PHOTOSYNTHESIS

DEFINITION

Photosynthesis is the process ...ich green plants synthesize organic food ... carbondioxide and water using energy ...nlight.

OR

The process by which green ...s and certain other organisms transform ... energy into chemical energy.

OR

The process by which plants, ...e bacteria, and some protistans use the ...gy from sunlight to produce sugar, which ...ar respiration converts into ATP, the "fuel" ... by all living things.

RAW MATERIALS

Carbondioxide and water are ... as raw materials in the process for ...hesis of organic food molecules. Chlorophyll ... other photosynthetic pigments capture ...gy of sunlight and convert it into ...mical energy.

AUTOTROPHS

Autotrophic organisms which are green plants are able to carry out photosynthesis. Heterotrophic organisms cannot carry out photosynthesis and are unable to use direct energy of sunlight. They, therefore ~~are~~ are dependant for their energy requirements on green plants.

REACTION

Overall reaction of photosynthesis is:

$$6CO_2 + 12H_2O \xrightarrow[\text{Chlorophyll}]{\text{Light}} C_6H_{12}O_6 + 6O_2 + 6H_2O$$

PHOTOSYNTHETIC REACTANTS AND PRODUCTS

The water and carbondioxide are the reactants in photosynthesis while glucose and oxygen are the product.

IMPORTANCE

i) FOOD SOURCE

Photosynthesis acts as energy capturing and storing process. Energy of sunlight is used in the fixation of CO_2 to a carbohydrate. This serves as food not only for plants but for the entire life on the planet earth. Therefore all living organisms directly or indirectly depends on photosynthesis

2) FOSSIL FUELS

Energy produced by photosynthesis carried out by plants millions of years ago is responsible for the fossil fuels (i-e coal, oil and gas) that power industrial society. In past ages, green plants and small organisms that fed on plants increased faster than they were consumed, and their remains were deposited in Earth's crust by sedimentation and other geological processes. There, protected from oxidation, these organic ~~matter~~ remains were slowly converted to fossil fuels. These fuels not only provide much of the energy used in factories, homes, and transportation but also serve as the raw material for plastics and other synthetic products.

FACTORS AFFECTING RATE OF PHOTOSYNTHESIS

The amount of light, the carbondioxide supply, temperature, water supply, and the availibility of minerals are the most important environmental factors that affect the rate of photosynthesis in land plants.

Role Of Sunlight In Photosynthesis

Sun is the main source of energy for all living organisms. Light is a kind of energy that travels in the form of electromagnetic waves of different wavelengths. It also acts as beam of particles of different frequencies called photons. Their is a wide range of waves for synthesis of organic food molecules (wavelengths occuring between gamma rays and radio waves).

Energy Content

Energy content of photons is inversely proportional to the wavelengths. Short wavelengths are more energetic i-e have high energy content than long wavelength

Visible Spectrum

A portion of the solar radiation is called visible spectrum. Our eyes are sensitive to only a small portion of this solar radiation i-e visible light that ranges from about 390nm to 760nm in wavelength. Photosynthetic pigments absorb and utilize a portion of the visible spectrum.

Wavelengths of ...

have the right amount of energy absorbed by photosynthetic pigments for photosynthesis.

ULTRAVIOLET RADIATION

Wavelength shorter than the visible light i-e ultraviolet radiation are more energetic and are dangerous to the cells because they can break organic molecules.

INFRARED RADIATION

Wavelengths longer than visible light i-e infrared have low energy content that cannot affect photosynthetic process.

LIGHT ABSORPTION

About forty percent of the total of sunlight that enters our atmosphere reaches the earth surface. Most of this radiation is within the visible light range. Dangerous higher energy wavelengths are screened out by the ozone layer and upper layers of atmosphere. Lower energy wavelengths are mostly absorbed or reflected by water vapours and gases or are scattered in the atmosphere. Of the green plants only about a fraction (i.e 1%) is used in the photosynthesis. This small portion of sunlight sustain all forms of life on earth.

ABSORPTION OF LIGHT IN PHOTOSYNTHETIC PIGMENTS

There are two types of photosynthetic pigments i.e chlorophylls and carotenoids.

Chlorophylls absorb mostly violet-blue wavelengths (390-430 nm) and red wavelengths (670-700 nm). Green wavelengths are mostly reflected therefore chlorophyll appears green.

The carotenoids which are called accessory pigments absorb light in the visible spectrum ranging b.w 500 nm and 600 nm in wavelengths.

QURANIC VERSE

"This is He Who made the constellation in the skies, and placed therein a lamp which is not only a source of light but also a source of energy sustaining all life forms on the earth."

PHOTOSYNTHETIC PIGMENTS

DEFINITION

A pigment is any substance that absorbs light. Photosynthetic pigments absorb different wavelengths of solar radiation. The color of pigment comes from the wavelengths of light reflected.

TYPES OF PIGMENTS

There are two types of photosynthetic pigments involved in photosynthesis which are:

1. Chief pigments
2. Accessory / Antenna pigments.

CHIEF PIGMENTS

Chief pigments are the chlorophylls which perform the main function.

ACCESSORY PIGMENTS

Carotenoids and Xynthophyll are the accessory pigments which helps chlorophyll. Chlorophyll acts as a TV set while carotenoids acts as an antenna.

QUANTASOMES

Chlorophyll and other accessory

CHLOROPLASTS

In eukaryotes photosynthetic pigments are located in the chloroplasts. A chloroplast consists of three components; an outermost covering (envelop), grana (singular granum) and stroma.

ENVELOP

The outermost covering (envelop) of the chloroplast is formed by a double membrane structure that encloses the grana and stroma.

GRANA

A granum consists of many flattened fluid-filled membranous sacs or discs called thylakoids which form stacks and resemble a pile of coins. The grana are visible under the light microscope as grains. There are many grana which are interconnected by lamellae called intergrana.

Chlorophyll and other photosynthetic pigments (carotenoids) are present within the membranes of thylakoids. These membranes are the sites of light trapping reaction (light reaction) of photosynthesis.

The cavity of thylakoid is called lumen. The chlorophyll perform oscillatory motion in the lumen.

STROMA

The double membranes enve of the chloroplast surrounds a large central space called stroma. The stroma is basically a solution of enzymes and sm molecules. The dark reactions occur in the stroma, the soluble enzymes of whic catalyze the conversion of CO_2 and miner to carbohydrates and other organic compo The capacity of carbon fixation and reduction is lost if the outer membrane o the chloroplast is broken, allowing the str enzymes to leak out.

PHOTOSYNTHETIC PROKARYOTES

Photosynthetic prokaryotes lack chloroplasts but they do have unsta photosynthetic membranes, which work like thylakoid membrane. Chlorophyll is attached to the thylakoid membrane.

MECHANISM OF PHOTOSYNTHESIS

The mechanism of photosynthesis consists of two distinct steps; one that requires light is called 'light reaction' and the other that doesnot require light called 'dark reaction'.

1. LIGHT REACTION

(LIGHT DEPENDANT REACTION)

Light Reaction takes place in the granum of chloroplast.

PHOTOSYSTEMS

It is initiated when photosynthetic pigments capture light energy. Photosynthetic pigments are organized into clusters called photosystems.

TYPES OF PHOTOSYSTEMS

There are two photosystems i-e photosystem I (PSI) and Photosystem II (PSII). Each photosystem consists of several hundred pigment molecules including chlorophyll a, chlorophyll b, carotenoids and

PHOTOSYSTEM I

Photosystem I absorbs light ≤ 700nm and is called P700.

PHOTOSYSTEM II

Photosystem II absorbs light ≤ 680nm and is called P680.

PARTS OF PHOTOSYSTEM

Their are two parts of each photosystem:

1. Antenna complex
2. Reaction center

ANTENNA COMPLEX

The antenna complex has many molecules of chlorophyll b and carotenoids, all absorb energy and transfer it to the reaction center.

REACTION CENTER

Reaction center has one or more molecules of chlorophyll a molecules along with primary electron acceptor and electron carriers.

The primary electron acceptor traps the electrons from the reaction center and then passes them on to the series of electron carriers.

ELECTRON PATHWAYS

There are two possible pathways of the electrons in the light reaction of photosynthesis. They are:

1. Non-cyclic electron transport
2. Cyclic electron transport

1. NON-CYCLIC ELECTRON TRANSPORT

ABSORPTION OF LIGHT

When sunlight strikes the photosystem II (P680) energy is absorbed by the chlorophyll molecules. The photons are captured in the light-harvesting antenna complexes of photosystem II by chlorophyll and other accessory pigments. The activated chlorophyll loses its two electrons and positively charged chlorophyll molecule is left in the photosystem with a gap of two electrons.

The high energy electrons instead of falling back into the photosystem are captured by an electron acceptor called Plastoquinone (PQ).

..ECTRON TRANSPORT CHAIN

From plastoquinone the electrons ..ss along a series of electrons acceptor ..olecules from one to another in oxidation ..duction process. These electron acceptors ..clude cytochrome 'b', cytochrome 'f' and ..astocyannin. This transfer of electrons ..nstitutes electron transport chain. Each ..olecule in the electron transport chain is ..ternately reduced when it gains electron ..d is oxidized when it losses electrons.

PHOTOPHOSPHORYLATION

When electrons are passed ..rough electron transport chain, they lose energy. Some of the energy lost by electrons between cytochrome 'b' and cytochrome 'f' ..s used in making ATP from ADP and ..norganic phosphate. The process of formation of ATP from ADP and inorganic phosphate using energy from sunlight is called photophosphorylation.

PHOTOSYSTEM I

The electrons from plastocyannin are received by another photosystem called Photosystem I (P700). At the same time light falls on photosystem I and activates its two electrons. Activated electrons are received by Ferrodoxin reducing substance (FRS); electron acceptor of PSI.* The electrons are then passed along a chain of electron acceptors to which it transfers some of its energy(*). The energy delivered to the electron acceptors is used to move hydrogen ions across the thylakoid membrane into the lumen.

REDUCTION OF NADP

From FRS electrons are passed to oxidized NADP (Nicotinamide Adenine Dinucleotide Phosphate). The reduced NADP receives hydrogen from water and is converted into $NADPH_2$.

PHOTOLYSIS OF WATER

The breaking of water molecules with the help of light is known as photolysis of water.

When photosystem II absorbs light, water molecules splits into OH^- and H^+. The OH^- ions react to form some water again and release oxygen and electrons.

$4H_2O \longrightarrow 4H^+ + 4(OH^-) + 2e^-$
$4(OH^-) \longrightarrow 2H_2O + O_2$

ZIGZAG SCHEME (Z-SCHEME)

Electrons from water molecules accepted by positively charged chlorophyll ... of Photosystem II, filling the gap between ...ed by the two energized electrons. The ... deficiency of photosystem I has been ... by electrons coming from photosystem II. ...ansport of electrons is called Non-cyclic ... transport bcz electrons donot move in a ... It involves both the photosystems and ... zigzag path.

PRODUCTS

In non-cyclic electron transport system ...ons donot move in a cycle. Both the ...systems are involved and ATP and NADPH produced which are used in dark reaction. ...ore it is also called Z-scheme (Zigzag scheme

2. Cyclic Electron Transport

Condition

In contrast to non-cyclic electron transport, the cyclic electron transport involves only Photosystem I. It occurs in rare conditions if the activity of photosystem is blocked.

Process

When P700 form of chlorophyll molecule in photosystem I absorbs light, it is activated. The activated chlorophyll loses electrons which are captured by ferrodoxin reducing substance (FRS). Ferrodoxin is an iron containing protein which acts as an electron carrier. A second electron carrier Plastoquinone (Pq) carries the electrons to a complex of two cytochromes. The electrons are returned by Plastocyanin (Pc) to the P700 pigment in the reaction center to complete the cycle.

The electrons which are ejected from P700 molecules are cycled back in the above electron transport therefore the process is called cyclic electron transport

Cyclic Photophosphorylation

In the process, energy is provided to produce a proton gradient across the membrane which can be used for the ADP to ATP conversion. ATP synthesis during this cyclic electron flow is called cyclic photophosphorylation.

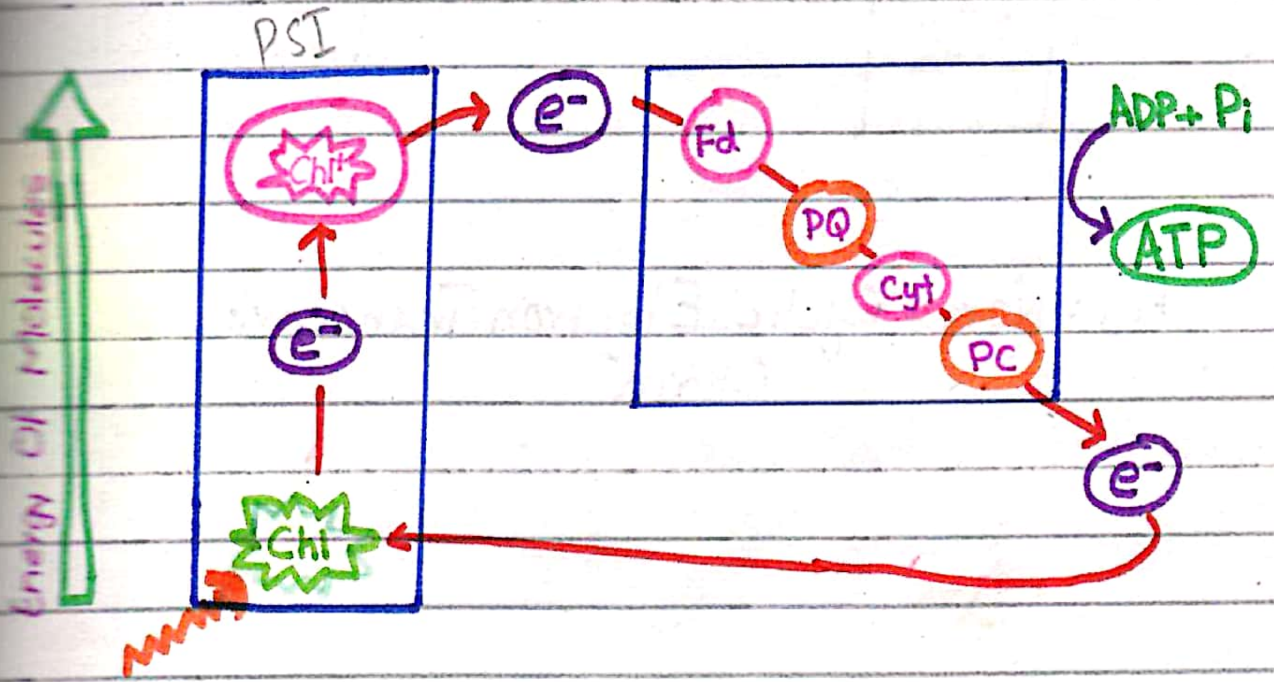


Fig: Cyclic Electron Transport

Products Of Light Reaction

Water and energy of sunlight are used in light reaction. The products of light reactions are ATP and NADPH. Both of these are transported from grana to stroma for use in dark reactions.

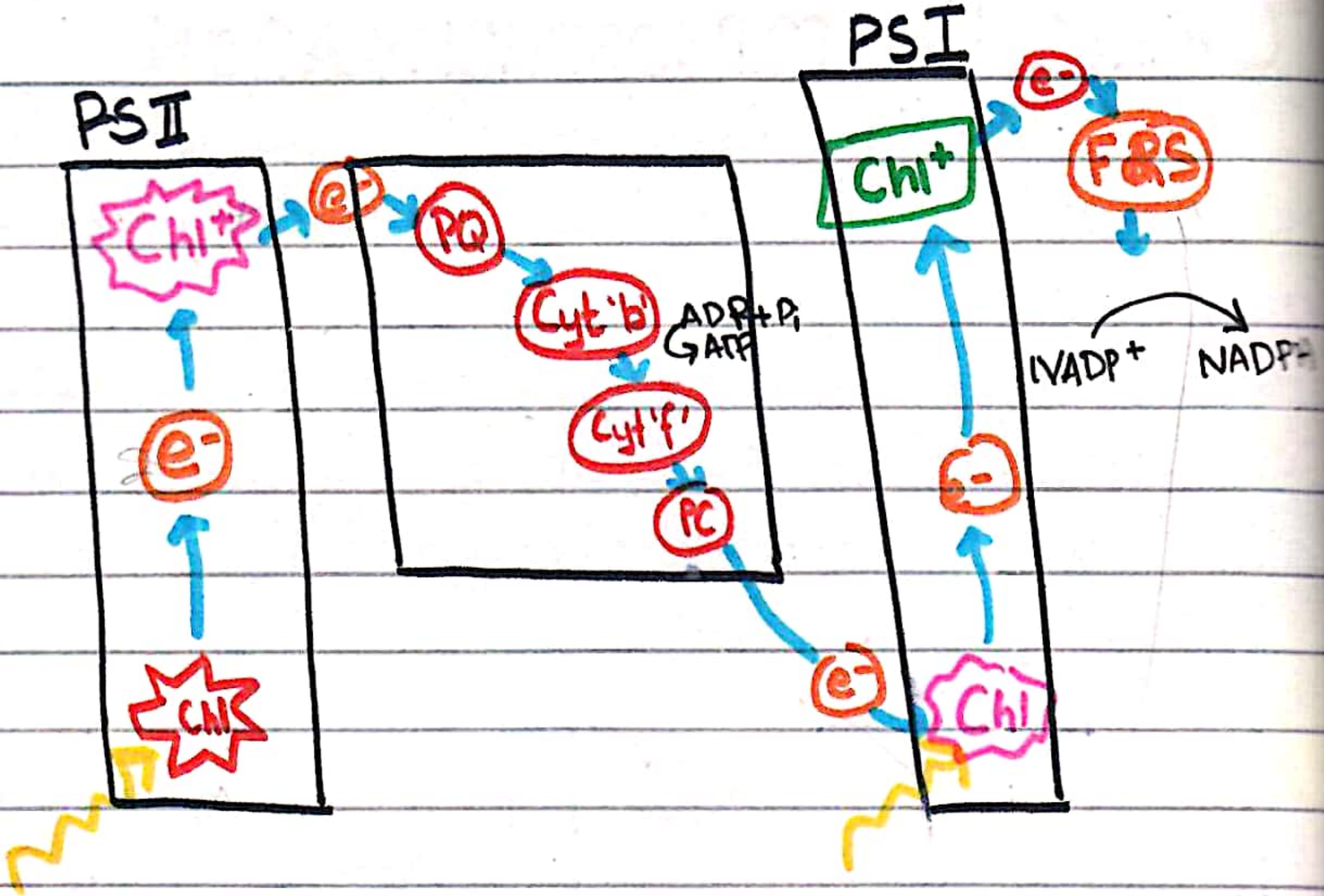


Fig : Non - Cyclic Electron Transport Chain

2. Dark Reactions (Calvin Cycle) (Light-Independant Reactions)

Light independent reactions donot require direct energy of sunlight. It may occur during day time but are called dark reactions so as to differentiate them from light reactions. The sequence of dark reactions was investigated by Melvin Calvin and his colleagues in 1950. They occur in a series of reactions in the stroma of the chloroplast and taking the course of a cycle known as Calvin-Benson cycle.

The Calvin cycle is completed in three stages:

1. Carbon fixation
2. Reduction
3. Regeneration of RuBP

1. Carbon Fixation

In the stroma, in addition to CO_2, two other chemicals are present to initiate the Calvin cycle; an enzyme abbreviated RuBisCo and the molecule Ribulose Bisphosphate (RuBP). RuBP, a 5-carbon sugar, already present in the stroma reacts with CO_2 of air to form a 6-Carbon compound. This compound is unstable and soon splits up into two molecules of 3-carbon compound called Phosphoglycerate (PGA).

[P.S: 'RuBisCo' (Ribolose Biphosphate Carboxylas catalyzes the reaction b.w CO_2 and RuBP forming the six-carbon compound

RuBisCo is regarded as the most common protein in nature. The carbon that was part of CO_2 molecule is now a part of an organic molecule. This is called carbon fixation. PGA is regarded as the first product of photosynthesis to be identified.

RuBP + CO_2 ⟶ short lived 6-C Compound

6-C Compound → 2PGA

2. REDUCTION

PGA formed in the previous step is reduced into phosphoglycerldehyde (PGAL) in this stage. The products of light reaction i-e NADPH and ATP are used in the process. Each molecule of phosphoglyceric acid (PGA) receives energy from ATP and hydrogen from NADPH of light reaction.

forming phosphoglyceraldehyde (PGAL) and water. ATP and NADPH use their stored energy to convert the three-carbon compound, PGA into another three-carbon compound called PGAL. This type of reaction is called reduction reaction, bcz it involves the gain of electrons. The molecules of ADP and NADP, resulting from the reduction reaction, return to light reaction where ADP is converted into ATP and NADP is reduced to NADPH. In reduction process fixed carbon is reduced to a 3-carbon sugar molecule of PGAL.

$$PGA + ATP + NADPH \xrightarrow{H_2O} PGAL + ADP + P + NADP$$

3. REGENERATION OF RuBP

In this stage RuBP molecules are regenerated so as to continue the cycle. The PGAL molecules formed in the reduction stage have many alternatives. Out of every six molecules of PGAL formed, only one molecule leaves the cycle to be used by the plant for making glucose and other organic compounds. The other five PGAL molecules are recycled to regenerate 3 molecules of five carbons RuBP by the following steps.

STEP 1:

Two PGAL combines to form 6-C compound

3-C + 3-C → 6-C

STEP 2:

With this 6-C compound another PGAL (3-C) combines to form 9-C compound which quickly decomposes into a 4-C and 5-C compound.

6-C + 3-C → 9-C → 4-C
→ 5-C

STEP 3:

The 5-C is converted into RuBP in the presence of ATP

$$5\text{-}C \xrightarrow{ATP} RuBP$$

While with the 4-C compound another PGAL (3-C) combines forming 7-C compound.

4-C + 3-C → 7-C

STEP 4:

With this 7-C compound another PGAL (3-C) combines forming 10-C compound which quickly decomposes in two 5-C compounds

7-C + 3-C → 10-C

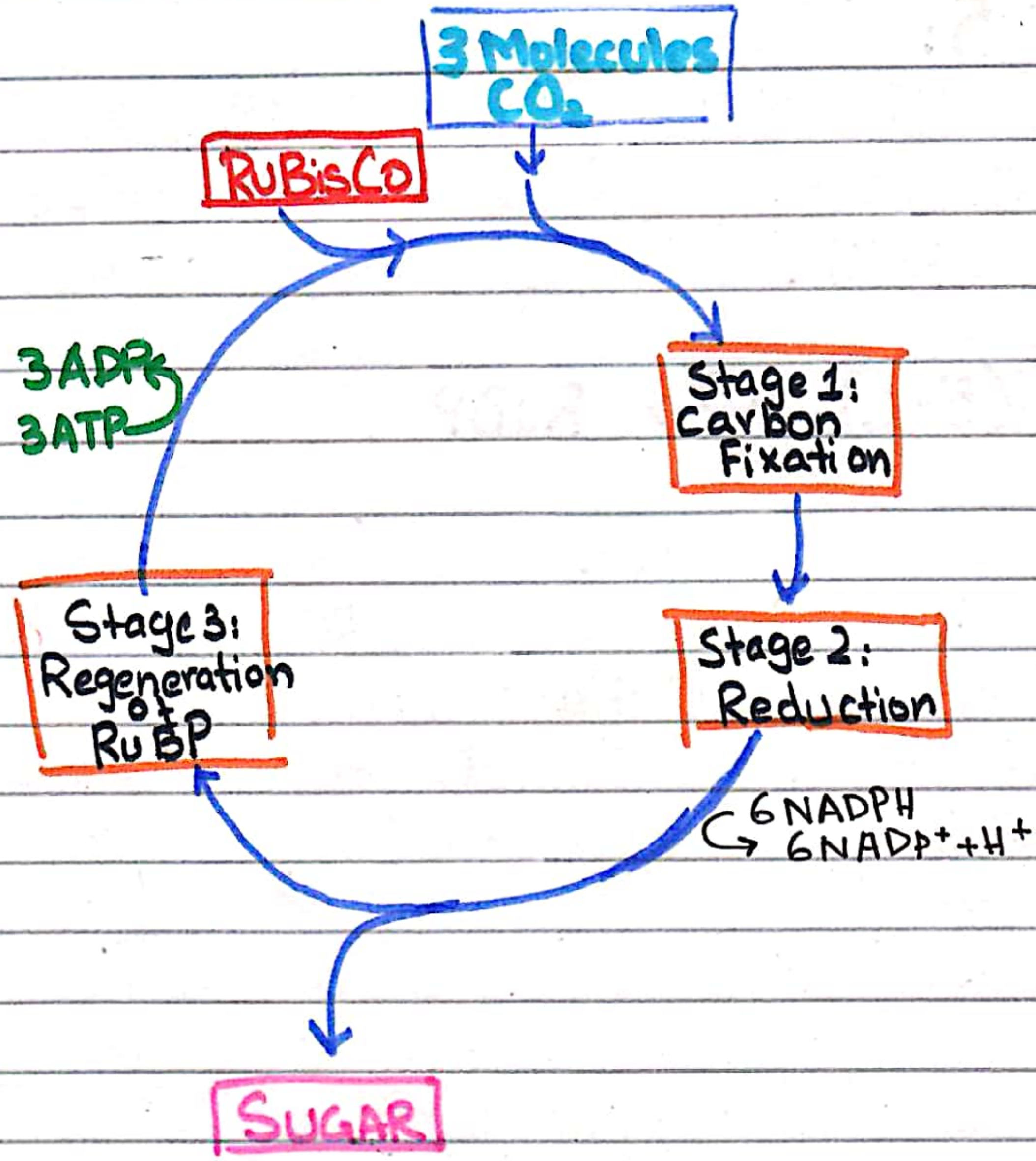
10-C → 5-C + 5-C

STEP 5:

In the presence of ATP, these two 5-C compounds are converted into 2 RuBP.

(5-C) $\xrightarrow{ATP}$ RuBP

This process uses some ATP produced in light reaction. Ribulose biphosphate (RuBP) is then available to accept CO_2 and restart the cycle. With the regeneration of RuBP the Calvin cycle or Dark reactions complete.



[A sugar molecule is formed from ~~three~~ six successive Calvin cycles.]