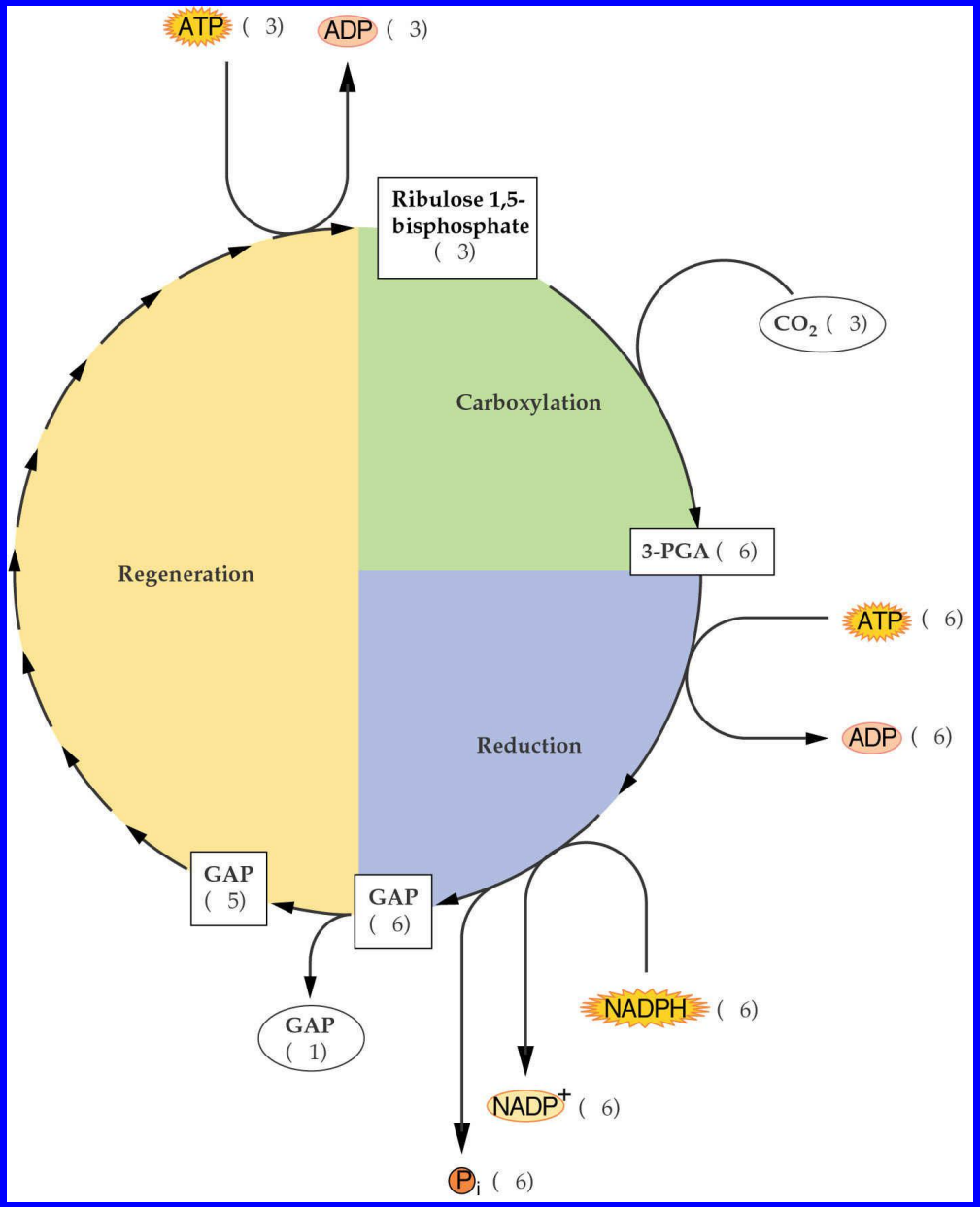
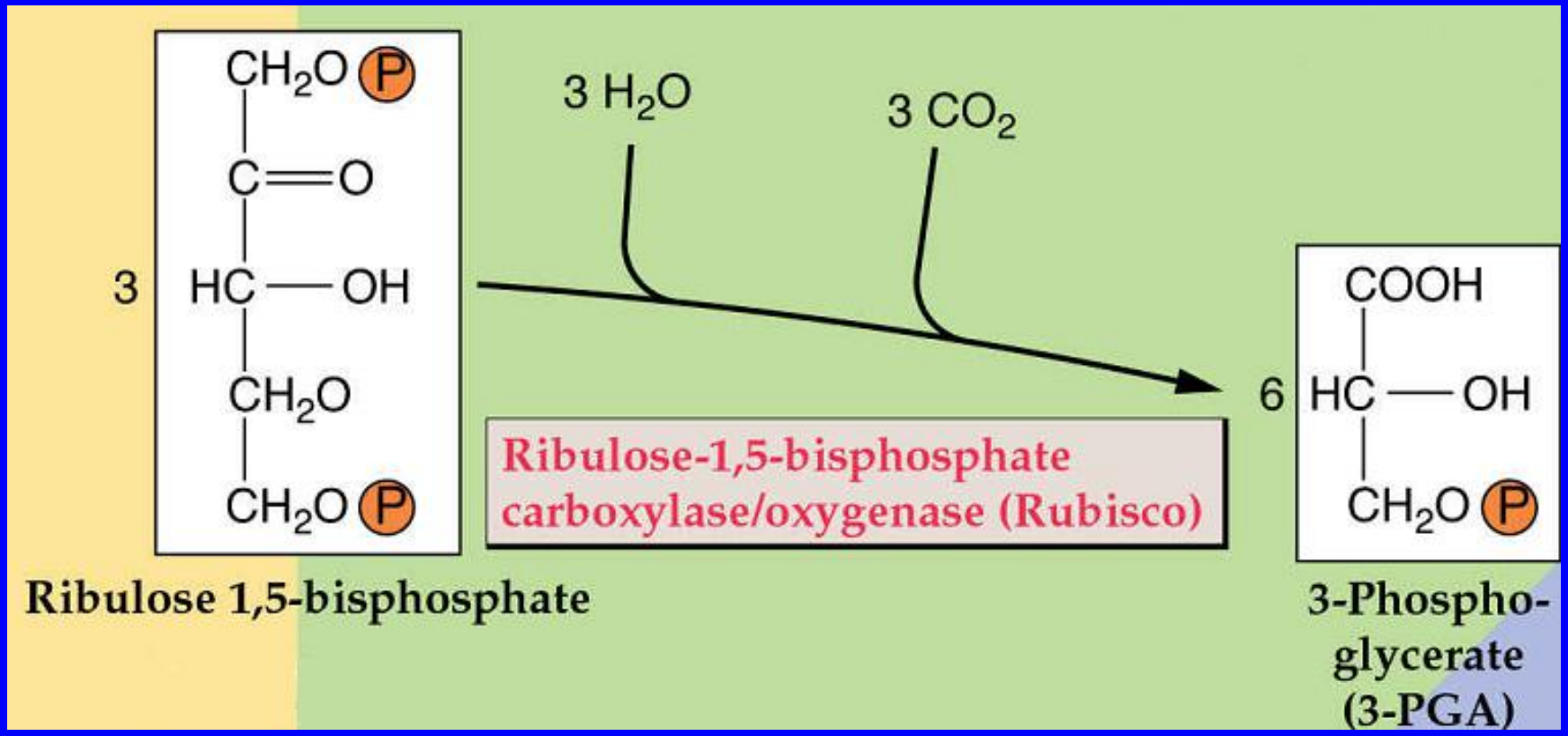
VI. Carbon Assimilation

Refer to a process in which chemical energy active in NADPH and ATP is converted into stable chemical energy stored in sugars. It is conducted in the stroma of chloroplast.

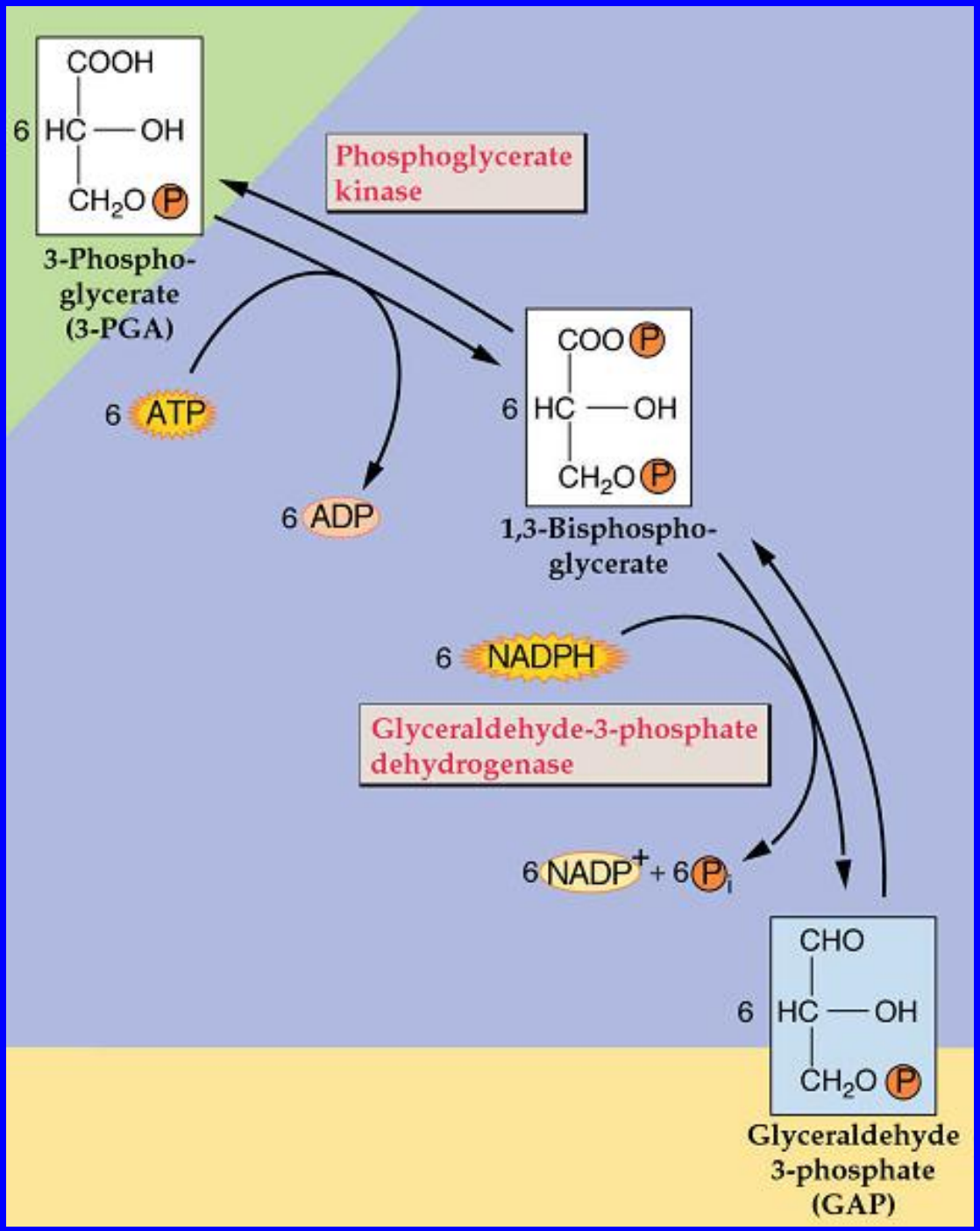
(I) Calvin cycle (C_3 pathway)



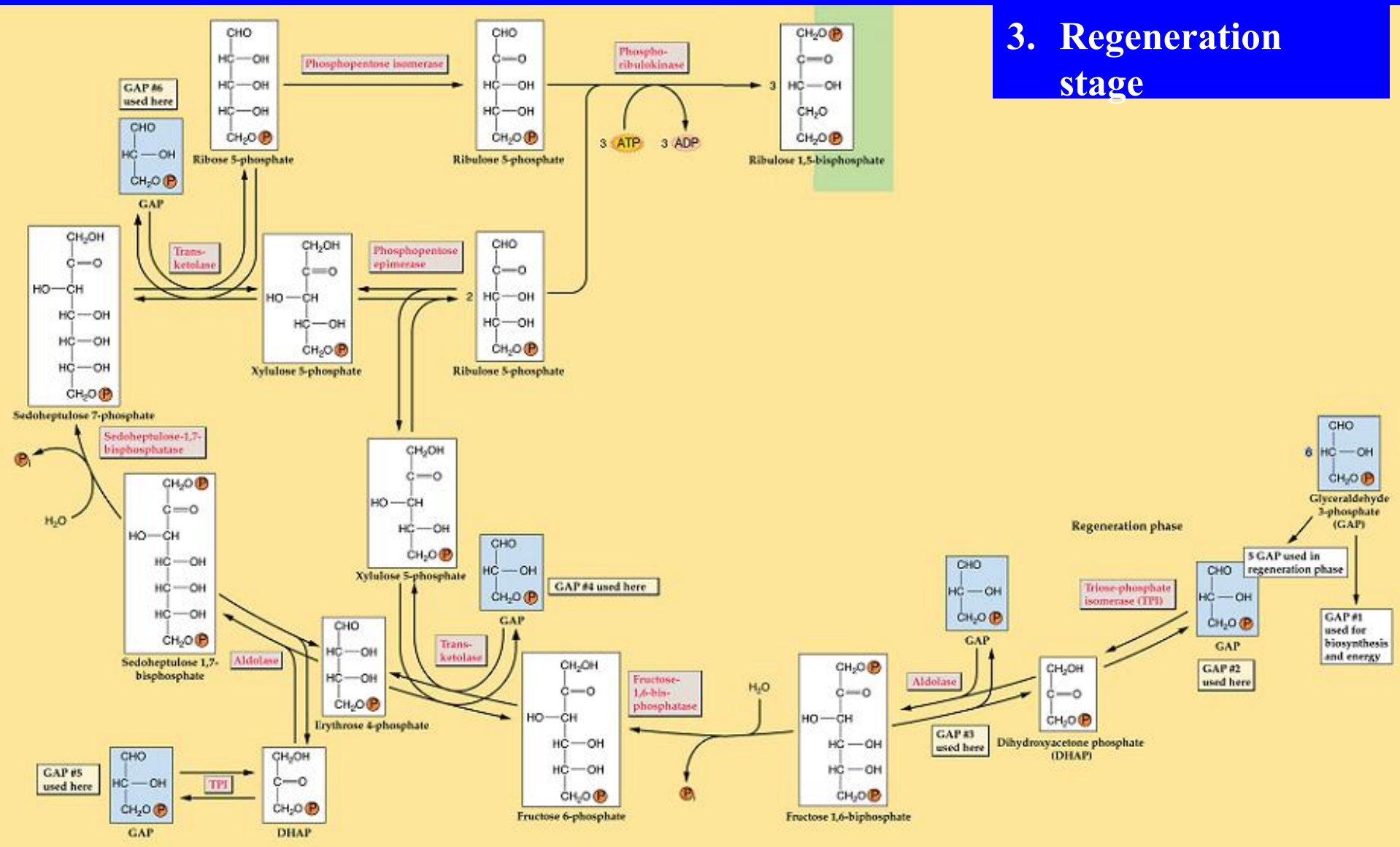
1. Carboxylation stage



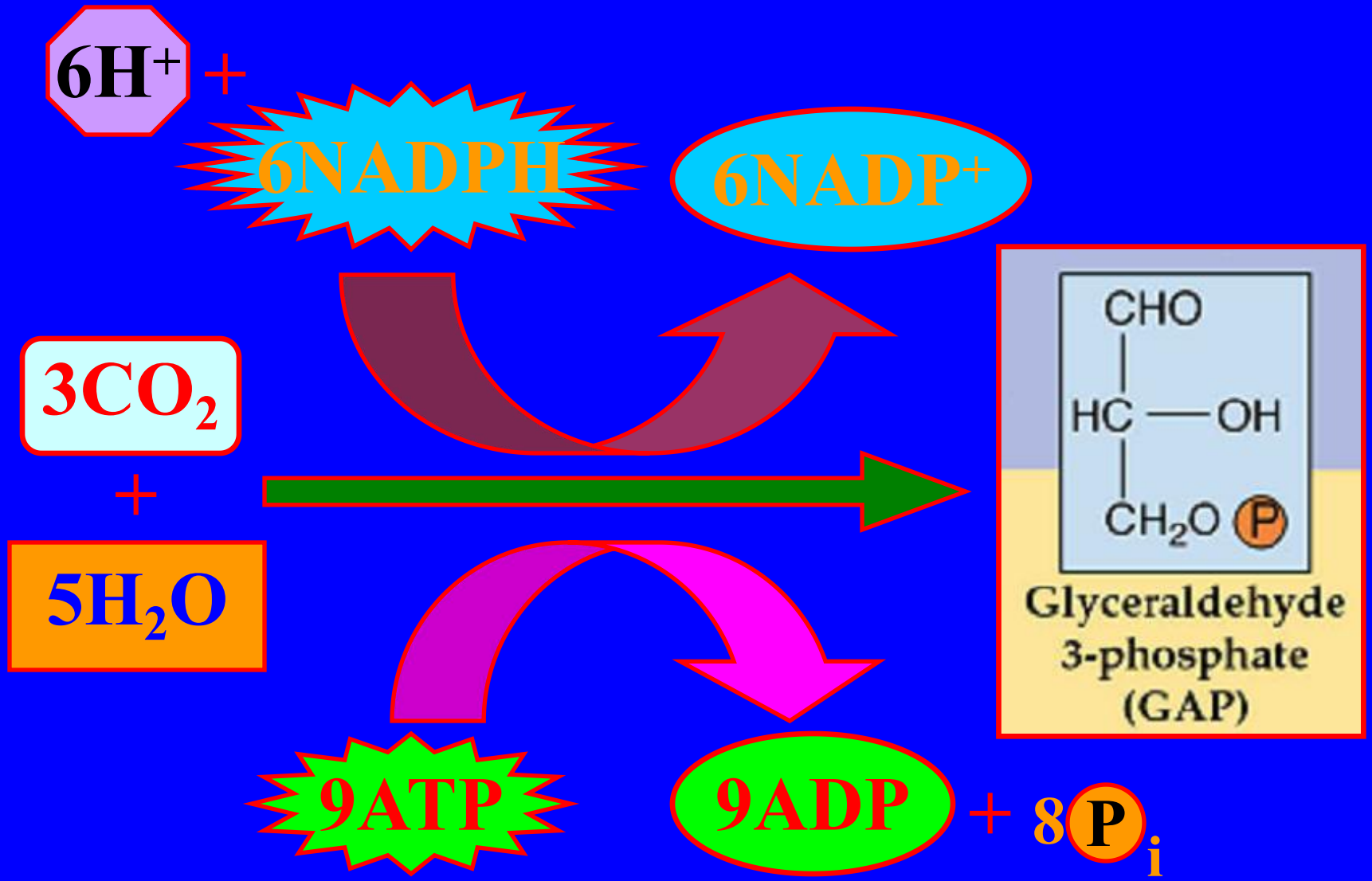
2. Reduction stage



3. Regeneration stage



4. Overall reaction:



5. Regulation of Cavin cycle

(1) Autocatalysis: Intermediate products are necessary for maintenance of the cycle

(2) Regulation of light:

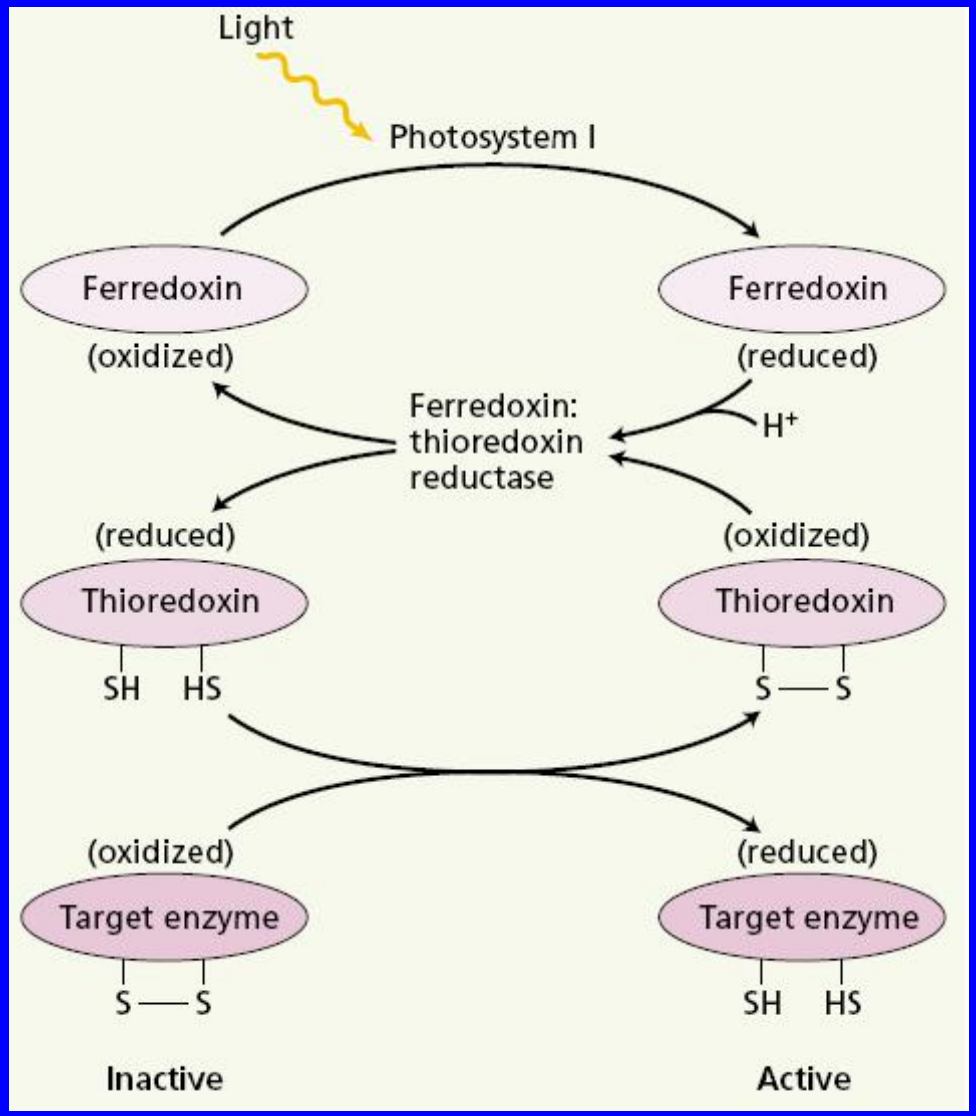
A. Ion migration: Indirectly influence the activity of some enzymes for dark reaction

Light $\rightarrow H^+$ enters the thylakoid cavity $\rightarrow Mg^{2+}$ leaves the cavity $\rightarrow (pH+[Mg^{2+}])_{stroma}\uparrow \rightarrow$ activity of every enzyme $\uparrow$

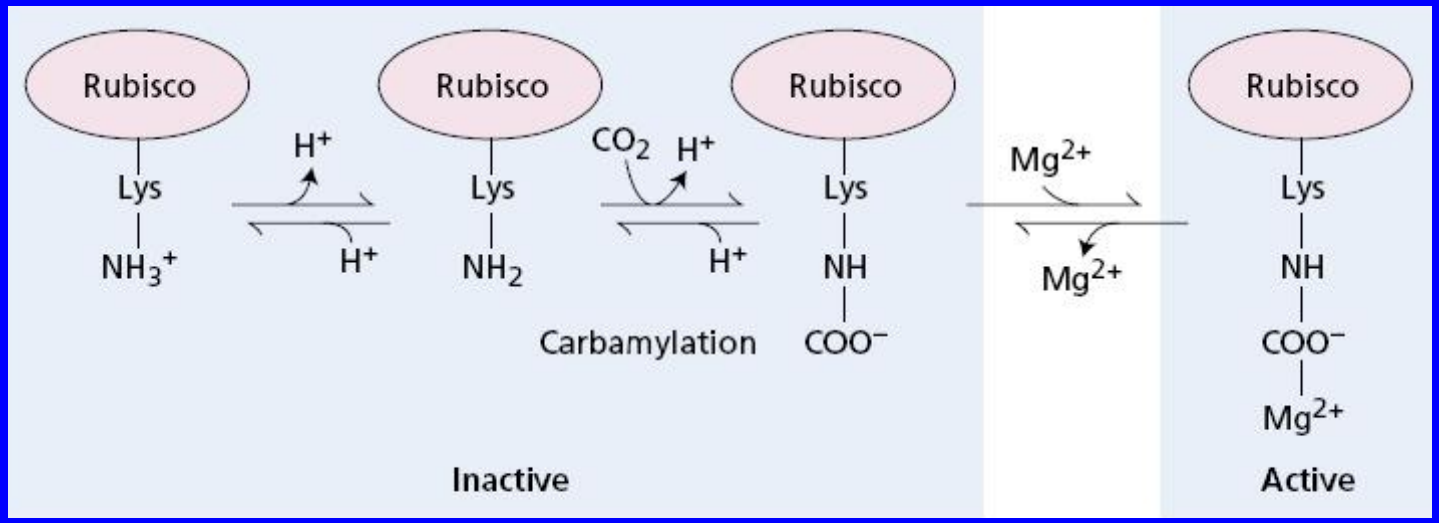
B. Through ferredoxin – thioredoxin system:

In the dark, the residue of Fdx-Tdx is in form of -S-S- and enzymes are not activated or are sub-activated; under light, it is in form of –SH, and enzymes are activated.

The ferredoxin-thioredoxin system reduces specific enzymes (e. g. glyceraldehyde-3-phosphate dehydrogenase, fructose-1, 6-bis-phosphatase) in the light.



C. Light enhances Rubisco activity:



Sugar phosphate is bound with Rubisco and stops carbamoylation, so Rubisco loses activity. Rubisco activating enzyme can relieve restrained sugar phosphate and activate Rubisco.

Carboxyarabinitol -1-phosphate also inhibits Rubisco: At night, Rubisco is bound with this inhibitor and loses activity; next morning, when light is enhanced, Rubisco activating enzyme can remove the inhibitor, and Rubisco will resume activity.

(3) Transport of photosynthetic products :

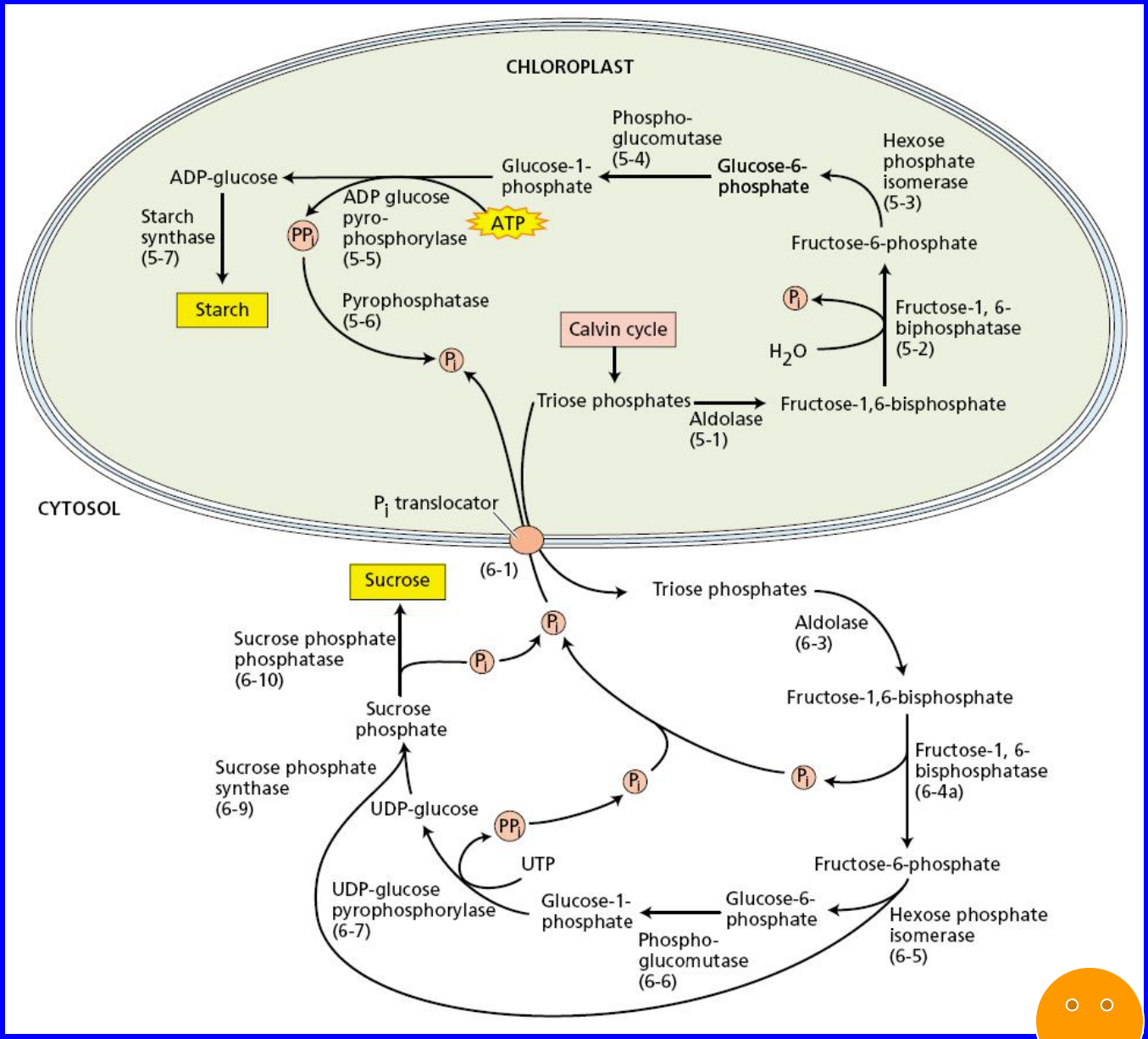
TP enters cytoplasm →synthesize sucrose and release Pi → $[Pi]_{cytoplasm}$ ↑→help Pi enter chloroplast and transport TP out→ photosynthesis rate ↑

(4) Regulation of mass action:

PGA + ATP ↔ DPGA + ADP

DPGA + NADPH + H^+ ↔ GAP + $NADP^+$ + Pi

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.

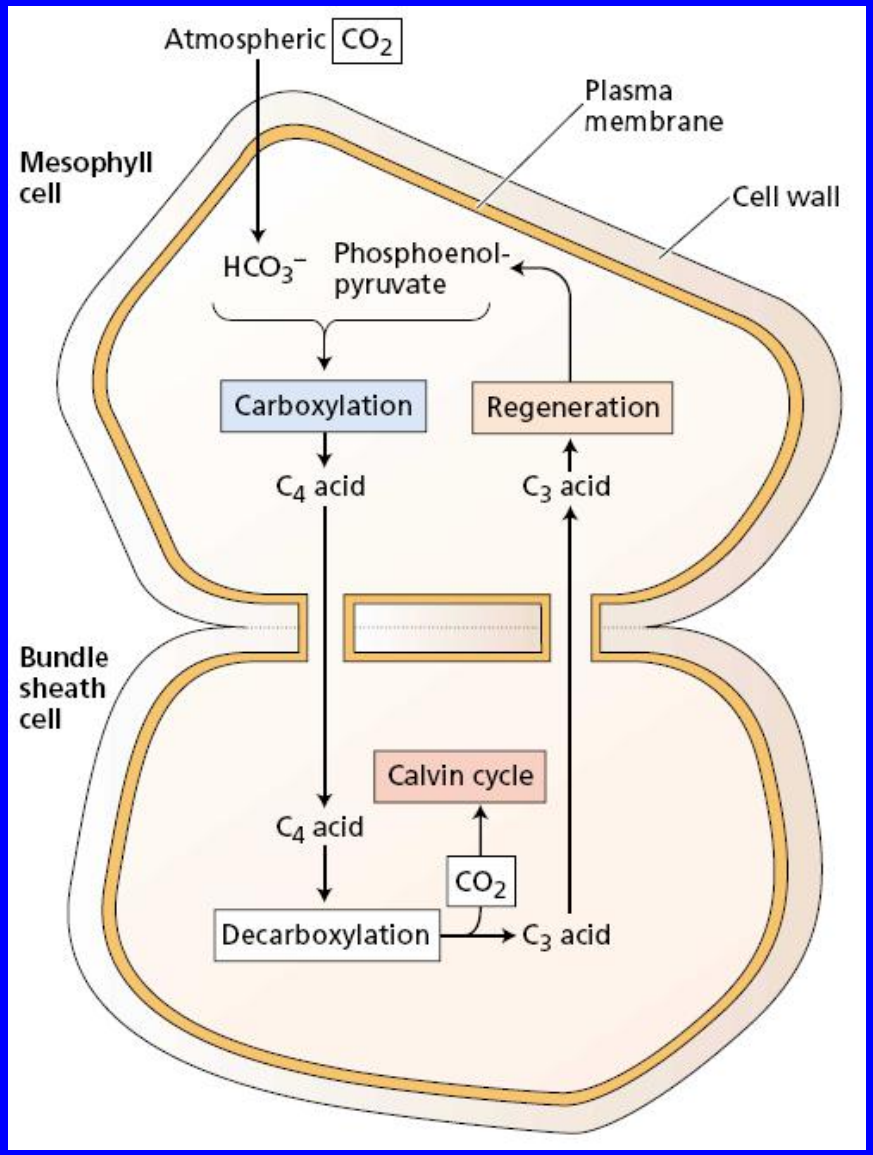


(II) C_4 pathway (Hatch-Slack pathyway)

$$PEP + HCO_3^- \xrightarrow{PEPC} OAA + Pi$$

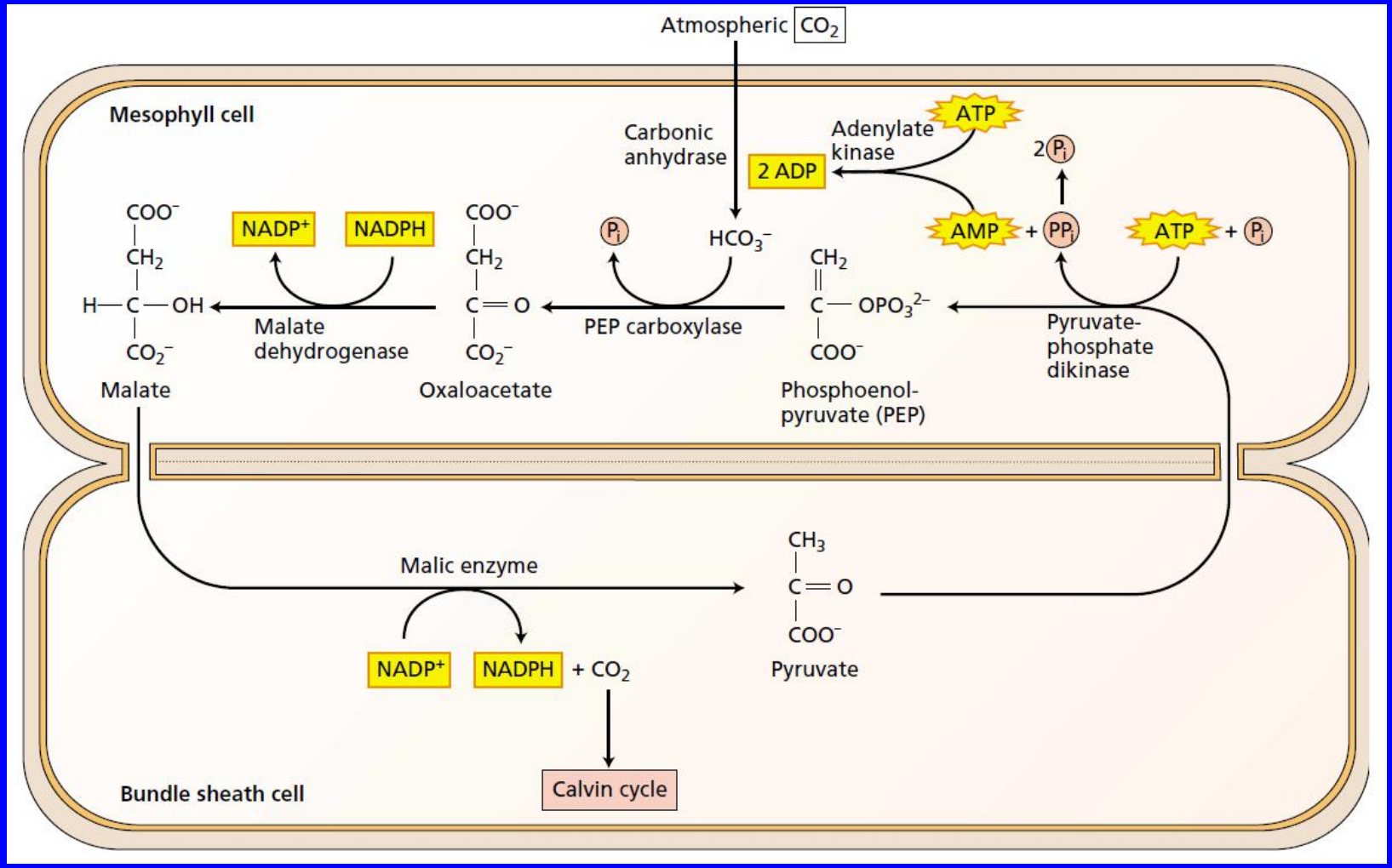
Include carboxylation and reduction, conversion and decarboxylation, regeneration and other steps

1. Three types

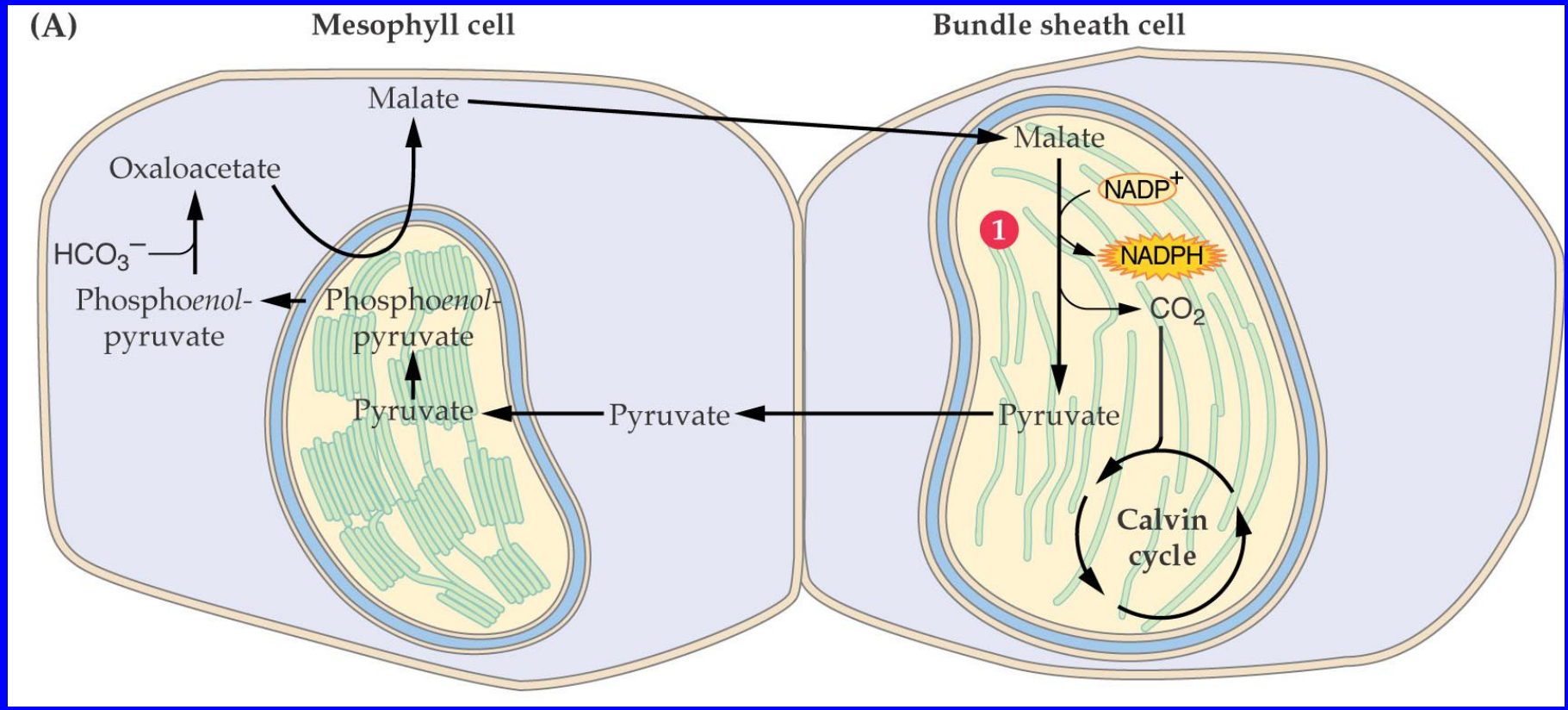


General aspects of the C_4 pathway.

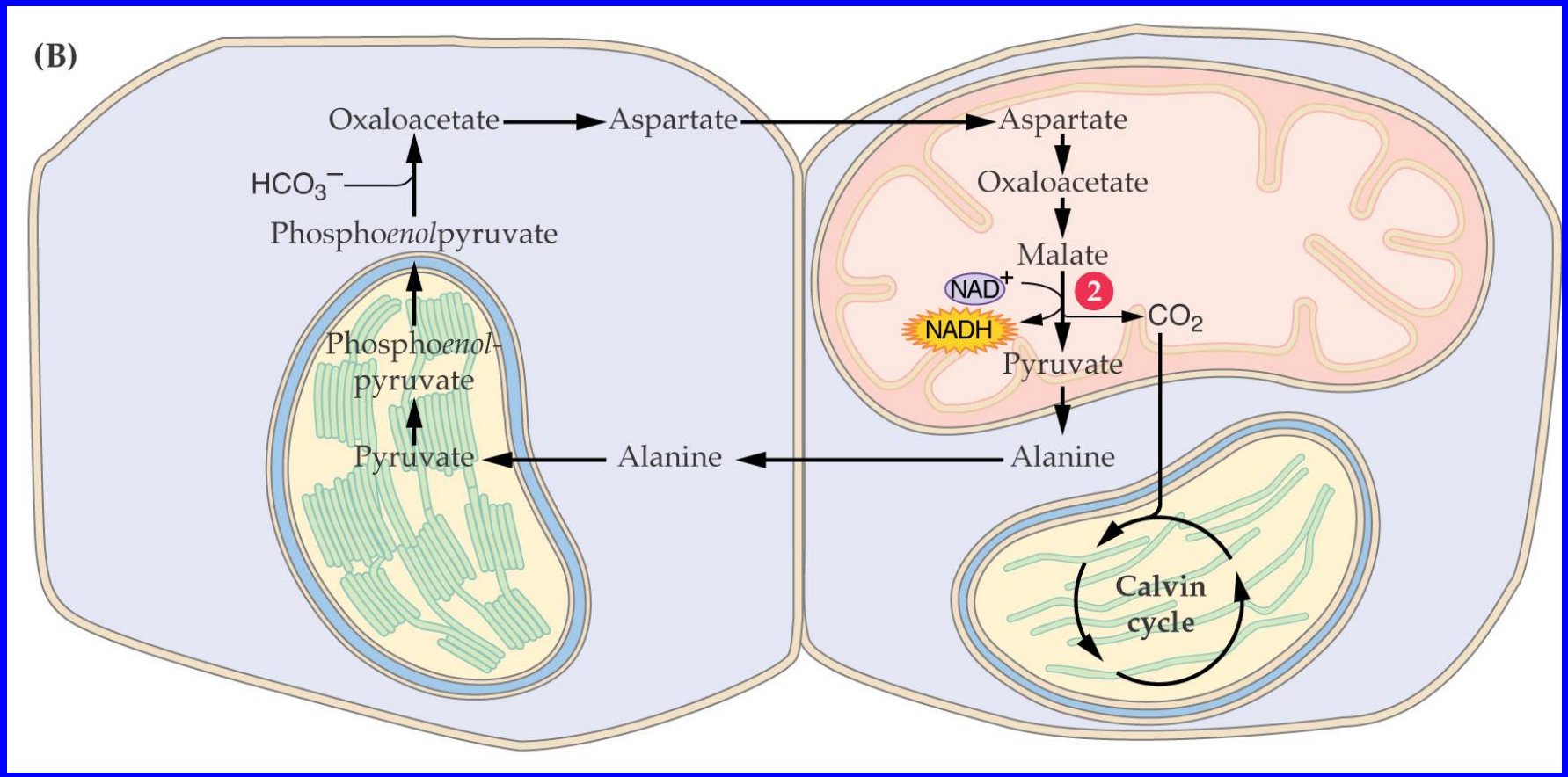
The C_4 photosynthetic pathway. The hydrolysis of two ATP drives the cycle in the direction of the arrows, thus pumping CO_2 from the atmosphere to the Calvin cycle of the chloroplasts from bundle sheath cells.



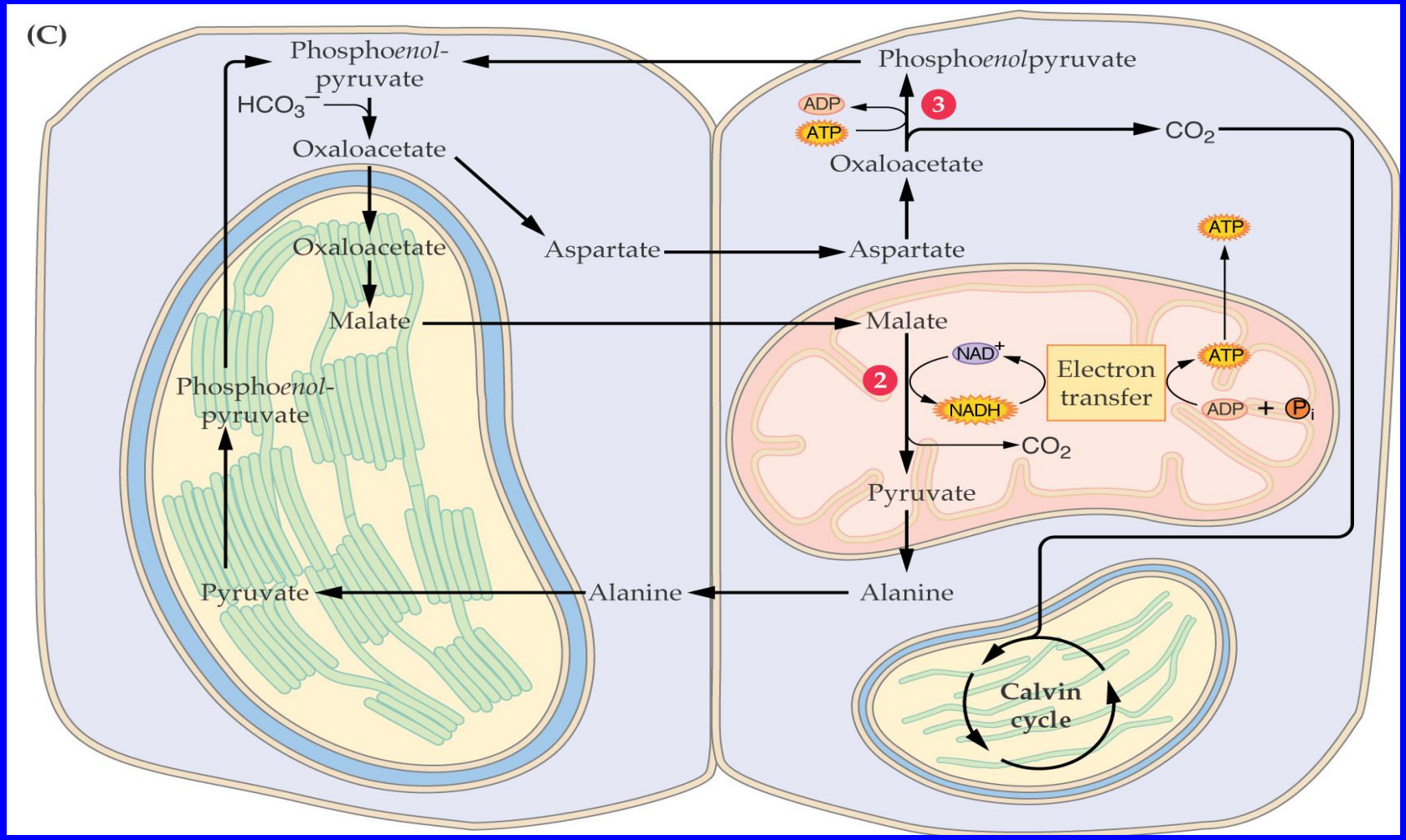
NADP+- malic enzyme type



NAD+- malic enzyme type



PEP carboxykinase type



2. Regulation

(1) Light: Activate MDH and PPDK and be proportional to light intensity.

(2) Effecter: Malic acid and Asp inhibit PEPC activity, and G-6-P enhances its activity.

(3) Divalent metal ions:

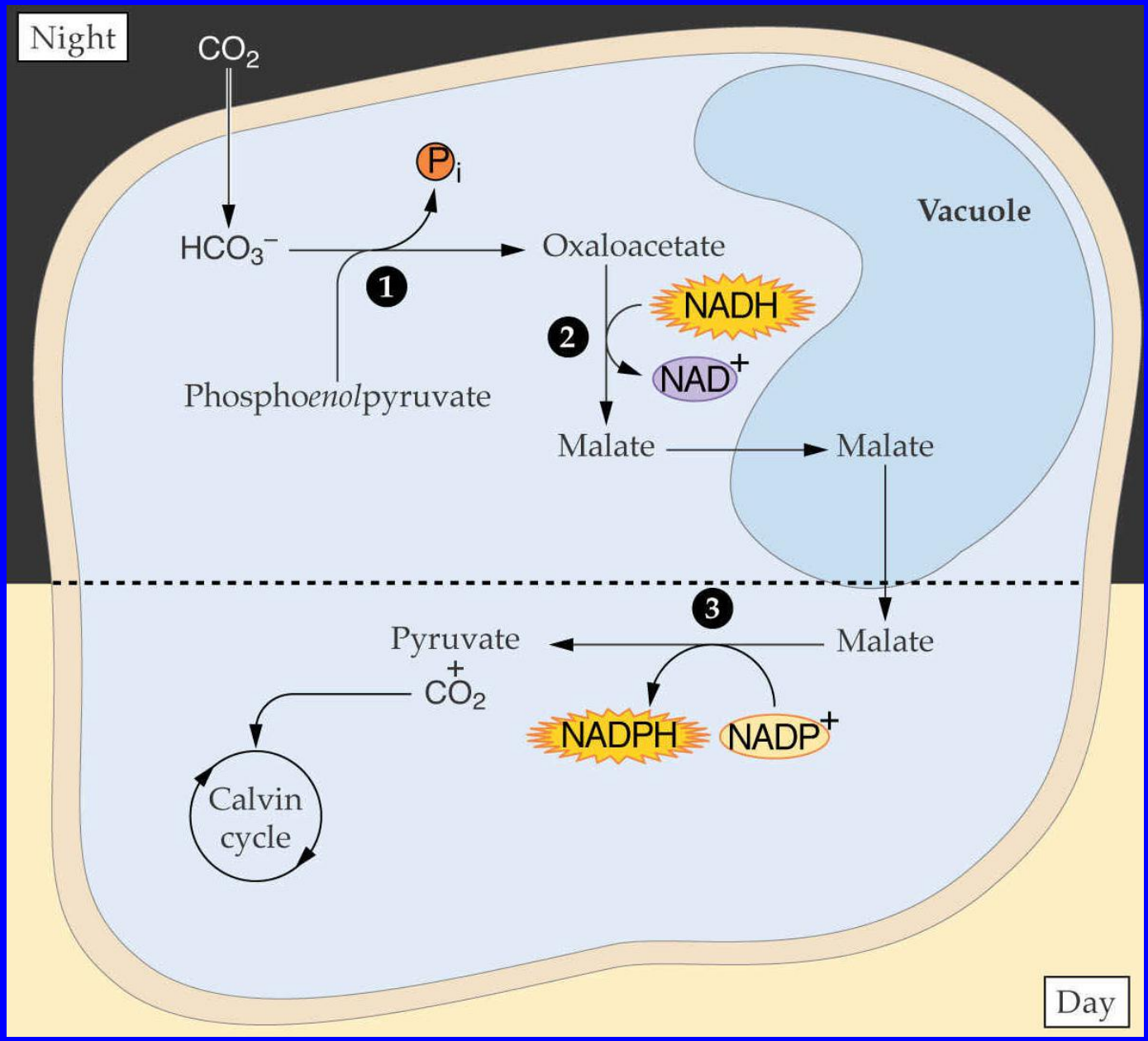
NADP$^+$-ME: Mg^{2+} or Mn^{2+}

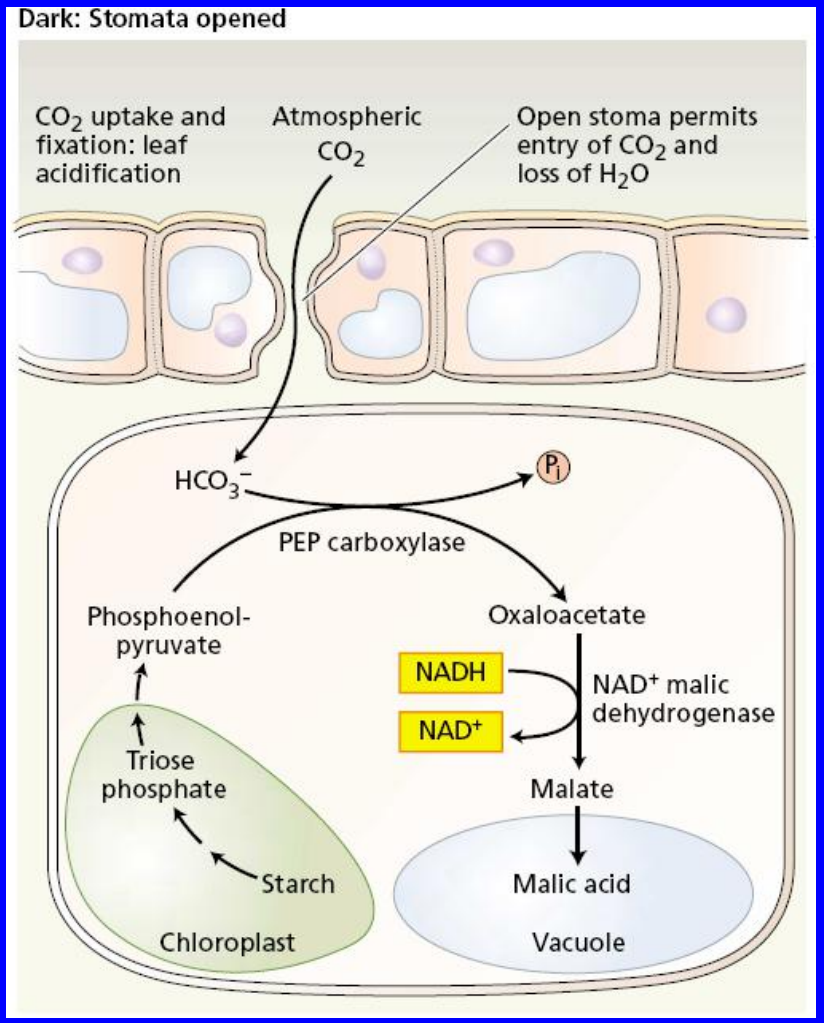
NAD$^+$-ME: Mn^{2+}

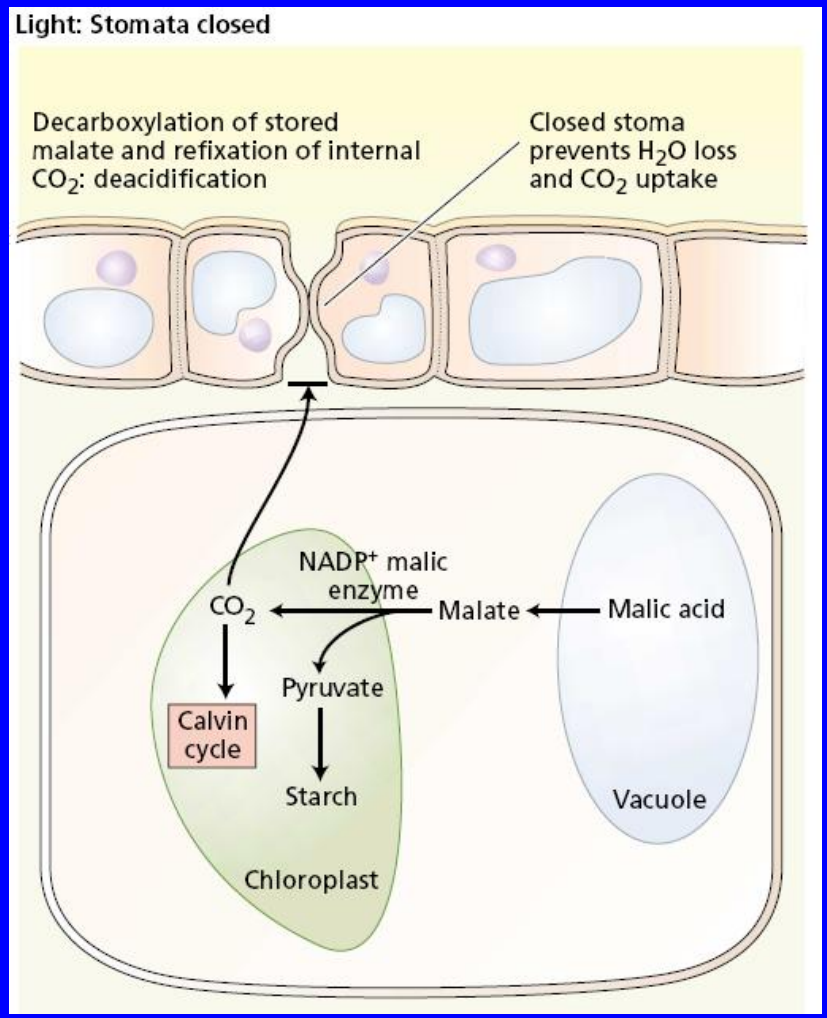
PEP carboxylase: Mg^{2+} and Mn^{2+}

(III) Metabolism of crassulacean acid

1. Process







Crassulacean acid metabolism (CAM). Temporal separation of CO_2 uptake from photosynthetic reactions: CO_2 uptake and fixation take place at night, and decarboxylation and refixation of the internally released CO_2 occur during the day.

2 Regulation

(1) Short-term regulation

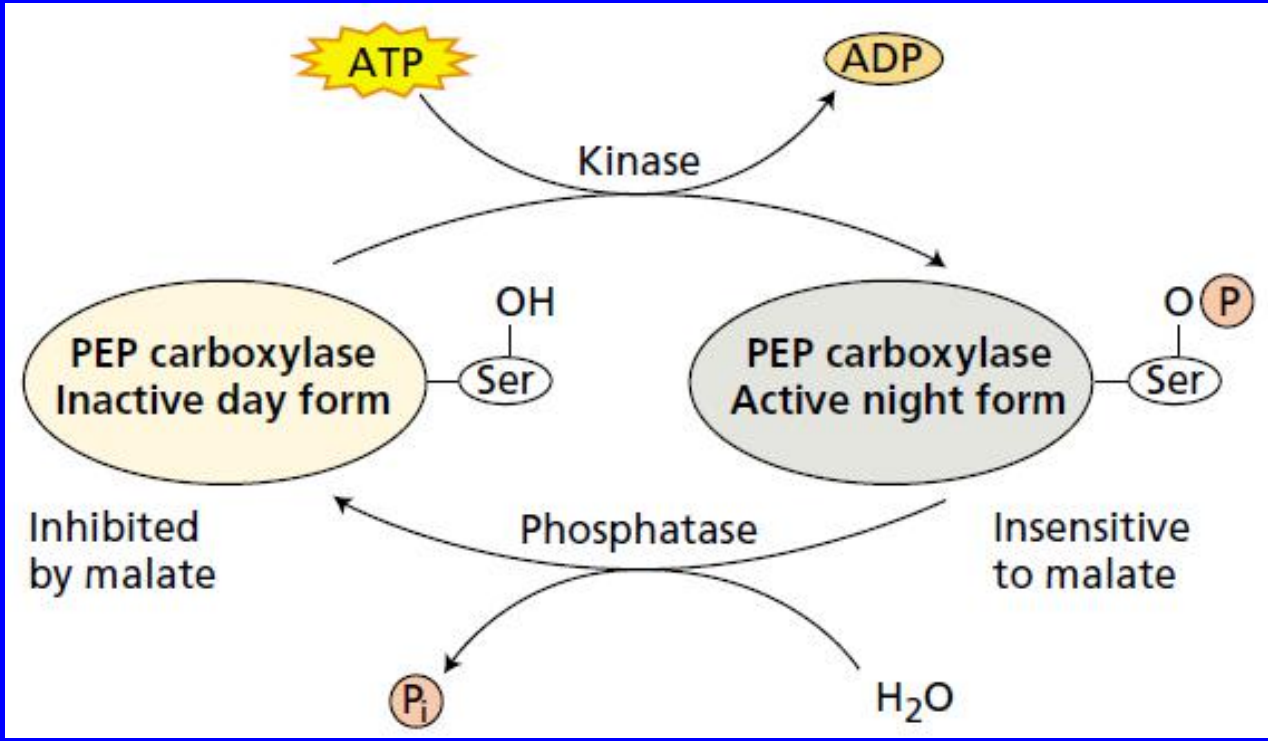
① Stomata are open to fix CO_2 at night; closed to release CO_2 in the daytime.

② Carboxylase takes effect at night; cocarboxylase has activity only in the daytime.

③ There are two forms of carboxylase: Nigh type - insensitive to malic acid; day type - inhibited by malic acid.

(2) Long-term regulation

Formed due to long-term growth under dry condition; when moisture is sufficient, it may be converted into C_3 type, open in the daytime and closed at night.



Diurnal regulation of CAM phosphoenolpyruvate (PEP) carboxylase. Phosphorylation of the serine residue (Ser-OP) yields a form of the enzyme which is active during the night and relatively insensitive to malate. During the day, dephosphorylation of the serine (Ser-OH) gives a form of the enzyme which is inhibited by malate.