B.Sc. II Semester

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Unit III

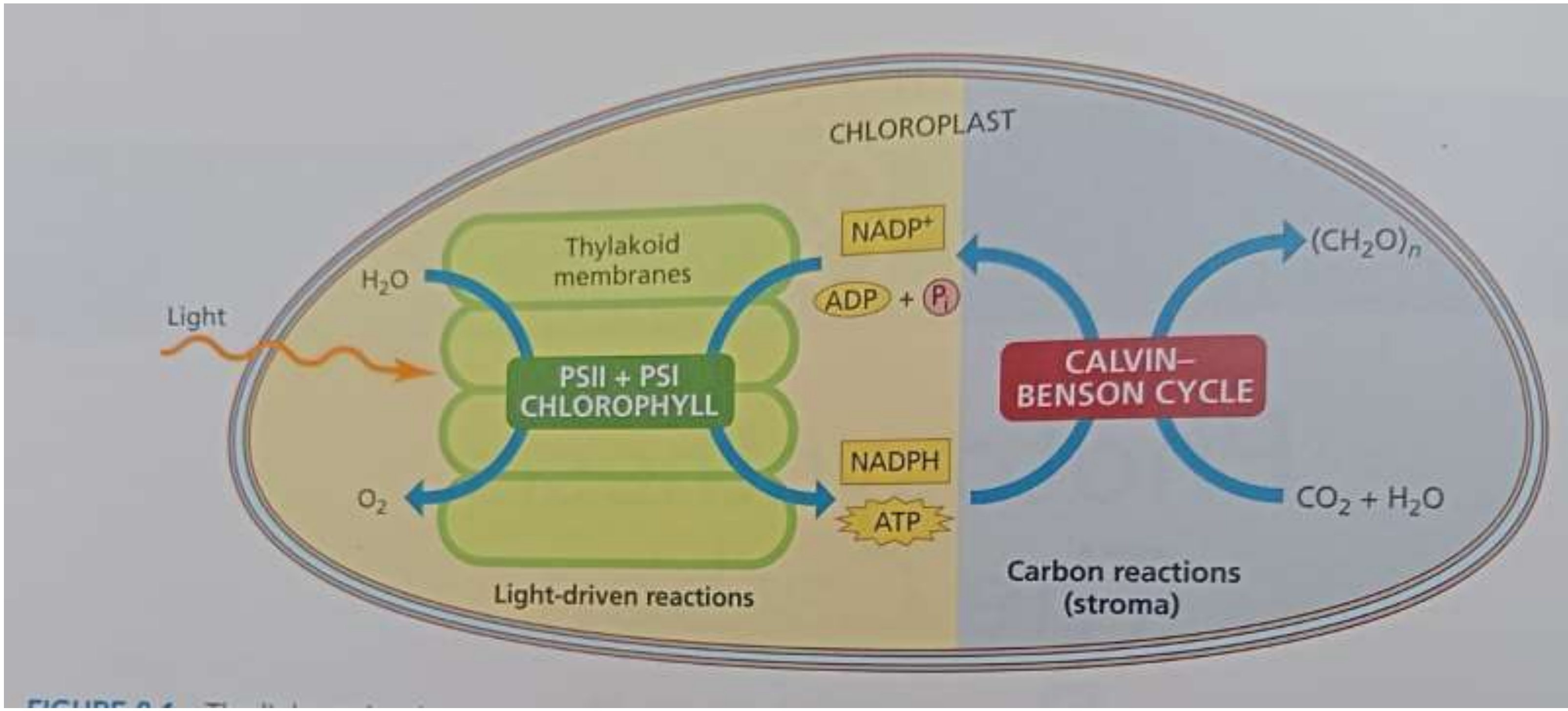
Photosynthesis

Dr. Madhulika Singh

Photosynthesis

- Green plants carry out 'photosynthesis', **a physico-chemical process by which they use light energy to drive the synthesis of organic compounds**.
- Ultimately, all living forms on earth depend on sunlight for energy. The use of energy from sunlight by plants doing photosynthesis is the basis of life on earth.
- Photosynthesis mostly takes place **in the green parts of the plant that have chloroplasts**. Mesophyll cells in the leaves have a large number of chloroplasts in them. This is because the chloroplasts can find the optimum quantity of sunlight they need for photosynthesis at the edges of the mesophyll cells of the leaves

Light & Dark Reaction



Light Reaction

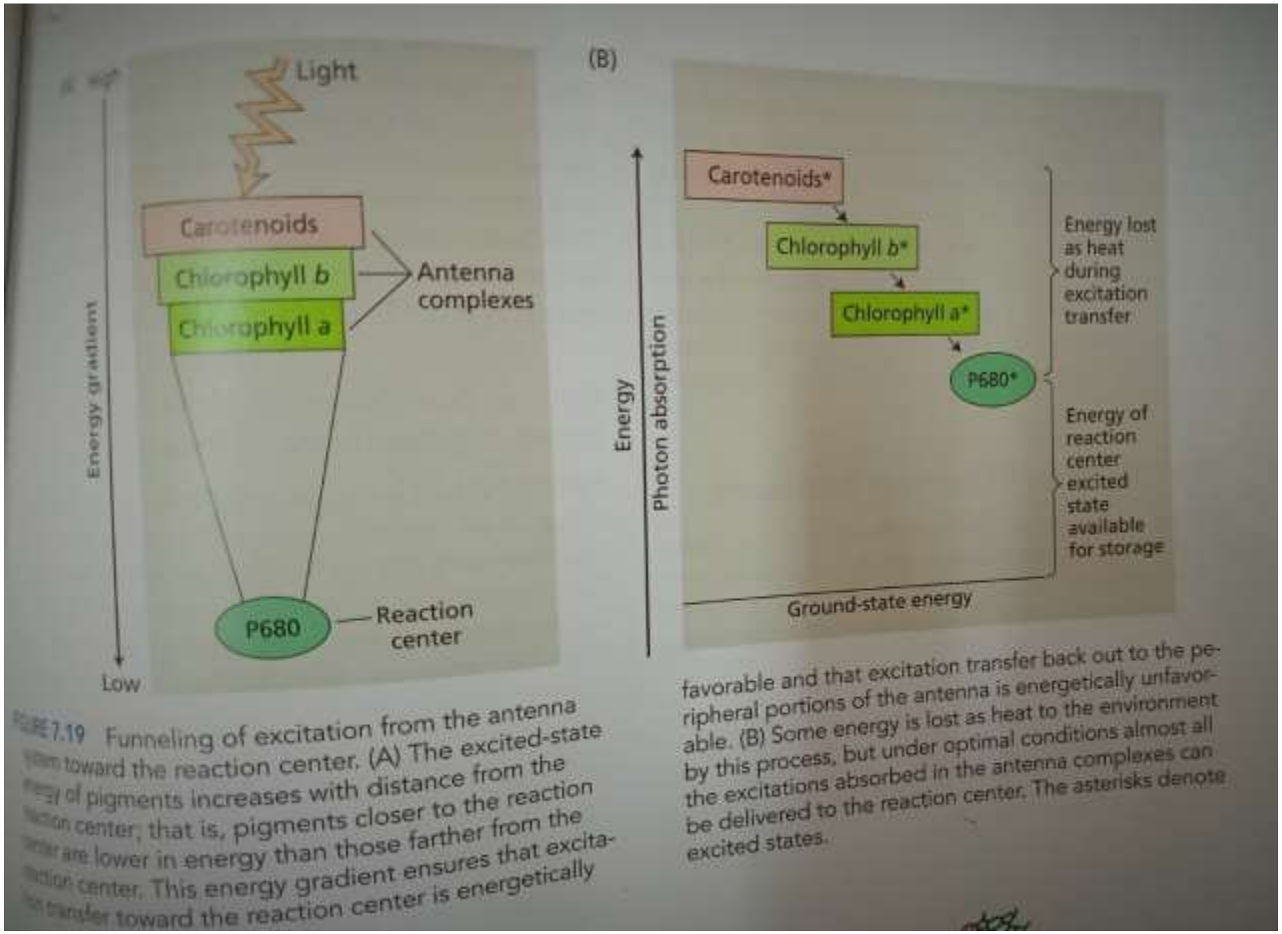


FIGURE 7.19 Funneling of excitation from the antenna system toward the reaction center. (A) The excited-state energy of pigments increases with distance from the reaction center; that is, pigments closer to the reaction center are lower in energy than those farther from the reaction center. This energy gradient ensures that excitation transfer toward the reaction center is energetically favorable and that excitation transfer back out to the peripheral portions of the antenna is energetically unfavorable. (B) Some energy is lost as heat to the environment by this process, but under optimal conditions almost all the excitations absorbed in the antenna complexes can be delivered to the reaction center. The asterisks denote excited states.

Light Reaction

Z scheme of photosynthesis

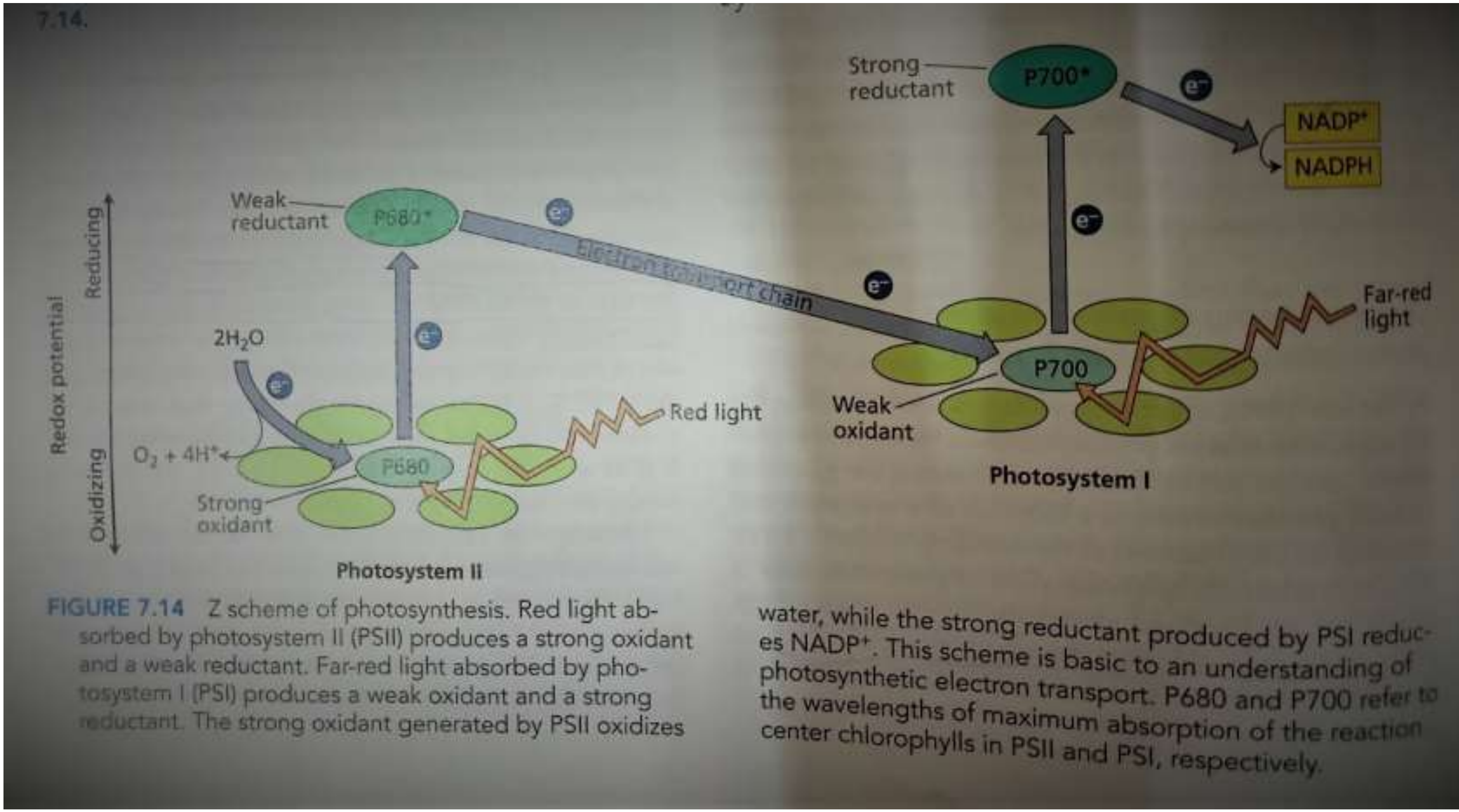


FIGURE 7.14 Z scheme of photosynthesis. Red light absorbed by photosystem II (PSII) produces a strong oxidant and a weak reductant. Far-red light absorbed by photosystem I (PSI) produces a weak oxidant and a strong reductant. The strong oxidant generated by PSII oxidizes water, while the strong reductant produced by PSI reduces $NADP^+$. This scheme is basic to an understanding of photosynthetic electron transport. P680 and P700 refer to the wavelengths of maximum absorption of the reaction center chlorophylls in PSII and PSI, respectively.

Z scheme of photosynthesis

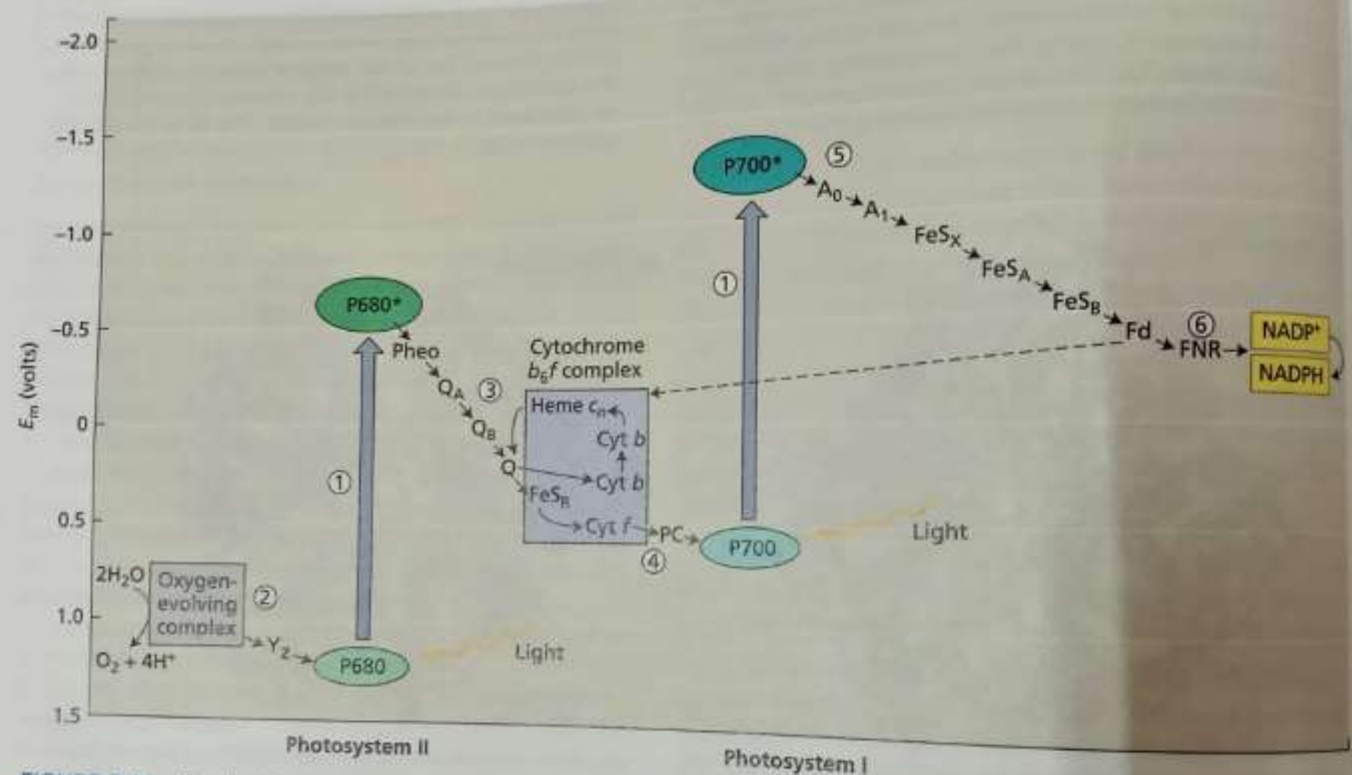


FIGURE 7.21 Detailed Z scheme for O_2-evolving photosynthetic organisms. The redox carriers are placed at their midpoint redox potentials (at pH 7). (1) The vertical arrows represent photon absorption by the reaction center chlorophylls: P680 for photosystem II (PSII) and P700 for photosystem I (PSI). The excited PSII reaction center chlorophyll, P680*, transfers an electron to pheophytin (Pheo). (2) On the oxidizing side of PSII (to the left of the arrow joining P680 with P680*), P680 oxidized by light is re-reduced by Y_Z, which has received electrons from oxidation of water. (3) On the reducing side of PSII (to the right of the arrow joining P680 with P680*), pheophytin transfers electrons to the acceptors Q_A and Q_B, which are plastoquinones. (4) The cytochrome b_6f complex transfers electrons to plastocyanin (PC), a soluble protein, which in turn reduces $P700^+$ (oxidized P700). (5) The acceptor of electrons from P700* (A_0) is thought to be a chlorophyll, and the next acceptor (A_1) is a quinone. A series of membrane-bound iron–sulfur proteins (FeS_X, FeS_A, and FeS_B) transfers electrons to soluble ferredoxin (Fd). (6) The soluble flavoprotein ferredoxin–NADP reductase (FNR) reduces $NADP^+$ to NADPH, which is used in the Calvin–Benson cycle to reduce CO_2 (see Chapter 8). The dashed line indicates cyclic electron flow around PSI. (After Blankenship and Prince 1985.)

Transfer of Electron

NADPH & ATP synthesis

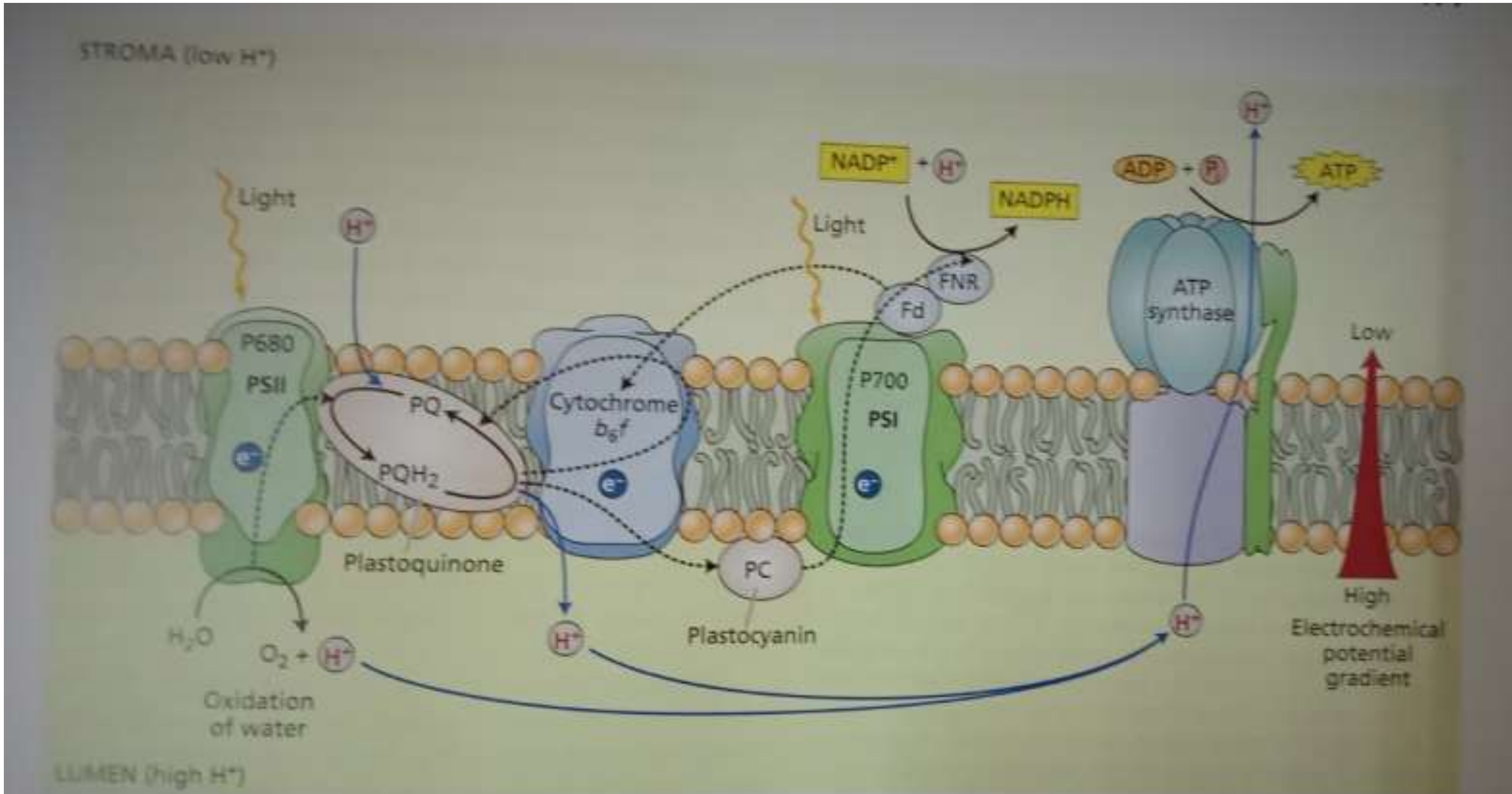
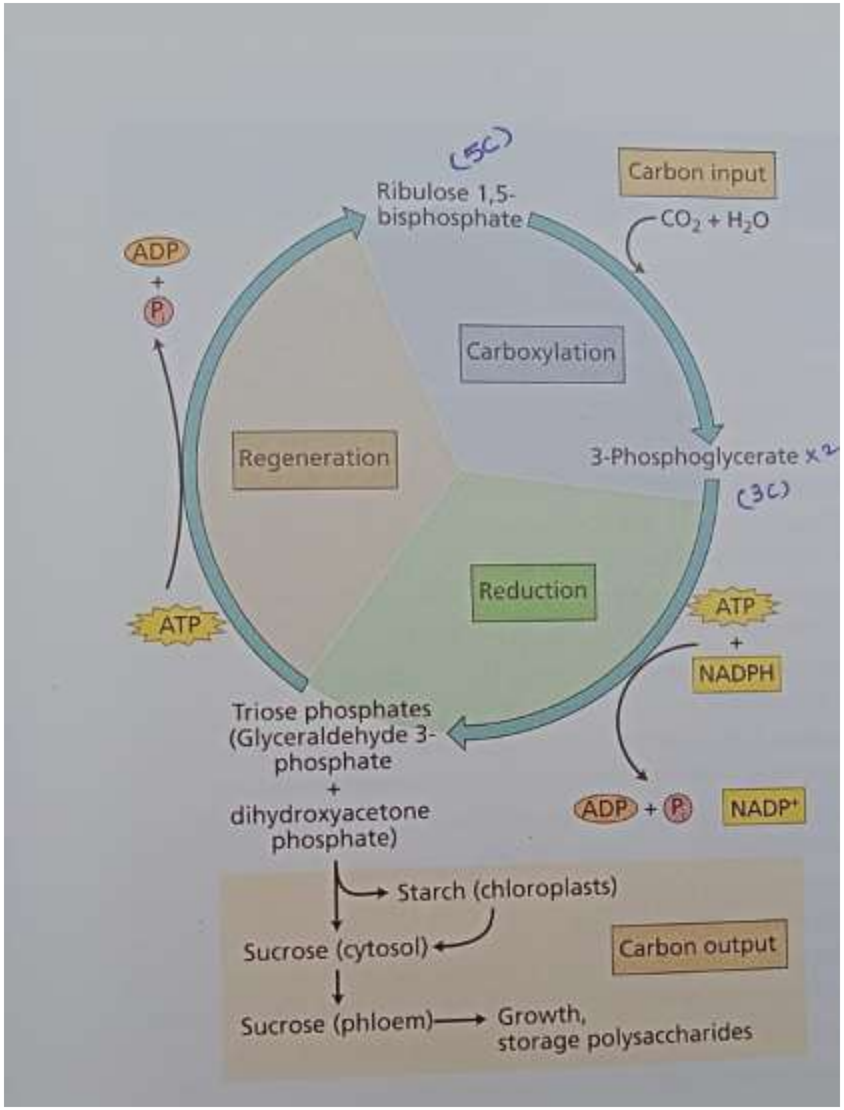


FIGURE 7.22 The transfer of electrons and protons in the thylakoid membrane is carried out vectorially by four protein complexes (see Figure 7.18B for structures). Water is oxidized and protons are released in the lumen by PSII. PSI reduces $NADP^+$ to NADPH in the stroma, via the action of ferredoxin (Fd) and the flavoprotein ferredoxin–NADP reductase (FNR). Protons are also transported into the lumen by the action of the cytochrome b_6f complex and contribute to the electrochemical proton gradient. These protons must then diffuse to the ATP synthase enzyme, where their diffusion down the electrochemical potential gradient is used to synthesize ATP in the stroma. Reduced plastoquinone (PQH_2) and plastocyanin transfer electrons to cytochrome b_6f and to PSI, respectively. The dashed lines represent electron transfer; solid lines represent proton movement.

Dark Reaction



Dark Reaction

TABLE 8.1
Reactions of the Calvin–Benson cycle

Enzyme	Reaction
1. Ribulose 1,5-bisphosphate carboxylase–oxygenase (rubisco)	3 Ribulose 1,5-bisphosphate + 3 CO_2 + 3 H_2O → 6 3-phosphoglycerate + 6 H^+
2. 3-Phosphoglycerate kinase	6 3-Phosphoglycerate + 6 ATP → 6 1,3-bisphosphoglycerate + 6 ADP
3. NADP–glyceraldehyde-3-phosphate dehydrogenase	6 1,3-Bisphosphoglycerate + 6 NADPH + 6 H^+ → 6 glyceraldehyde 3-phosphate + 6 $NADP^+$ + 6 P_i
4. Triose phosphate isomerase	2 Glyceraldehyde 3-phosphate ↔ 2 dihydroxyacetone phosphate
5. Aldolase	Glyceraldehyde 3-phosphate + dihydroxyacetone phosphate → fructose 1,6-bisphosphate
6. Fructose-1,6-bisphosphatase	Fructose 1,6-bisphosphate + H_2O → fructose 6-phosphate + P_i
7. Transketolase	Fructose 6-phosphate + glyceraldehyde 3-phosphate → erythrose 4-phosphate + xylulose 5-phosphate
8. Aldolase	Erythrose 4-phosphate + dihydroxyacetone phosphate → sedoheptulose 1,7-bisphosphate
9. Sedoheptulose-1,7-bisphosphatase	Sedoheptulose 1,7-bisphosphate + H_2O → sedoheptulose 7-phosphate + P_i
10. Transketolase	Sedoheptulose 7-phosphate + glyceraldehyde 3-phosphate → ribose 5-phosphate + xylulose 5-phosphate
11a. Ribulose 5-phosphate epimerase	2 Xylulose 5-phosphate → 2 ribulose 5-phosphate
11b. Ribose 5-phosphate isomerase	Ribose 5-phosphate → ribulose 5-phosphate
12. Phosphoribulokinase (Ribulose 5-phosphate kinase)	3 Ribulose 5-phosphate + 3 ATP → 3 ribulose 1,5-bisphosphate + 3 ADP + 3 H^+

Net: 3 CO_2 + 5 H_2O + 6 NADPH + 9 ATP → glyceraldehyde 3-phosphate + 6 $NADP^+$ + 3 H^+ + 9 ADP + 8 P_i

Note: P_i stands for inorganic phosphate.

Dark Reaction

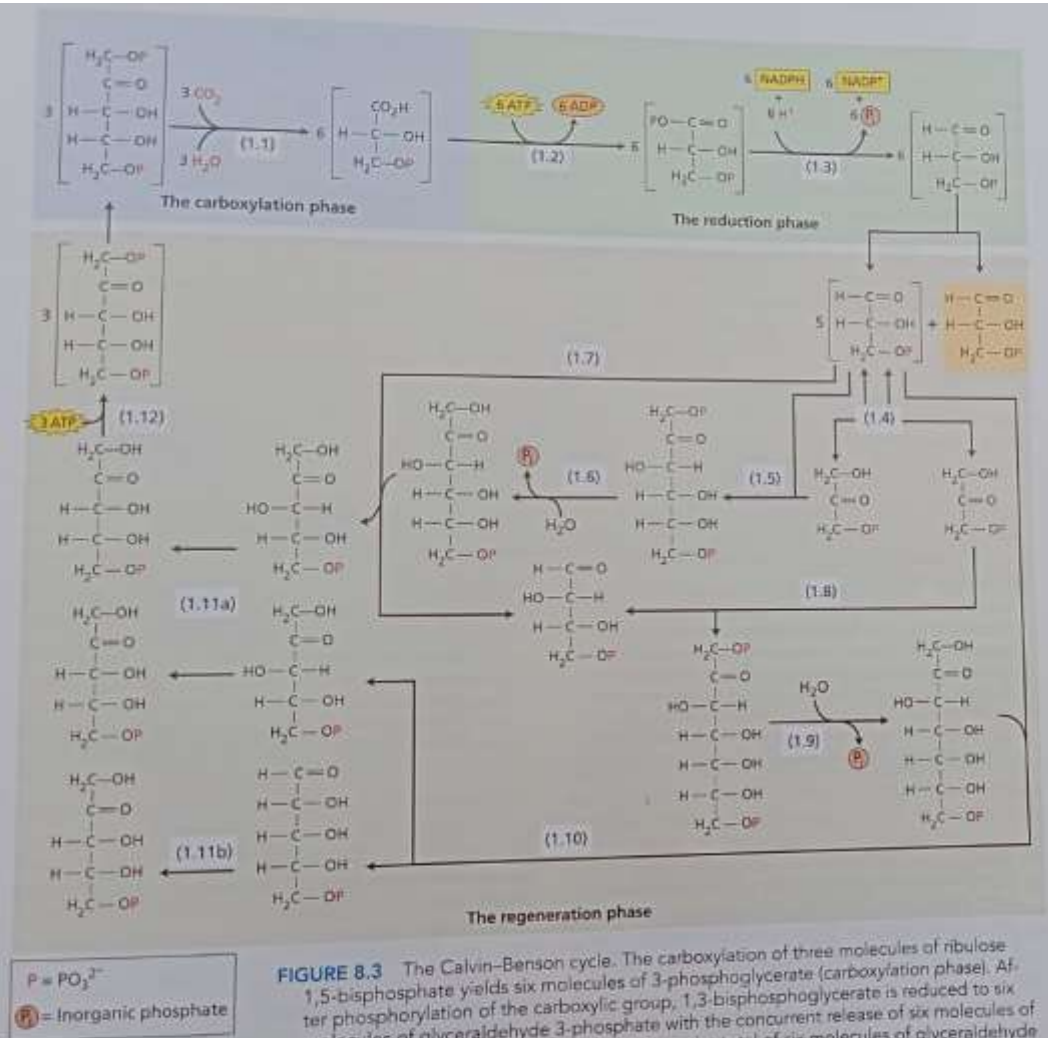


FIGURE 8.3 The Calvin–Benson cycle. The carboxylation of three molecules of ribulose 1,5-bisphosphate yields six molecules of 3-phosphoglycerate (*carboxylation phase*). After phosphorylation of the carboxylic group, 1,3-bisphosphoglycerate is reduced to six molecules of glyceraldehyde 3-phosphate with the concurrent release of six molecules of inorganic phosphate (*reduction phase*). From the total of six molecules of glyceraldehyde 3-phosphate, one represents the net assimilation of three molecules of CO_2 while the other five undergo a series of reactions that finally regenerate the three starting molecules of ribulose 1,5-bisphosphate (*regeneration phase*). See Table 8.1 for a description of each numbered reaction.

Thanks