Section B and C

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A. PHOTOSYNTHESIS

1. INTRODUCTION

Photosynthesis is the single most important physico-biochemical process of the world on which the existence of life on earth depends. It is the ability of green plants only to utilize the energy of light to produce carbon containing organic material from stable inorganic matter by photosynthetic process. It is from the carbohydrate produced by photosynthesis may directly or indirectly all the countless number of organic compounds which compose the living world are derived. The oxidation of organic compounds releases stored energy to be utilized by organisms to drive essential metabolic processes. Any energy released during oxidation of organic compounds is ultimately derived from light energy intercepted by green plants during photosynthesis.

PHOTOSYNTHESIS ON EARTH

General data regarding the amount of light received on earth and its utilization during photosynthesis are tentatively available now. The outer atmosphere receives about 1300xl0^{21} cal/year, me earth surface receives 650x10^{21} cal/year, me probable absorption by green plants on land is 25 x10^{21} cal/year. Considering two per cent efficiency, photosynthesis by land plants equals to 50 x10^{9} tons/year and by ocean plants 150x10^{9} tons/year of organic carbon produced. For crops between 2 and 2.5% and under laboratory conditions between 20 and 25% efficiency of photosynthesis has been observed.

The amount reaching the earth surface 650 x 10^{21} cal/year is equivalent to a daytime average of 0.5 cal/cm^{2} /min. About sixty per cent radiation received on earth is far and infrared which does not participate in photosynthesis. It leaves about, 260 x 10^{21} cal/year, i.e. about 180 x 10^{21} cal/year for the oceans and 80 x10^{21} cal/year for the land areas. More than half area of land produces little or no vegetation. If the efficiency of photosynthesis is two per cent, this represents about 0.5 x 10^{21} cal/year, i.e. 50 x 10^{9} ions of organic carbon.

DEFINITION OF PHOTOSYNTHESIS

In simple terms, the photosynthesis can be defined as the formation of carbon containing compounds from carbon dioxide and water by illuminated green cells, water and oxygen being the by-products. The simplest equation for photosynthesis can be:

$$6CO_2 + 6H_2O \rightarrow C_6 H_{12} O_6 + 6O_2$$

Since Ruben and Kamen (1941) demonstrated mat the source of liberated oxygen is the water, the equation may be corrected as:

$$6CO_2 + 12H_2O \rightarrow C_6H_{12}O_6 + 6H_2O + 6O_2$$

Because 6 molecules of water are insufficient for the release of 6 molecules of oxygen, more water molecules (at least 12 per molecule of hexose formed) have to be incorporated in the equation.

Of these components, water is obtained from the soil by roots of the terrestrial plants and by the general surface by hydrophytes. As a source of light, sunlight is utilized. The terrestrial plants absorb CO_2 from the atmosphere where it is present up to 0.03 per cent while hydrophytes obtain it from the water where it is found dissolved in water up to 0.3 per cent or even more. Due to this reason, the hydrophytes can produce more photosynthetic products as compared to terrestrial plants. The CO_2 is absorbed by the hydrophytes through the general surface while by the terrestrial plants through the leaves.

PHOTOSYNTHESIS AS A PROCESS

Photosynthesis is an oxidation reduction process in which water is oxidized and carbon dioxide is reduced to carbohydrate level, the water and oxygen being byproducts. The reduction of CO_2 to carbohydrate level needs assimilatory powers such as ATP and NADPH + H^+. Reduction of CO_2 occurs in dark but the production of assimilatory powers is light-dependent. Hence, the process of photosynthesis consists of two phases, one light-dependent phase (light reaction or Hill reaction) and other light-independent phase (dark reaction or Blackman's reaction). Emerson and Arnold (1932) carried out the flashing light experiment and showed the existence of light and dark reactions.

LIGHT REACTION

(Activities found in thylakoids or grana)

Until 1930s it was thought that photosynthetic reaction is reverse of respiration and oxygen evolved during the process comes from CO_2 and water combines with carbon dioxide to produce carbohydrate.

$$CO_2 + H_2O \leftrightarrow (CH_2O) + O_2$$

In 1937, Robert Hill demonstrated that isolated chloroplasts evolved oxygen when they were illuminated in the presence of suitable electron acceptor, such as ferricyanide. The ferricyanide is reduced to ferricyanide by photolysis of water. This reaction is now called **Hill Reaction** and it explains that water is used as a source of electrons for CO_2 fixation and oxygen is evolved as a by product.

Ruben, Randall and Kamen (1941) using heavy isotope of oxygen (O^{18}) in their experiments provided the direct proof that oxygen evolved in photosynthesis comes from water and not from carbon dioxide. When photosynthesis is allowed to proceed in presence of H_2O^{18} and normal CO_2 the evolved oxygen contains the heavy isotope.

$$2\ H_2O^{18} + CO_2 \leftrightarrow (\ CH_2O) + O2^{18}$$

And if photosynthesis is allowed to proceed in presence of CO^{18} and normal water (H_2O_2), heavy oxygen is not evolved.

$$2\ H_2O\ + CO_2^{18} \rightarrow O_2\ + (CH_2O^{18}) + H_2O^{18}$$

The reaction also allows assuming with reasonable certainty that hydrogen necessary for CO_2 reduction is provided by water.

According to recent studies, the light reaction phase of photosynthesis is a considerably complicated process with several important events. It may be briefly discussed with the help of following subheadings:

I. Red drop- Emerson effect and two pigment systems.

(a) Red drop and Emerson effect.

(b) Two pigment systems.

II. Production of assimilatory powers.

(a) Electron transport system in photosynthesis or reduction of NADP.

(b) Photophosphorylation

(i) Non-cyclic Photophosphorylation.

(ii) Cyclic Photophosphorylation.

(iii) Pseudocyclic Photophosphorylation.

III. Energy relationships and efficiency of photosynthesis.

IV. Interrelationship between light and dark reactions.

2. LIGHT HARVESTING COMPLEXES

Two Pigment Systems: With the discovery of red drop and Emerson effect it was concluded that at least two pigment systems are involved in photosynthesis. These two pigment systems have been referred to as pigment system I (PS I) and pigment system II (PS II). The presence of two such systems has been supported by studies based on chloroplast fractionation process which showed two types of particles within the chloroplast membrane, smaller and lighter particles of PS I and larger and heavier particles of PS II.

PS I complex consists of 200 chlorophylls, 50 carotenoids, a molecule of P 700, one cytochrome f, one plastocyanin, two *cyt-b*, FRS (ferredoxin reducing substance), one or two membrane bound ferredoxin molecules etc. It is rich in *chl-a*, iron and copper. Now its *chl-a* is called *chl-a-I*. PS I controls the process of producing a strong reductant to reduce NADP into NADPH + H^+.

PS II Complex consists of 200 chlorophylls, 50 carotenoids, a molecule of P 680, a primary electron acceptor Q as *plastoquinone*, four plastoquinone equivalents four Mn^{++} molecules bound to one or more proteins, two cyt-b_6 559, one *cyt*-b_6 and chloride. It's *chl-a* is now called *chl-a-II*. PS II is concerned with generation of strong oxidant and weak reductant coupled with the release of oxygen.

Salisbury and Ross (1986) proposed that grana mainly contain PS-II while stroma lamellae PS-I. For PS-I light energy is gathered by *chl-a* (P700) and possibly by some *chl-b* and some carotenoids, while for PS II light energy is collected by *chl-a* (P-673), *chl-b* and xanthophylls. The carotenoids collect light energy for both the systems. Reduced carotenoids such as carotenes are found in PS-I while more oxidised forms as xanthophylls, violaxanthin and neoxanthin are found in PS-II. Park (1970) proposed that four subunits of PS-II are found attached to one subunit of PS-I. It is thought that in quantasome, P-700 acts as a photochemical reaction centre and the energy absorbed by the large number of *chl-a 683* molecules is funnelled to P-700 to keep it continuously in excited state. In PS-II, primary electron acceptor is colourless chl. a that lacks Mg and called pheophytin (Pheo). Closely associated with *-pheo* is a quinone called Q because of its ability to quench fluorescence of P-680 by accepting its excited electron.

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