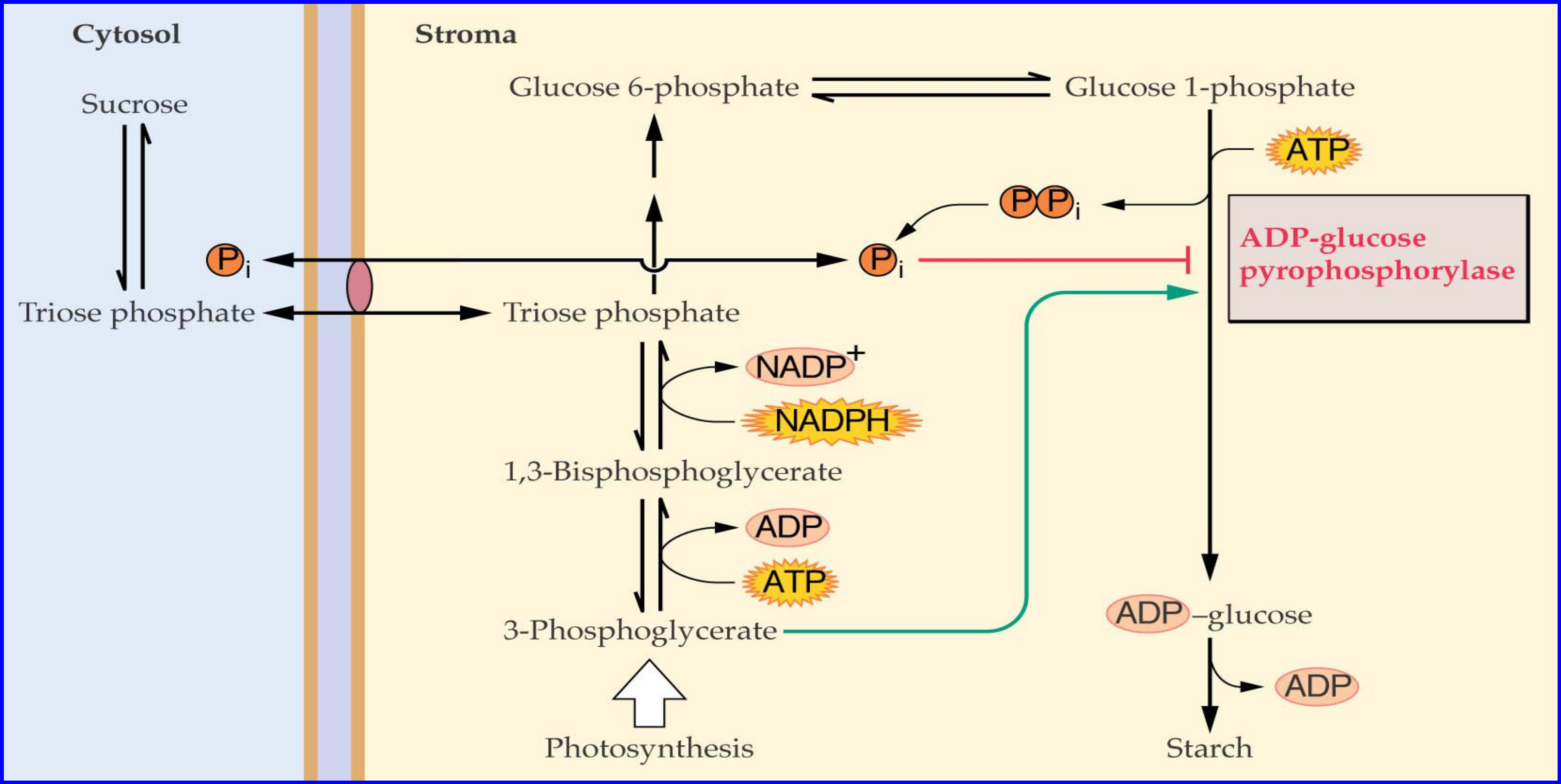


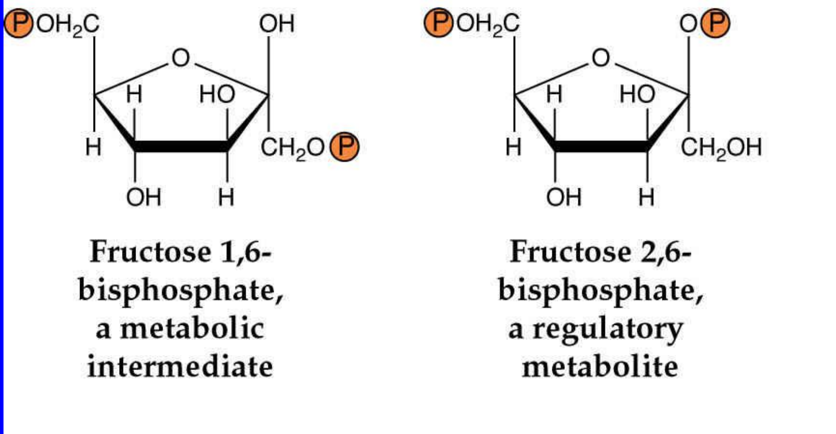
(IV) Regulation of starch and sucrose

- Low concentration of P_i in cytosol will restrict TP from being transported out from chloroplast and promote starch synthesis in chloroplast.
- ADPG pyrophosphorylase is activated by 3-phosphoglyceric acid and inhibited by Pi.
- F-2, 6-P_2 as analogues of intermediate products of metabolism participate in competitive inhibition to regulate starch synthesis.

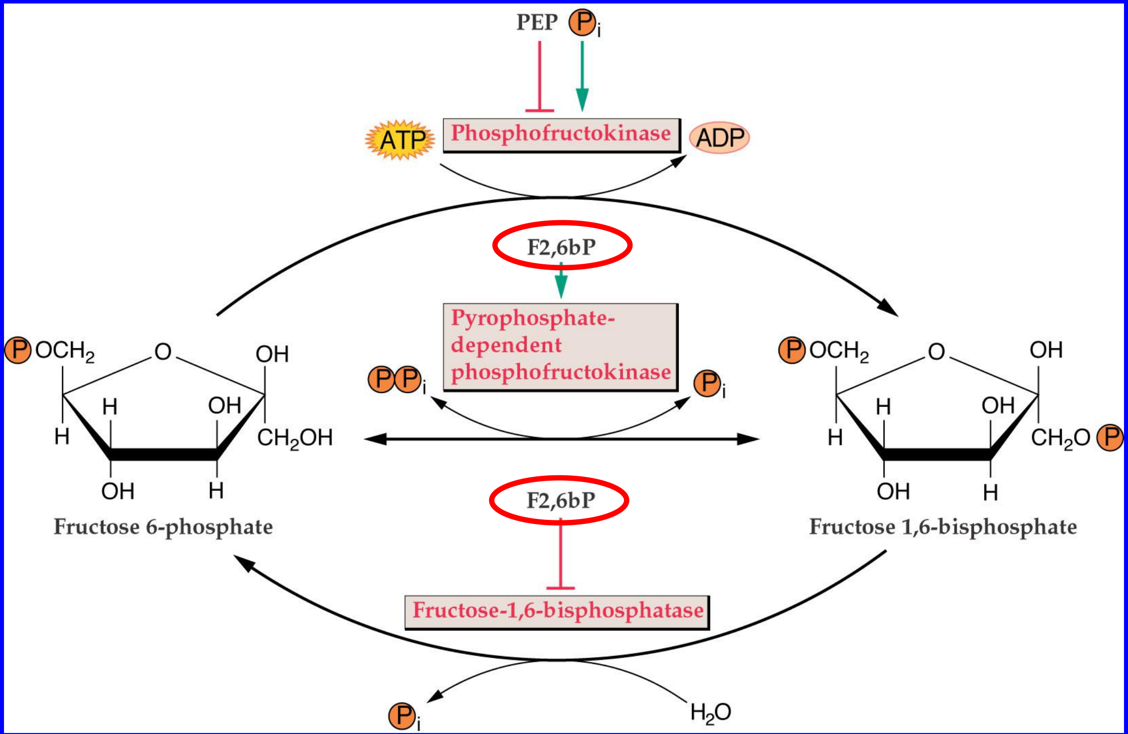


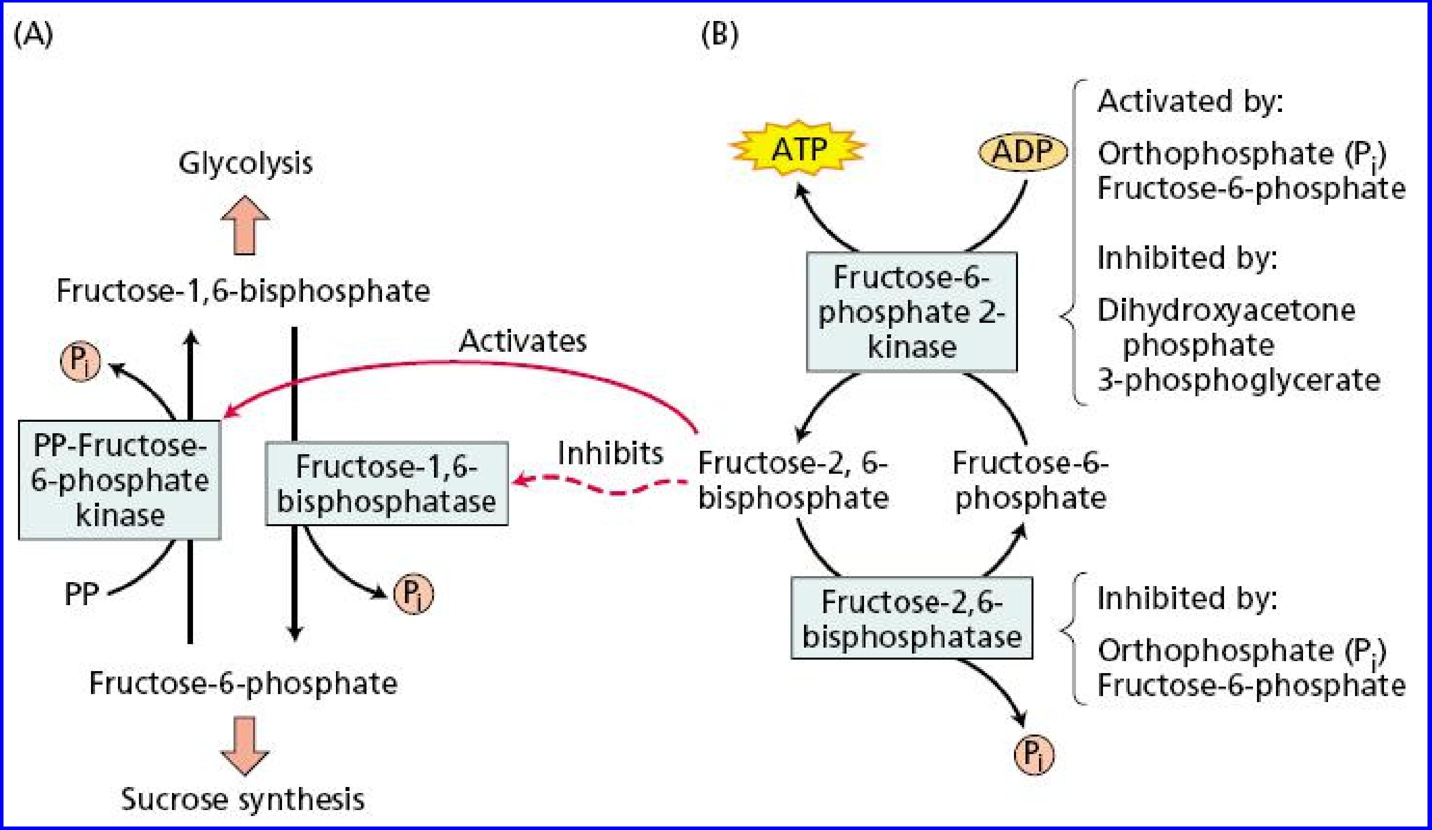
Regulation of starch synthesis in chloroplasts. When 3-phosphoglycerate is abundant, starch synthesis is activated. Inorganic phosphate, an indicator of the status of the triose phosphate pool, inhibits starch synthesis.

Structure of F-1, 6-P_2 and F-2, 6-P_2.



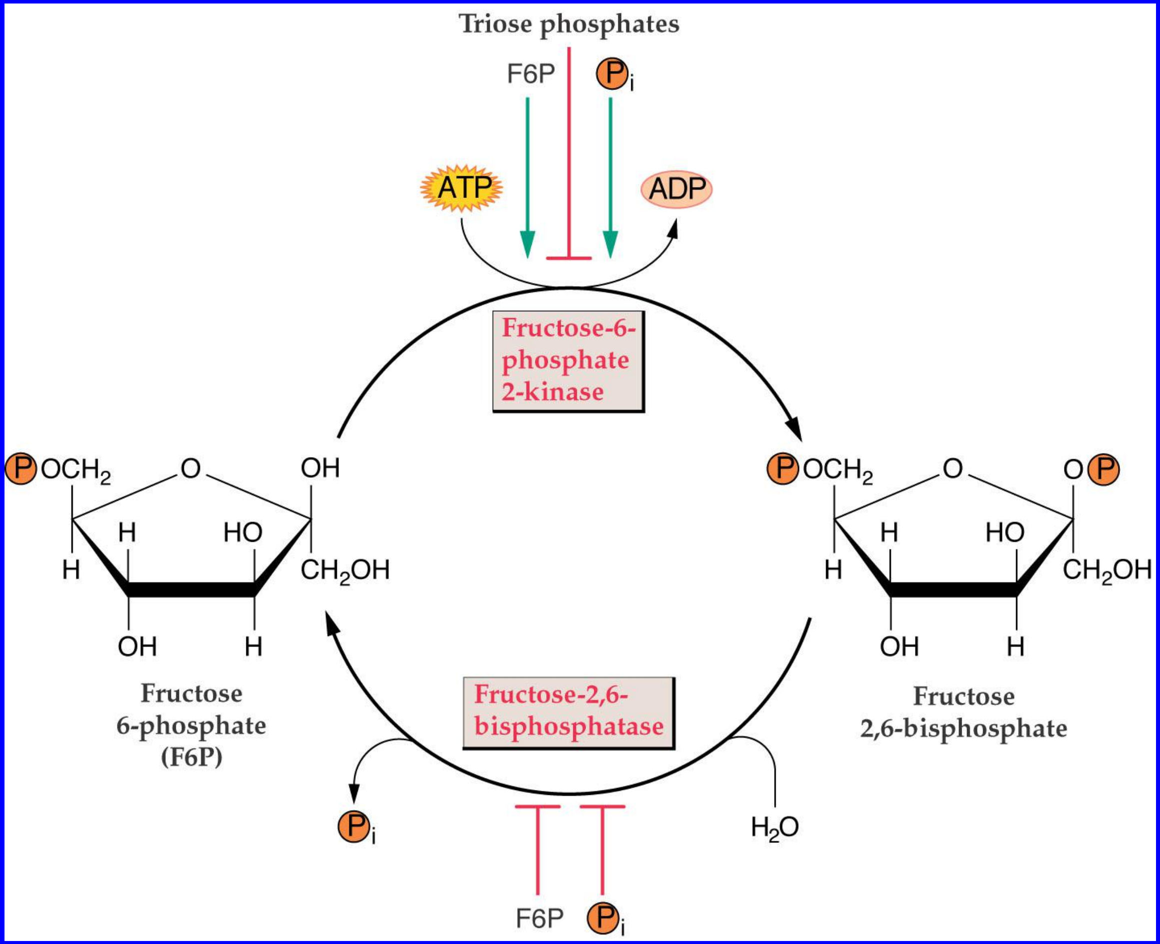
Interconversion in the cytosol of F-6-P and F-1, 6-P_2 by ATP-dependent PFK, PP_i-dependent PFK, and F-1, 6-bisphosphatase.





Regulation of the cytosolic interconversion of fructose-6-phosphate and fructose-1, 6-bisphosphate. (A) The key metabolites in the allocation between glycolysis and sucrose synthesis. The regulatory metabolite fructose 2, 6-bisphosphate regulates the interconversion by inhibiting the phosphatase and activating the kinase, as shown. (B) The synthesis of fructose-2, 6-bisphosphate itself is under strict regulation by the activators and inhibitors shown in the figure.

Formation and degradation of F-2, 6-P_2 by F-6-P 2-kinase and F-2, 6-bisphosphatase. Regulation by P_i, TP, and F-6-P is indicated.



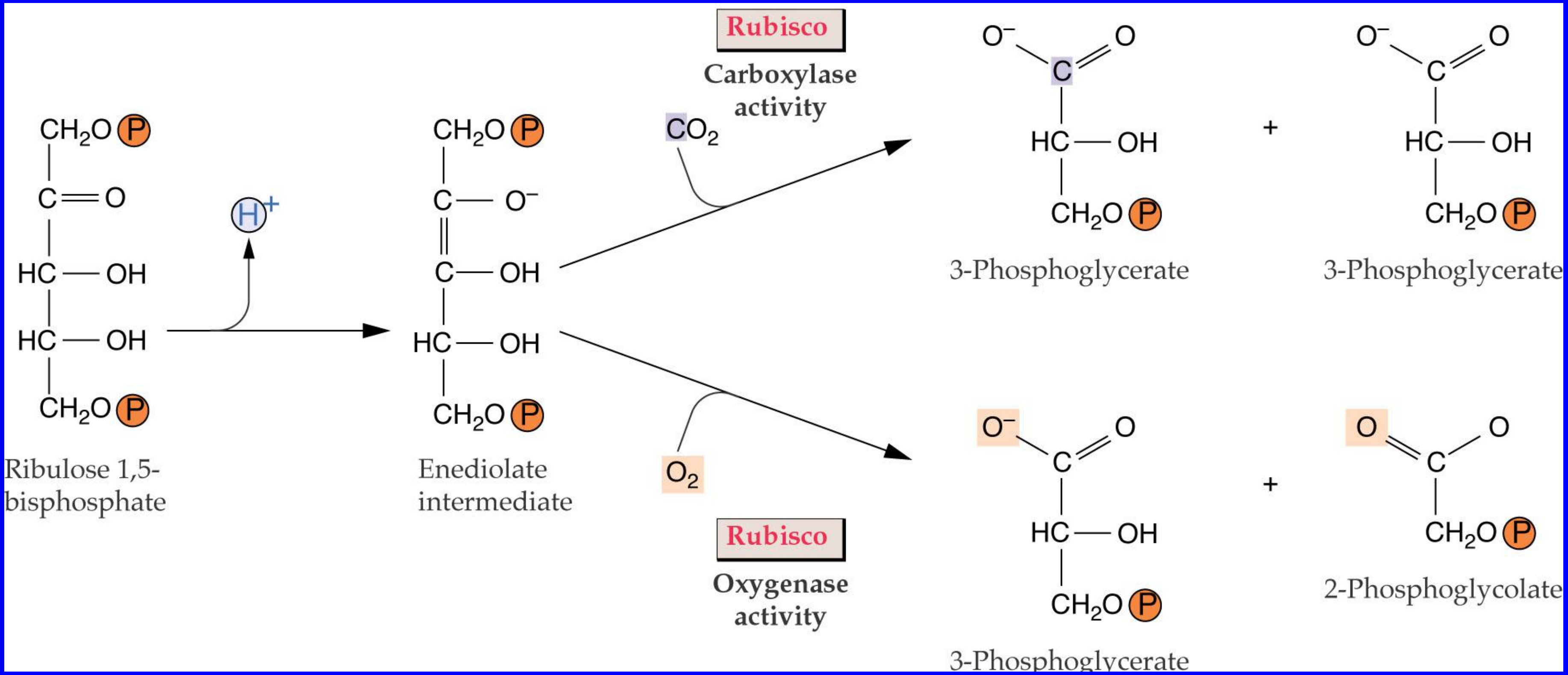
I. Pathways of Photorespiration

(I) Definition

A process of absorbing O_2 and giving out CO_2 as the green cells of plants rely on illumination

(II) Biochemistry of photorespiration

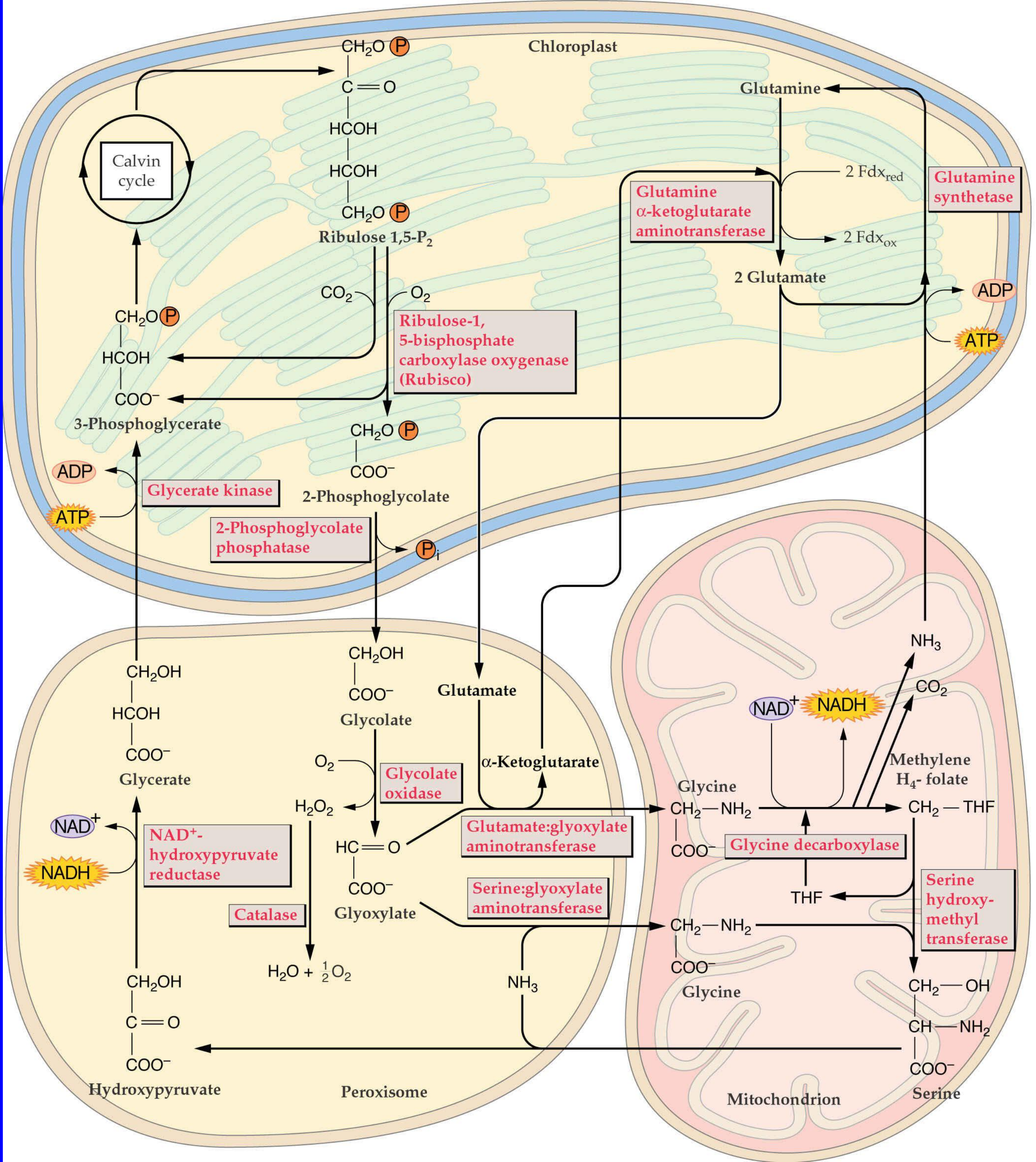
1. Process



Rubisco catalyzes two types of reactions, carboxylation and oxygenation.

Chapter VII Photosynthesis -Photorespiration

Reactions of the oxidative photosynthetic carbon (C_2) pathway.



2. Regulation

① O_2 inhibits photosynthesis and CO_2 inhibits photorespiration;

② Photorespiration is enhanced with the increase of light intensity, temperature and pH.

II. Physiological Effect of Photorespiration

1. In the period of drought and high radiation, stomata are closed to avoid photoinhibition:

Photorespiration→CO_2↑→consume excessive energy→protect photosynthetic organ →avoid photoinhibition

2. Avoid excessive loss of CO_2:

Under aerobic condition, 75% of carbon may be recovered through photorespiration to avoid excessive loss.

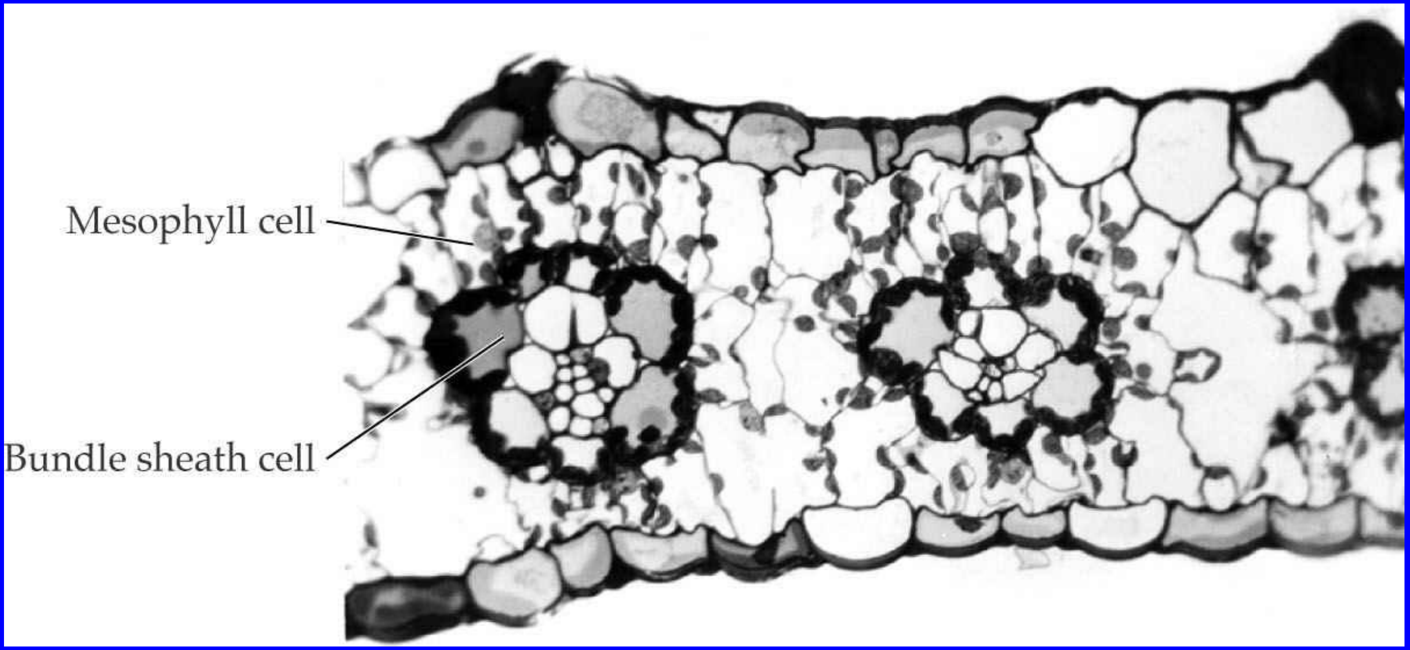
III. Photosynthetic Characteristics of C_3 plants and C_4 plants

C_4 plants have stronger photosynthetic effect than C_3 plants do.

(I) Blade structure

1. C_4 plants

Micrograph showing Kranz anatomy in maize, a C_4 plant.



Electron micrograph comparing the chloroplasts of a bundle sheath cell (bottom) and a mesophyll cell (top) in a C_4 plant (sorghum).

① The parenchyma cells of vascular bundle sheaths of leaf veins are larger, contain larger chloroplast and don’t have granum and granum mal-development;

② A layer of mesophyll cells arranged in a ring shape or roughly in a ring shape are tightly connected outside the sheath, forming a “garland shape”. There is a large amount of chloroplast in a small size. There are grana;

③ There is a large amount of piasmodesma between parenchyma cells of sheaths and adjacent mesophyll cells;

④ Starch is formed only inside parenchyma cells of sheaths.

2. C_3 plants

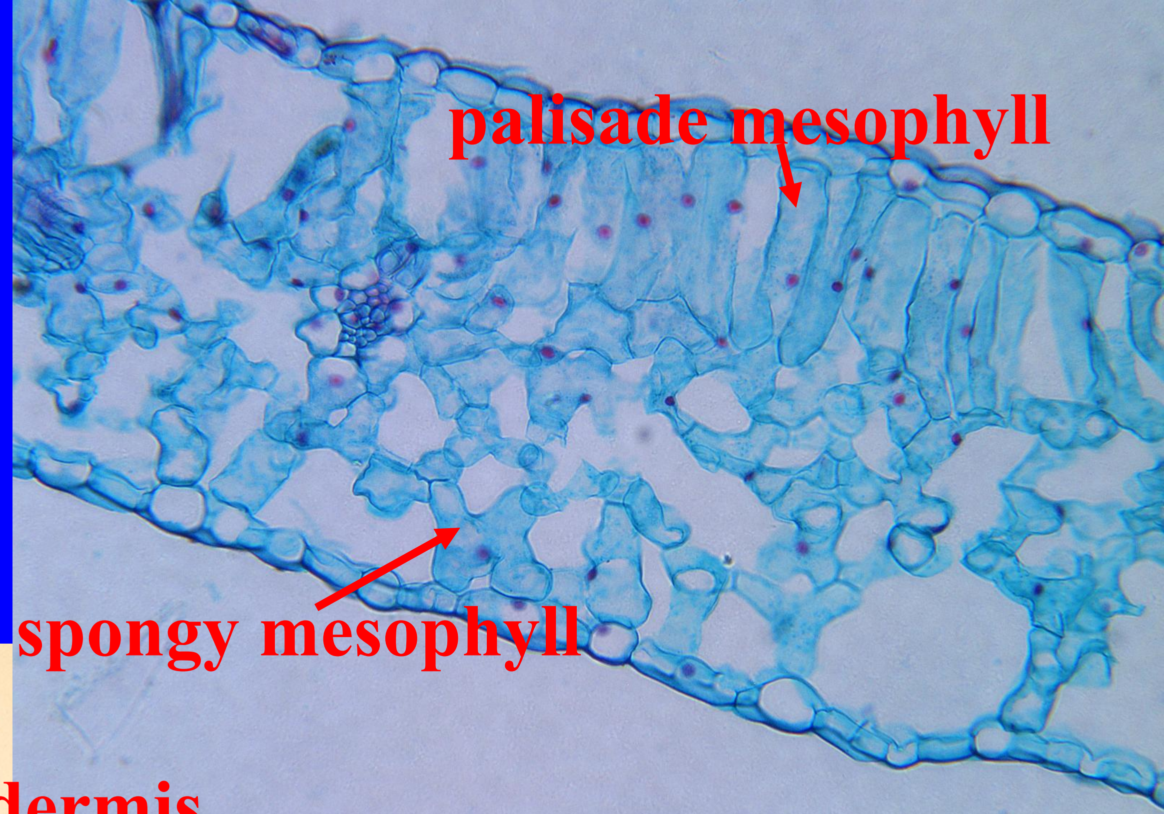
① The parenchyma cells of sheaths are small and don’t contain or contain a little amount of chloroplast;

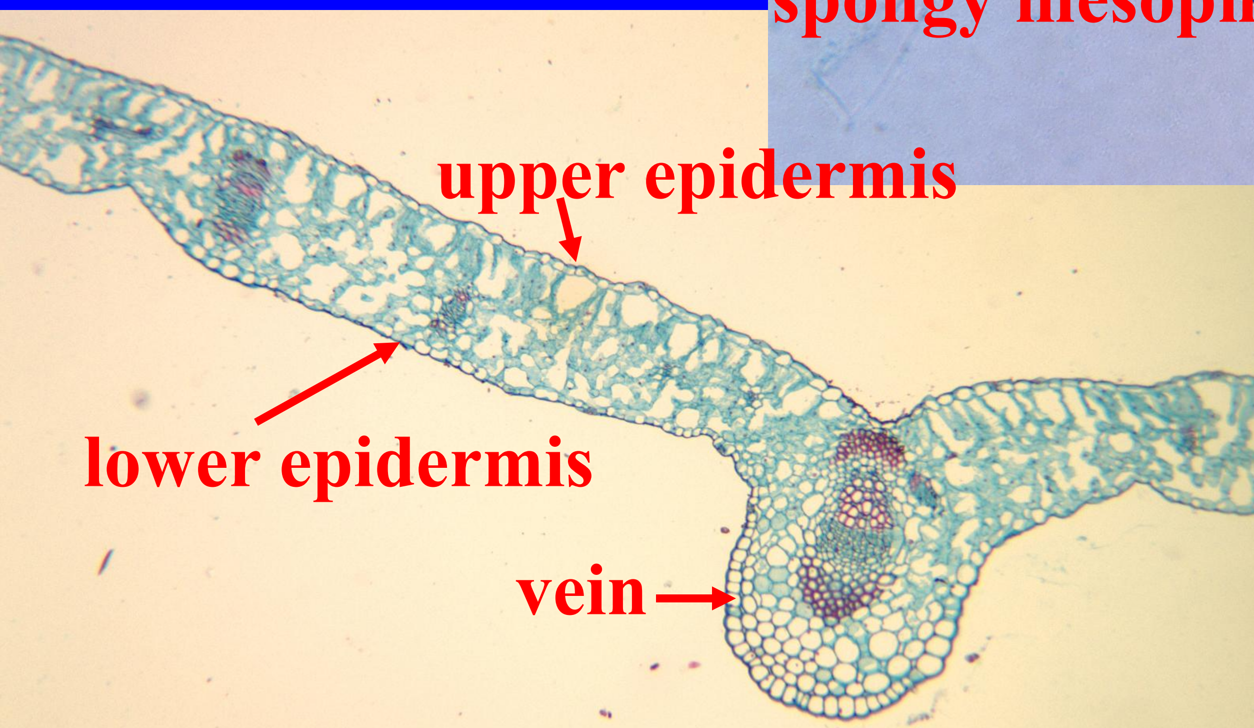
② No “garland shaped” structure;

③ The mesophyll cells around a sheath are loosely arranged;

④ Starch is accumulated in mesophyll cells.

Chapter VII Photosynthesis - Photorespiration





This micrograph especially shows the palisade and spongy mesophyll cells.

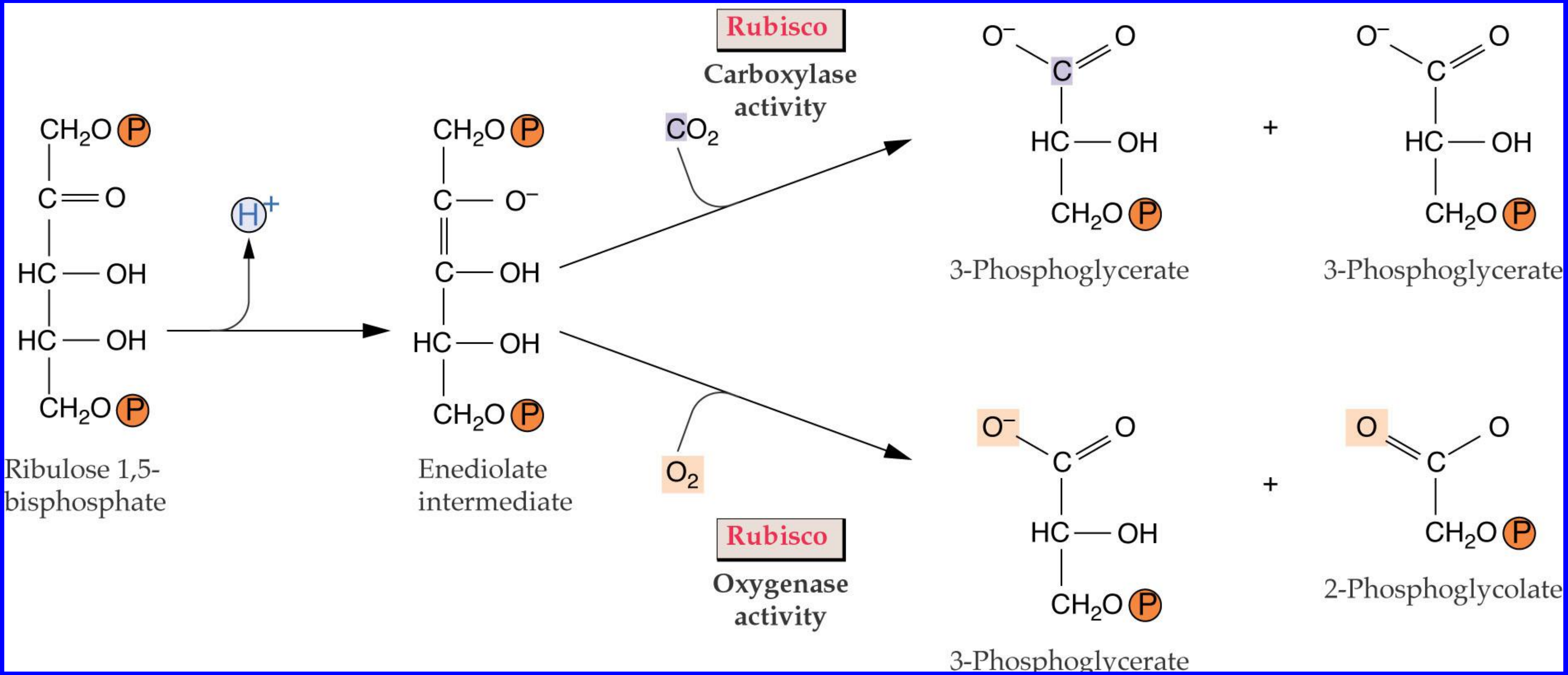
(II) Photosynthetic characteristics

① The Km value of PEP carboxylase to CO_2 is 7 μmol, the affinity is large and the CO_2 compensation point of C_4 plants is low;

② The Km value of RuBP carboxylase to CO_2 is 450 μmol, the affinity is small and the CO_2 compensation point of C_3 plants is high;

③ PEP carboxylase of C_4 plants plays a role of "CO_2 pump", increases the ratio of CO_2/O_2 inside parenchyma cells of sheaths, makes RuBP carboxylase take carboxylation reaction and reduces photorespiration;

④ The photorespiration enzyme system of C_4 plants is mainly concentrated inside parenchyma cells of sheaths. Mesophyll cells contain PEP carboxylase with very strong affinity to CO_2 and the CO_2 given out during respiration can be easily reutilized.



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