Quadrant II – Transcript and Related Materials

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Module Name: Photosystem I and II

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Notes

History of Photosystem discovery

Robert Emerson and Lewis (1943) while determining the quantum yield of photosynthesis in *Chlorella* by using monochromatic light of different wavelength noticed a sharp decrees in quantum yield at wavelength greater that 680 nm. Because this decrease in the quantum yield took place in the red part of the spectrum, the phenomenon was called red drop.

Emerson and his co-workers later on found that the inefficient far red light in *chlorella* beyond 680 nm could be made fully efficient if supplemented with light of shorter wavelengths. The quantum yield from the two combined beams of light was found to be greater than the sum effect of both beams used separately. This enhancement of photosynthesis is called as Emerson's Enhancement effect.

The discovery of red drop & the Emerson's enhancement effect has led scientists to suggest that photosynthesis is driven by two photochemical processes. These processes are associated with two groups of photosynthetic pigments called as Pigment system I and pigment system II. Wavelengths of light shorter than 680nm affect both the pigment system. While wavelength longer than 680 nm affect only the Pigment system I.

Definition of Photosystem

Photosystems are the functional units for photosynthesis, defined by a particular pigment organization and association patterns, whose work is the absorption and transfer of light energy, which implies transfer of electrons.

Introduction to Photosystems

- Chlorophyll *a* is present in different forms which have maximum absorption at different wavelength of visible light. Two forms of chlorophyll *a* are Chl *a* 683 (P680) & chl *a* 703 (P700) with peak absorption at 683 nm & 703 nm respectively.
- These pigments are anchored in thylakoids in separate units of organization called Photosystems. These forms the two Photosystem ie Photosystem I (P700) and Photosystem II (P680).
- Their main function is to harvest light energy & transfer it to their respective reaction centre.

Location of Photosystems

Physically, photosystems are found in the thylakoid membranes of the chloroplast. There are two kinds of photosystems: photosystem I (PSI) and photosystem II (PSII). PSII acts first during the light transformation process in photosynthesis, but it was named PSII because it was discovered second.

Components of Photosystem

- Each photosystem consists of two closely linked components. The first is the antenna complex formed by hundreds of pigment molecules and proteins. They capture photons and transfer the harvested light energy to the second component (Core complex). Therefore they are called Light Harvesting complex (LHC). Core complex containing reaction center possesses Chl *a* molecules in a matrix of protein. A single photosystem consist of about 250-400 pigment molecules. Carotenoids are present in both the pigment systems.

<u>Composition of Photosystem</u>

- Two large multimolecular protein pigment complexes in PSI & PSII consist of about 18 & over 30 distinct subunits respectively.
- These subunits are grouped as Protein, Lipids, Pigments & Coenzyme & co-factors.

<u>Similarities & Differences between PSI & PSII</u>

1. PSI located on Non-appressed regions & PSII on Appressed regions
2. Reaction centre of PS II is P680 and Reaction centre of PS I is P700
3. Pigment System of PSII-PS II contains chlorophyll *b* & some forms of chlorophyll *a* (such as Chl *a* 662, chl *a* 670, chl *a* 677). Very small amount of special form of chlorophyll *a* called P 680 constitutes the reaction centre of pigment system II.

   Pigment system of PSI- PS I contains chlorophyll-*b*, different forms of chlorophyll *a* -such as Chl-*a* 670, chl-*a* 680, or chl -677, chl *a* 684, chl *a* 692 or chl 673, chl *a* 683. *These differ according to different workers). Very small amount of a special form of chlorophyll *a* absorbing at 700 nm, ie. P700, constitutes reaction centre.
4. Chlorophyll, Carotenoid pigments RATIO in PS I is (20-30:1) and in PS II is PS II (3-7:1).

5. In PSI, CCI contains two large proteins called PsaA & PsaB with molecular mass ranging from 66 to 70 k Da. In PSII, CCII contains two large membrane proteins called D1 & D2.

6. Involved in cyclic (PS I) & non –cyclic photo-phosphorylation (PSI & PSII)

7. Pigment system I is relatively very weakly fluorescent & Pigment system II is relatively Strongly fluorescent.

Working of Photosystems

Non-cyclic Photophosphorylation

Photosystem II

The light driven reaction of photosynthesis also called the light reaction (Hill Reaction), referred to as the electron transport chain, was first propounded by Robert Hill in 1939. The electron transport chain of photosynthesis is initiated by absorption of light by Photosystem II (P_{680}). When P_{680} absorbs light, it is excited and its electrons are transferred to an electron acceptor molecule. Therefore, P_{680} becomes a strong oxidizing agent and splits a molecule of water to release oxygen. This light dependent splitting of water molecule is called photolysis. However, Mn^{2+}, $Ca^{2+}$and Cl^- ions play important roles in photolysis of water. After photolysis of water, electrons are generated, which are then passed to the oxidized $P_{680.}$ Now, the electrons deficient P_{680} (as it had already transferred its electros to an acceptor molecule) is able to restore its electron from the water molecule. After accepting electrons from the excited P_{680}, the primary electron acceptor is reduced. The primary electron acceptor in plants is pheophytin. The reduced acceptor which is a strong reducing agent now donates its electrons to the downstream components of the electron transport chain.

Photosytem I

Similar to photosystem II (P_{680}), Photosystem I (P_{700}) is excited on absorption of light and gets oxidized, and transfers its electrons to the primary electron acceptor (pheophytin) which in turn gets reduced. While the oxidized P_{700} draws electrons from PSII, the reduced electron acceptor of PSI transfers electrons to ferredoxin-NADP reductase to reduce NADP to $NADPH_2$. $NADPH_2$ is a powerful reducing agent and is utilized in the reduction of CO_2 to carbohydrates in the carbon reaction of photosynthesis. The reduction of CO_2 to carbohydrates requires energy in the form of ATP in the presence of light in chloroplast is called photophosphorylation.

The other intermediate components of electron transport chain ie plastoquinone (PQ) & plastocyanin (PC) act as mobile electron carriers between this complex & either one of the two pigment systems

Plastoqsuinone which infact is a hydrogen carrier acts between pigment system II & cytochrome b_6f complex. Plastocyanin acts between cytochrome b_6f complex & pigment system I.

The ATPase or ATP synthase the enzymatic protein complexes responsible for photophosphorylation are found in the thylakoid membranes in those regions which are in direct contact with stroma of chloroplast.

ATP synthase consists to two subunits called CF_0 & CF_1. (CF=Coupling factor). CF_0 is an integral protein complex across the thylakoid membrane & consist so a cluster of at least four different types of polypeptides named a, b, b’ & c with stoichiometry of a, b, b’ & C12).

It forms a channel for movement of proton across the thylakoid membrane. The head piece CF_1 consists of five different polypeptides (3 copies each of α, β & one copy each of γ, δ & ε. The catalytic sites are situated largely on α & β subunits.

The four complexes (PSI, PSII, Cytb$_6$*f* & ATPase) are integral membrane proteins with a substantial portion of their structure embedded in the lipid bilayer.

The orientation of these four complexes is not random but is vectorial. This is essential feature of all energy transducing membranes & a prerequisite for their capacity to conserve energy through chemiosmosis.

PSI & PSII can be isolated from chloroplasts of green algae & higher plants by means of physical & chemical methods.

<u>Cyclic photophosphorylation</u>

In contrast to non cyclic electron transport, the cyclic electron transport involved only PSI and takes place under the conditions which exclude non cyclic photophosphorylation. This situation is created if the activity of pigment system II is blocked. The latter can be accomplished by the use of specific inhibitors or by using wavelengths of light greater than 680 nm. Under these conditions (i) only pigment system I remains active (ii) photolysis of water does not take place (iii) blockage of non cyclic ATP formation caused a drop in CO_2 assimilation in dark reaction and (iv) there is a consequent shortage of oxidized $NADP^+$.

Thus when P_{700} molecule is excited in PSI by absorbing a photon (quantum) of light, the ejected electron is captured by ferredoxin via FRS. From *ferredoxin* the electron cannot be drained off to the dark reaction of photosynthesis through oxidized $NADP^+$ (due to shortage of latter) and ultimately it falls back to the P_{700} molecule involving ofcourse a number of other intermediate electron carriers of redox system. These are probably cytochrome b$_6$, cytochrome *f* and plastocyanin. It is obvious from the values of E_0' that all these intermediate electrons carriers form an electrochemical gradient of decreasing negative values which facilitates the downhill transport of electron from FRS to P_{700} molecule. At two places during this electron transport ie between *ferredoxin* and cytochrome b_6 and; between b_6 and cytochrome *f* there is phosphorylation of one ADP molecule to form one ATP molecule. Thus two ATP molecules are produced in this cycle.

Because in the above electron transport system the electron which was ejected from P_{700} molecule is cycled back, the process has been called cyclic electron transport and the accompanying phosphorylation as the cyclic photophosphorylation.