Photosynthesis in Bacteria

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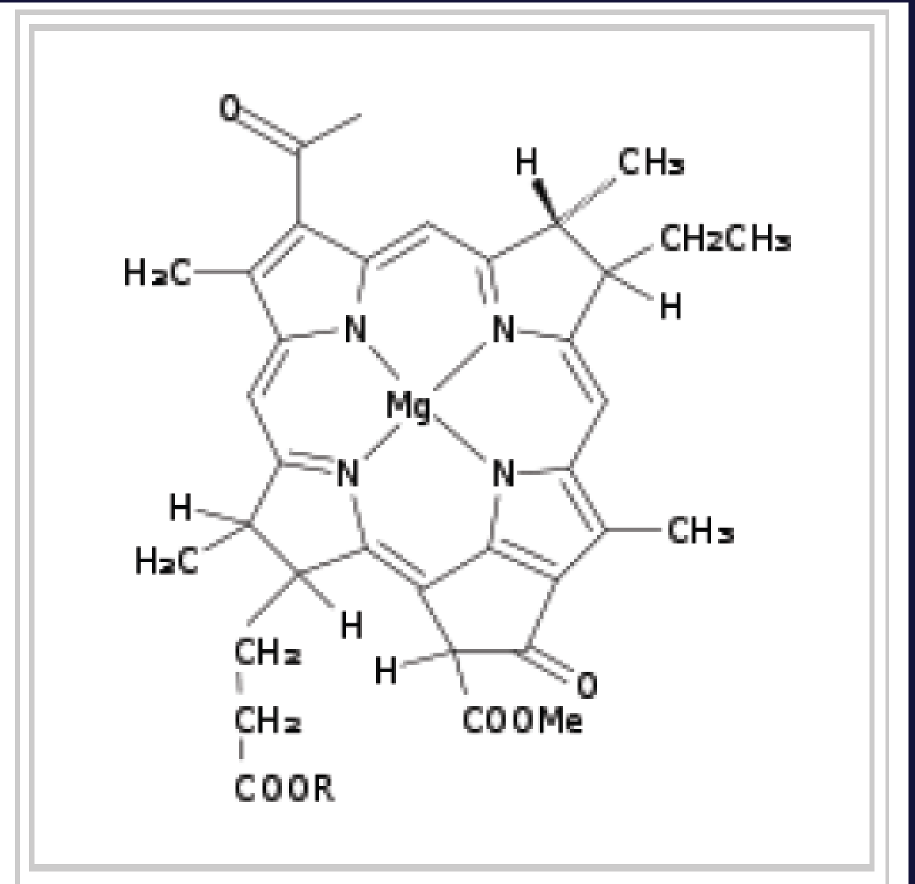
Photosynthesis

- Phototrophy is the use of light as a source of energy for growth, more specifically the conversion of light energy into chemical energy in the form of ATP.
- Procaryotes that can convert light energy into chemical energy include the photosynthetic cyanobacteria, the purple and green bacteria and the "halobacteria" (actually archaea).
- The cyanobacteria conduct plant photosynthesis, called oxygenic photosynthesis; the purple and green bacteria conduct bacterial photosynthesis or anoxygenic photosynthesis

Bacteriochlorophyll

- Bacteriochlorophylls are photosynthetic pigments that occur in various phototrophic bacteria.
- They were discovered by C. B. van Niel in 1932 .



Bacteriochlorophyll a

Pigment	**Bacterial group**	***in vivo* infrared absorption maximum (nm)**
Bacteriochlorophyll *a*	Purple bacteria, Heliobacteria, Green Sulfur Bacteria, Chloroflexi, *Chloracidobacterium thermophilum*[1]	805, 830-890
Bacteriochlorophyll *b*	Purple bacteria	835-850, 1020-1040
Bacteriochlorophyll *c*	Green sulfur bacteria, Chloroflexi, *C. thermophilum*	745-755
Bacteriochlorophyll c_s	Chloroflexi	740
Bacteriochlorophyll *d*	Green sulfur bacteria	705-740
Bacteriochlorophyll *e*	Green sulfur bacteria	719-726
Bacteriochlorophyll *f*	Green sulfur bacteria (currently found only through mutation; natural may exist)[2]	700-710
Bacteriochlorophyll *g*	Heliobacteria	670, 788

Carotenoids

- Carotenoids are always associated with the photosynthetic apparatus. They function as secondary light-harvesting pigments, absorbing light in the blue-green spectral region between 400-550 nm.
- Carotenoids transfer energy to chlorophyll, at near 100 percent efficiency, from wave lengths of light that are missed by chlorophyll. In addition, carotenoids have an indispensable function to protect the photosynthetic apparatus from photooxidative damage.

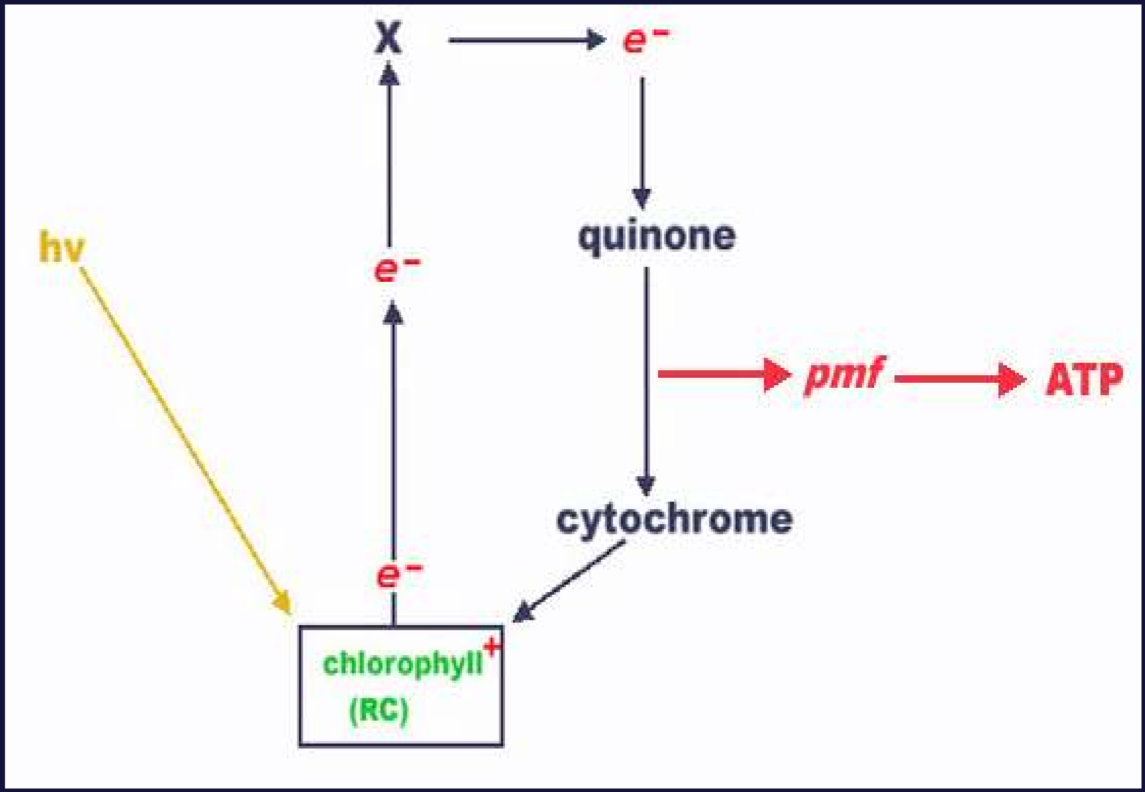
Phycobilins

- Phycobiliproteins are the major light harvesting pigments of the cyanobacteria. They also occur in some groups of algae.
- They may be red or blue, absorbing light in the middle of the spectrum between 550 and 650nm. Phycobiliproteins consist of proteins that contain covalently-bound linear tetrapyrroles (phycobilins).
- They are contained in granules called phycobilisomes that are closely associated with the photosynthetic apparatus. Being closely linked to chlorophyll they can efficiently transfer light energy to chlorophyll at the reaction center.

Light reaction

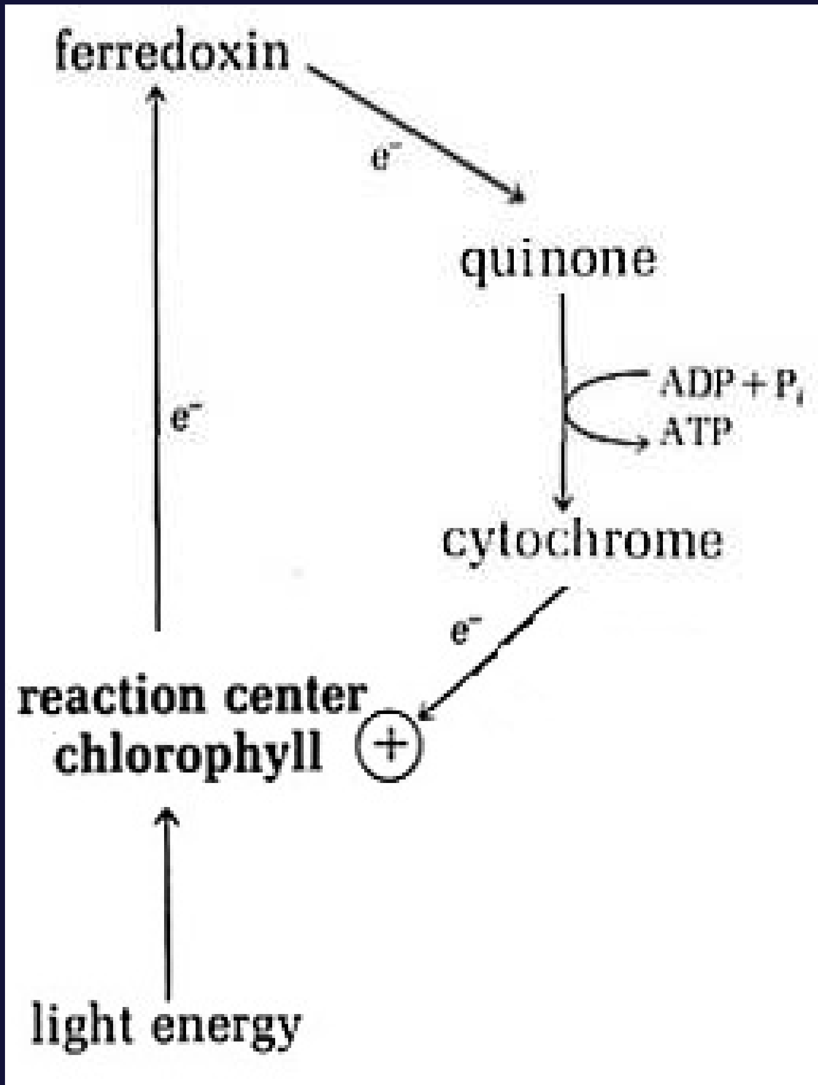
- The catabolic component of photosynthesis is the light reaction, wherein light energy is transformed into electrical energy, then chemical energy.

- The Light Reactions depend upon the presence of chlorophyll, the primary light-harvesting pigment in the membrane of photosynthetic organisms.
- Absorption of a quantum of light by a chlorophyll molecule causes the displacement of an electron at the reaction center.
- The displaced electron is an energy source that is moved through a membrane photosynthetic electron transport system, being successively passed from an iron-sulfur protein (X) to a quinone to a cytochrome and back to chlorophyll.
- As the electron is transported, a proton motive force is established on the membrane, and ATP is synthesized by an ATPase enzyme. This manner of converting light energy into chemical energy is called cyclic photophosphorylation.

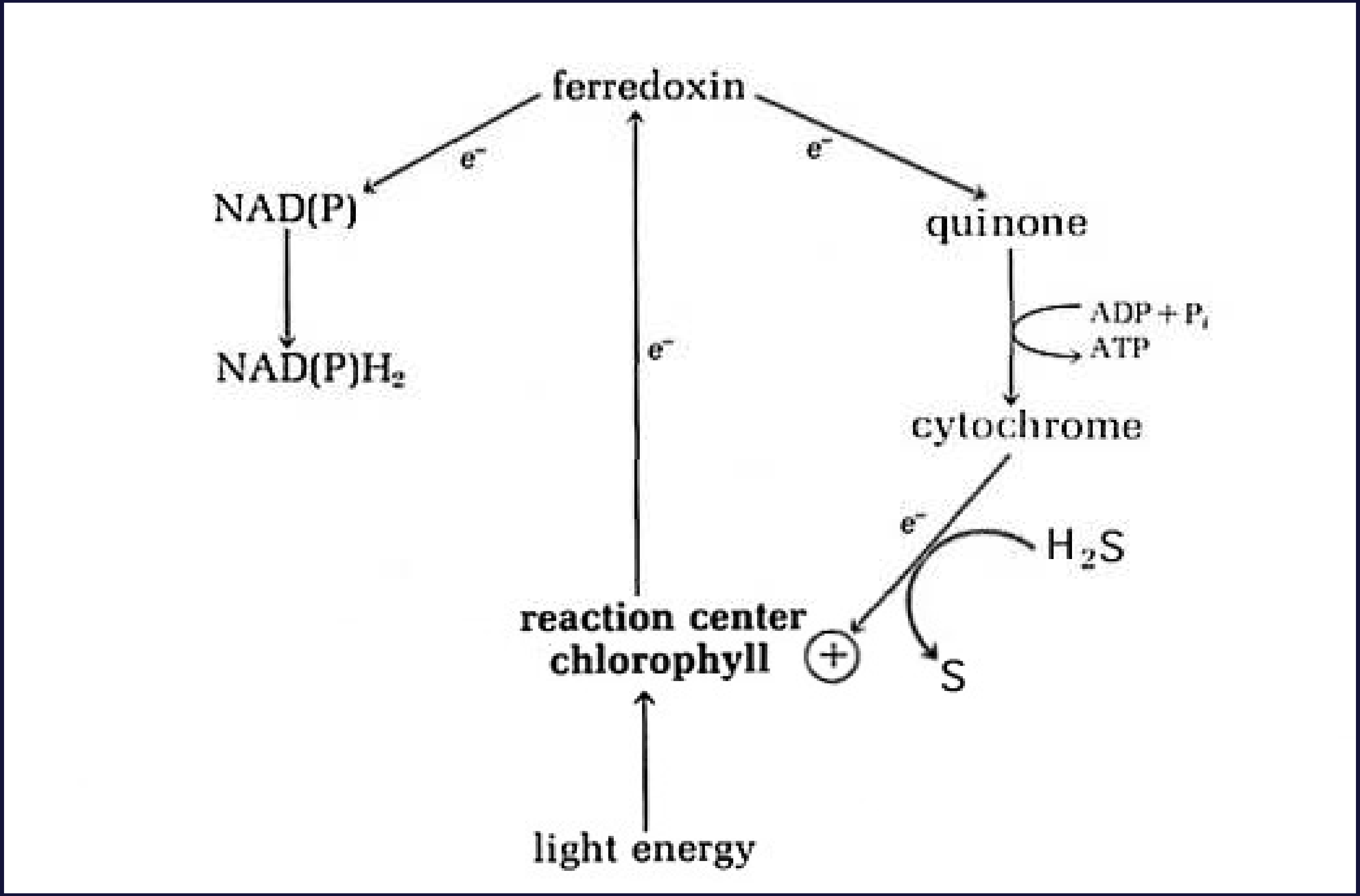


Photosystem I: cyclical electron flow coupled to photophosphorylation

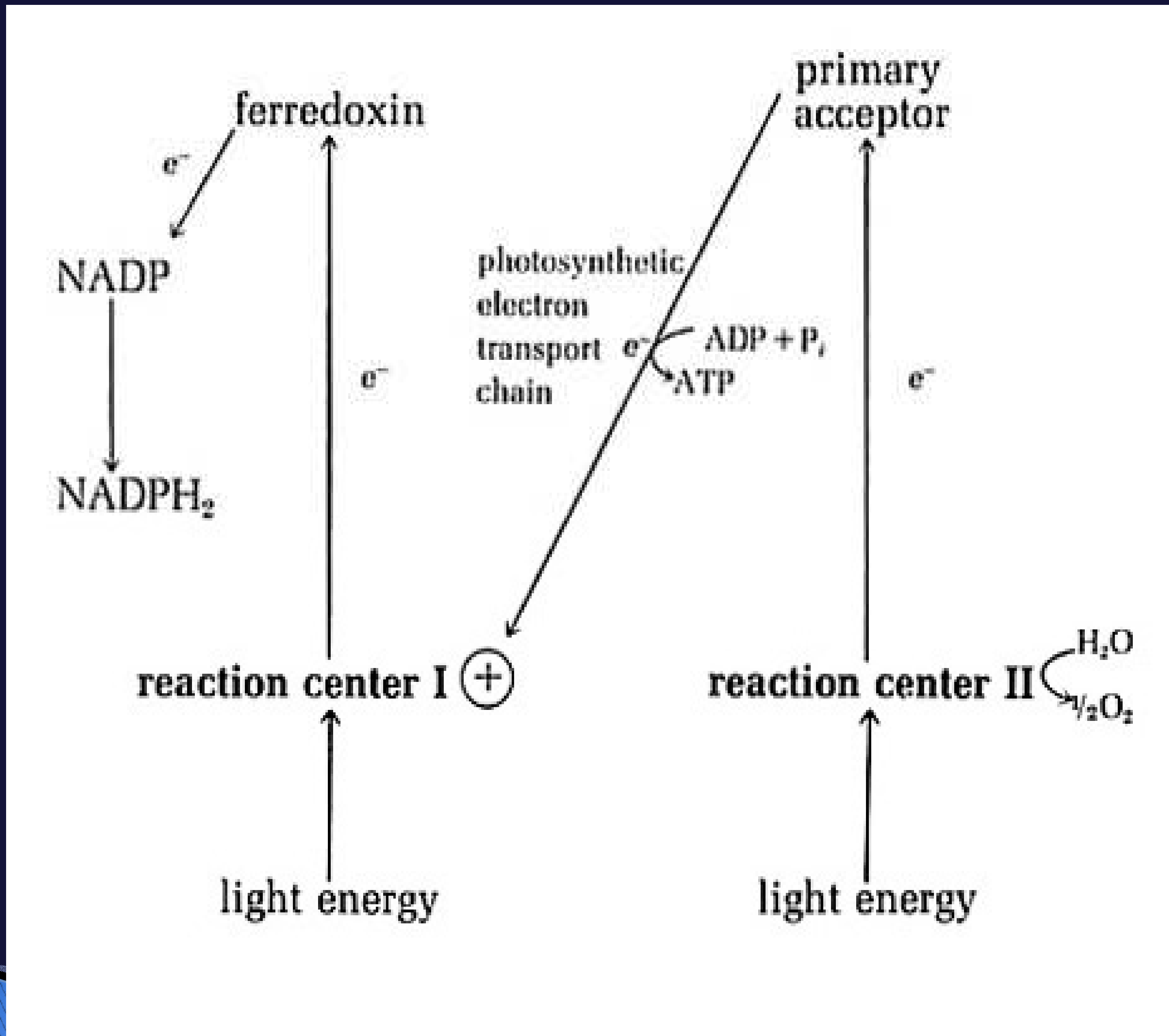
The functional components of the photochemical system are **light harvesting pigments**, a membrane **electron transport system**, and an **ATPase** enzyme. The photosynthetic electron transport system of is fundamentally similar to a respiratory ETS, except that there is a low redox electron acceptor (e.g.**ferredoxin**) at the top (low redox end) of the electron transport chain, that is first reduced by the electron displaced from chlorophyll.



A cluster of carotenoid and chlorophyll molecules at the Reaction Center harvests a quantum of light. A bacterial chlorophyll molecule becomes instantaneously oxidized by the loss of an electron. The light energy is used to boost the electron to a low redox intermediate, ferredoxin, (or some other iron sulfur protein) which can enter electrons into the photosynthetic electron transport system in the membrane. As the electrons traverse the ETS a proton motive force is established that is used to make ATP in the process of photophosphorylation. The last cytochrome in the ETS returns the electron to chlorophyll. Since light energy causes the electrons to turn in a cycle while ATP is synthesized, the process is called cyclic photophosphorylation.



In the case of the purple sulfur bacteria, they use H_2S as a source of electrons. The oxidation of H_2S is coupled to PSI. Light energy boosts an electron, derived from H_2S, to the level of ferredoxin, which reduces NADP to provide electrons for autotrophic CO_2 fixation.



ferredoxin
primary acceptor
e⁻
NADP
$NADPH_2$
photosynthetic electron transport chain
e⁻
$ADP + P_i$
ATP
e⁻
e⁻
reaction center I
reaction center II
H_2O
$\frac{1}{2}O_2$
light energy
light energy

Electron flow in plant (oxygenic) photosynthesis. Photosystem I and the mechanisms of cyclic photophosphorylation operate in plants, algae and cyanobacteria, as they do in bacterial photosynthesis. In plant photosynthesis, chlorophyll a is the major chlorophyll species at the reaction center and the exact nature of the primary electron acceptors (X or ferredoxin) and the components of the ETS are different than bacterial photosynthesis. But the fundamental mechanism of cyclic photophosphorylation is the same. However, when electrons must be withdrawn from photosystem I (ferredoxin--e^--->NADP in upper left), those electrons are replenished by the operation of Photosystem II. In the Reaction Center of PSII, a reaction between light, chlorophyll and H_2O removes electrons from H_2O (leading to the formation of O_2) and transfers them to a component of the photosynthetic ETS (primary electron acceptor). The electrons are then transferred through a chain of electron carriers consisting of cytochromes and quinones until they reach chlorophyll in PSI. The resulting drop in redox potential allows for the synthesis of ATP in a process called noncyclic photophosphorylation. The operation of photosystem II is what fundamentally differentiates plant photosynthesis from bacterial photosynthesis. Photosystem II accounts for the source of reductant for CO_2 fixation (provided by H_2O), the production of O_2, and ATP synthesis by noncyclic photophosphorylation

Thankyou