# BIOENERGY

**Chapter 1.** Photosynthesis. Process description.

**Chapter 2.** Biomass. Definition, biomass composition, biomass as a carbon dioxide storage, types of biomass.

**Chapter 3.** Biofuels. Introduction. Definition, classification. World markets, production, basic technologies for biofuel production. Relative production efficiency. Energy balance. Biofuels from the environmental point of view.

**Chapter 4.** Definition and composition of bioethanol, prime materials, production technologies, industrial processes, applications.

**Chapter 5.** Biodiesel. Definition, the transesterification process. Prime materials. Industrial production. Uses and applications.

**Chapter 6.** Definition and composition of biogas. Sources, process of biodegradation, production technologies, applications.

**Chapter 7.** Thermochemical technologies for solid biomass processing.

# 1. INTRODUCTION

## Photosynthesis

•Plants, algae and photosynthetic bacteria use a physical-chemical process to synthesize organic compounds using sun beam energy.

•Photosynthesis **is a fundamental process that enables live on earth** and has a deep impact on the climate and the atmosphere: every year, photosynthetic organisms capture 10% of all de carbon dioxide present in the atmosphere.

## Why do we look at photosynthesis when we start studying Bioenergy?

1. **Mention the different kind of energies present in planet Earth.**
2. **Where is the origin of each one?**
3. **What is essential for life on Earth?**

- The knowledge of this process is fundamental to understand **the balance of life on the planet** as it has a direct influence on the atmosphere and the climate.
- This means that **the raise in carbon dioxide concentration caused by humans, will have an effect on Photosynthesis.**

## 2. OXYGENIC AND ANOXYGENIC PHOTOSYNTHESIS

**All living organisms** conform three main groups called domains: Archaea, bacteria and Eucarya, all of the shaing a common ancestor.

When we talk about **Photosynthesis** we refer to **fotosynthetic organisms:** the ***bacteria*** *domain* (photosynthetic bacteria) and the ***Eucarya*** domain (cyanobacteria, algae, Plants and some protisto).

**PHOTOSYNTHESIS**

**Photosynthetic Organisms**

-Photosynthetic Bacteria

- Cianobacteria
- Algae
- Plants

**Transformation process**

Sunlight → Chemical Energy

The chemical energy is used to transform inorganic matter into Organic matter.

**Figure 1.** Schematic of the main photosynthetic organisms

## 2. OXYGENIC AND ANOXYGENIC PHOTOSYNTHESIS

### OXYGENIC

**Plant, algae** and **some photosynthetic bacteria,** during the photosyhthetic process, **use atmostheric carbon dioxide and water** to synthesize organic compounds while **releasing molecular oxygen** to the atmosphere.

This process is called **OXYGENIC PHOTOSYNTHESIS**.

### ANOXYGENIC

However, **some bacteria species** use sun light to obtain organic compounds, but they dont release oxygen as a subproduct.

In this case, we talk about **ANOXYGENIC PHOTOSYNTHESIS**.

## 2. OXYGENIC AND ANOXYGENIC PHOTOSYNTHESIS

The apparition and evolution of Photosynthesis is closely related to life on earth.

Earth formed about **4500 milion years ago**.

The presence of life is related to the evolution of biological processes.

At first, **air in the atmosphere had barely any oxygen on its composition**. The earliest living organisms, photosynthetic bacteria, used ANOXYGENIC photosynthesis, so they did not release any oxygen to the atmosphere.

## 2. OXYGENIC AND ANOXYGENIC PHOTOSYNTHESIS

**3000 milion years ago**, they make an appearance the first photosynthetic bacteria that used OXYGENIC PHOTOSYNTHESIS (cyanobacteria).

These bacteria **released oxygen to the atmosphere** as a subproduct of the process.

As **oxygen concentration progressively increased,** it brought an explosion of heterotrophe living organisms.

## 2. OXYGENIC AND ANOXYGENIC PHOTOSYNTHESIS

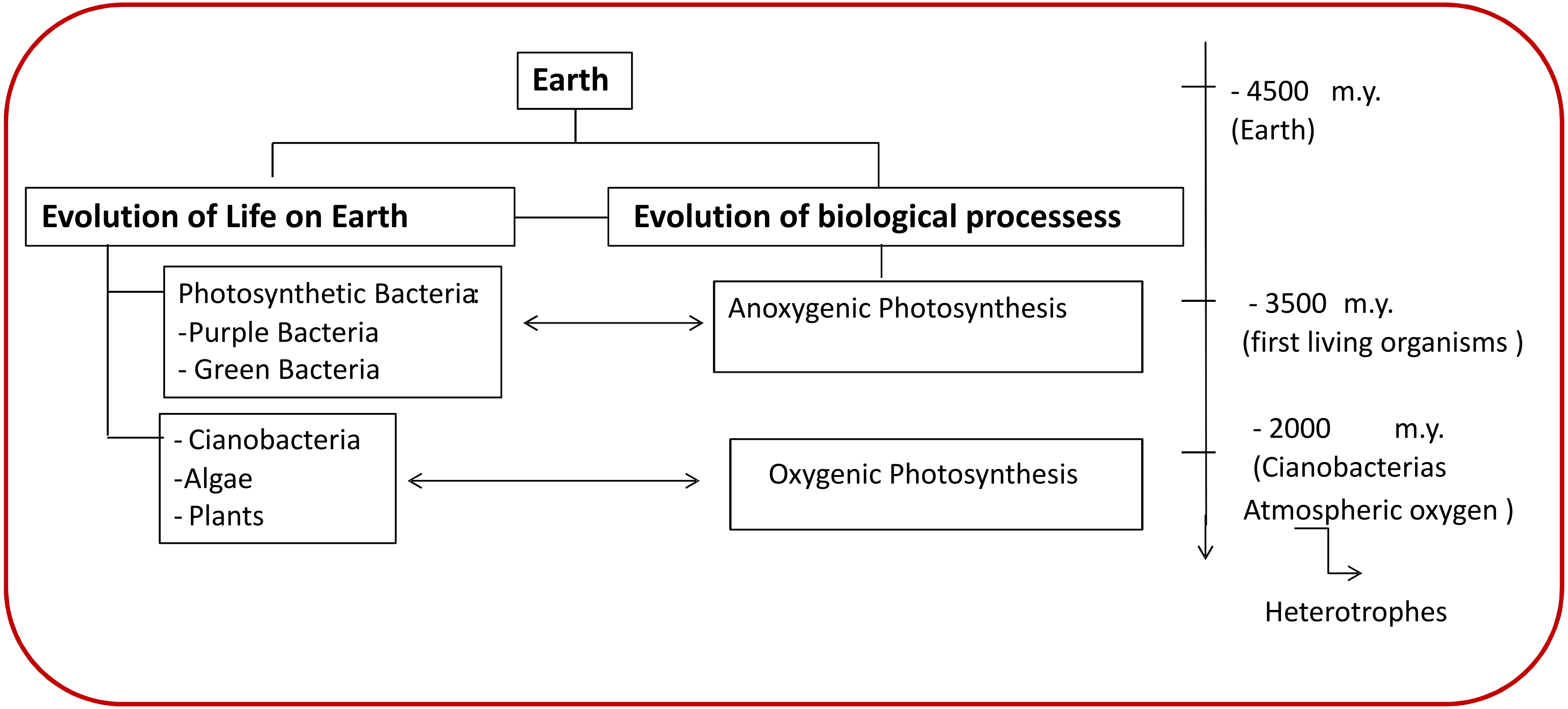


**Figure 2. Evolution of especies taking photosynthesis as reference.**

## 3. STAGES OF THE OXYGENIC PHOTOSYNTHESIS

### STAGES OF THE OXYGENIC PHOTOSYNTHESIS (general)

$CO_2$ + $H_2O$ + LIGHT (sunlight) → ORGANIC MATTER + $O_2$

### Detailed reaction for OXYGENIC photosynthesis

$6CO_2$ + $6H_2O$ + LIGHT (sunlight) → $C_6H_{12}O_6$ + $6O_2$

## 3. STAGES OF THE OXYGENIC PHOTOSYNTHESIS

Photosynthesis-processes have two stages:

- **Fotochemical Stage**

It consists of collecting energy from sunlight and converting it on chemical energy. The molecules in charge are photosynthetic pigments embedded in membranes: plasma membranes in the case of bacteria, thylakoidal membrane of chloroplasts in the case of cyanobacteria, algae and plants.

- **Biochemical Stage**

In this stage, molecules use the chemical energy obtained earlier to convert inorganic compounds ($H_2O$, $CO_2$) into organic compounds that will be used as sustenance for the living organism.

## 3. STAGES OF THE OXYGENIC PHOTOSYNTHESIS

**PHOTOSYNTHESIS**

**Photochemical stage:**

Solar Energy → Chemical Energy

**Biochemical stage:**

Inorganic Compounds → Organic Compounds

**Figure 3.** Stages of Photosynthesis

## 3. STAGES OF THE OXYGENIC PHOTOSYNTHESIS

### 3.1 LIGHT REACTIONS

All photosynthetic organisms have pigments that will enable them to absorb visible radiation energy and start the reactions necessary for photosynthesis.

**Pigments are divided in two main groups: Chlorophylls** and **Carotenoids.**

Both have one thing in common: a system where a double bond is combined with a single bond.

## 3. STAGES OF THE OXYGENIC PHOTOSYNTHESIS

These circumstance make possible to the electrons sited on the double bond to get **“excited“,** that is, to jump to a higher energy level without breaking the molecule.

Different pigments will be able to absorb different light wave lengths, and among all of the they will be able to cover the whole light spectra in a coordinated way.

Photosynthetic pigments do not arrange themselves by chance, they arrange themselves forming **fothosysthetic systems.**

## 3. STAGES OF THE OXYGENIC PHOTOSYNTHESIS

### 3.1 LIGHT REACTIONS

A photosystem is a functional unit where its main components are:

**a) Antenna-complex**

- Formed by several hundreds of chlorophyll, carotenoid and other proteins.
- Their function consists on the capture of energy from different wave-legths and direct it to a single chlorophyll molecule.
- The light-harvesting antenna works as funnel to channel light energy.

**b) Reaction centre**

- This chorophyll molecule in charge of collecting the light energy from antenna complexes forms a team with an electron donor and and electron acceptor and it will be different depending on the photosystem.
- There are two types of photosystems: **photosystem I (PS I) and photosystem II (PS II)**, depending on the type of chlorophyll at the core of the reaction centre.

# 3. STAGES OF THE OXYGENIC PHOTOSYNTHESIS

## 3.1 LIGHT REACTIONS

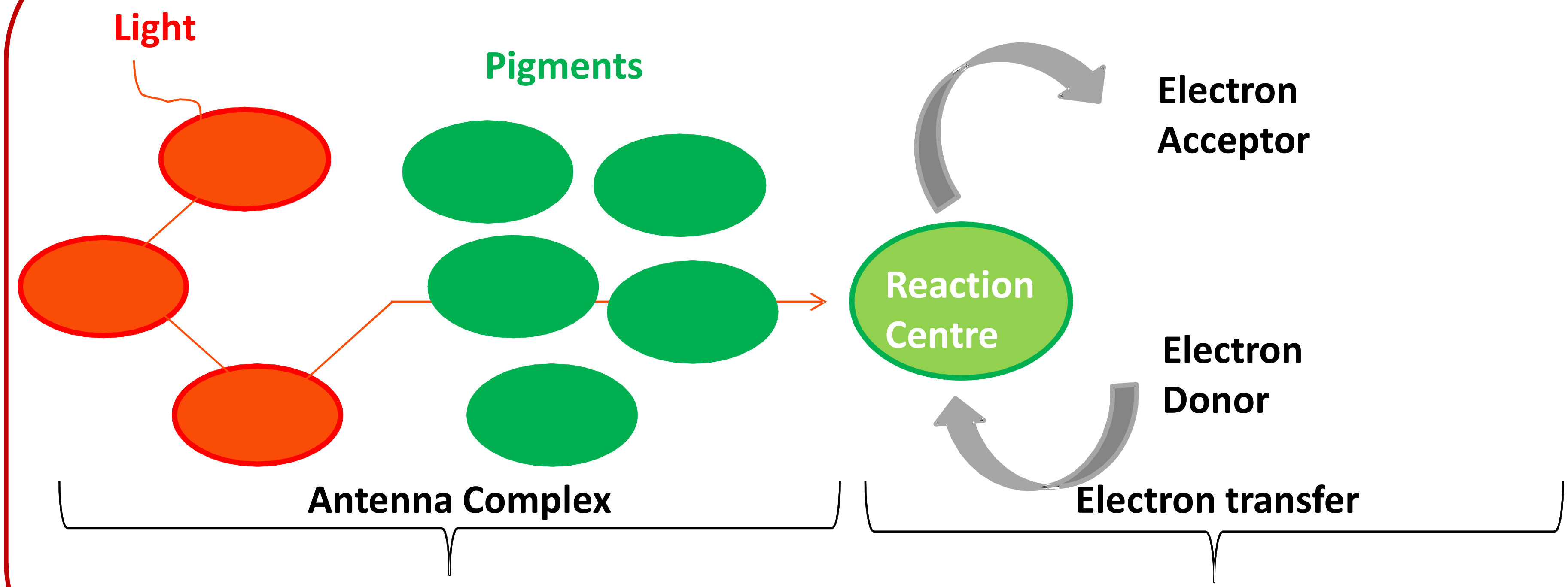


**Figure 4.** Structure and functioning of antenna pigments.

# 3. STAGES OF THE OXYGENIC PHOTOSYNTHESIS

## 3.1 LIGHT REACTIONS

During this phase, **two very important molecules in charge of the transformation of light energy into chemical energy are formed: ATP and NADPH.**

**ATP**: Adenosine Triphosphate, a primary nucleotide in charge of obtainign energy for the cell.

**$NADP^+$ and NADPH**: nikotinamide adenine dinucleotide phosphate, is a coenzyme used an several anabolic processes. Its oxidized form is $NADP^+$ and the reduced form is NADPH.

# 3. STAGES OF THE OXYGENIC PHOTOSYNTHESIS

## 3.1 LIGHT REACTIONS

**Process**

- Photons are captured by the antenna complexes of PS II and directed to a chlorophyll molecule at the core of the reaction centre that, when it obtains sufficient excitation energy, transfers an electron pair to the primary acceptor molecule. These electrons are shuttled through an electron transport chain.

- Now **PS II, which is in an oxidated state**, takes two electrons from a water molecule, returning to the initial state. This is made though a water photolisis process.

-**At the same time, another electron pair is excited in** PS I and go to another part of the electron transport chain that will reduce *NADP*$^+$ *to NADPH* .

-Electrons coming from PS II go to PS I to bring it to its original state.

# 3. STAGES OF THE OXYGENIC PHOTOSYNTHESIS

## 3.1 LIGHT REACTIONS

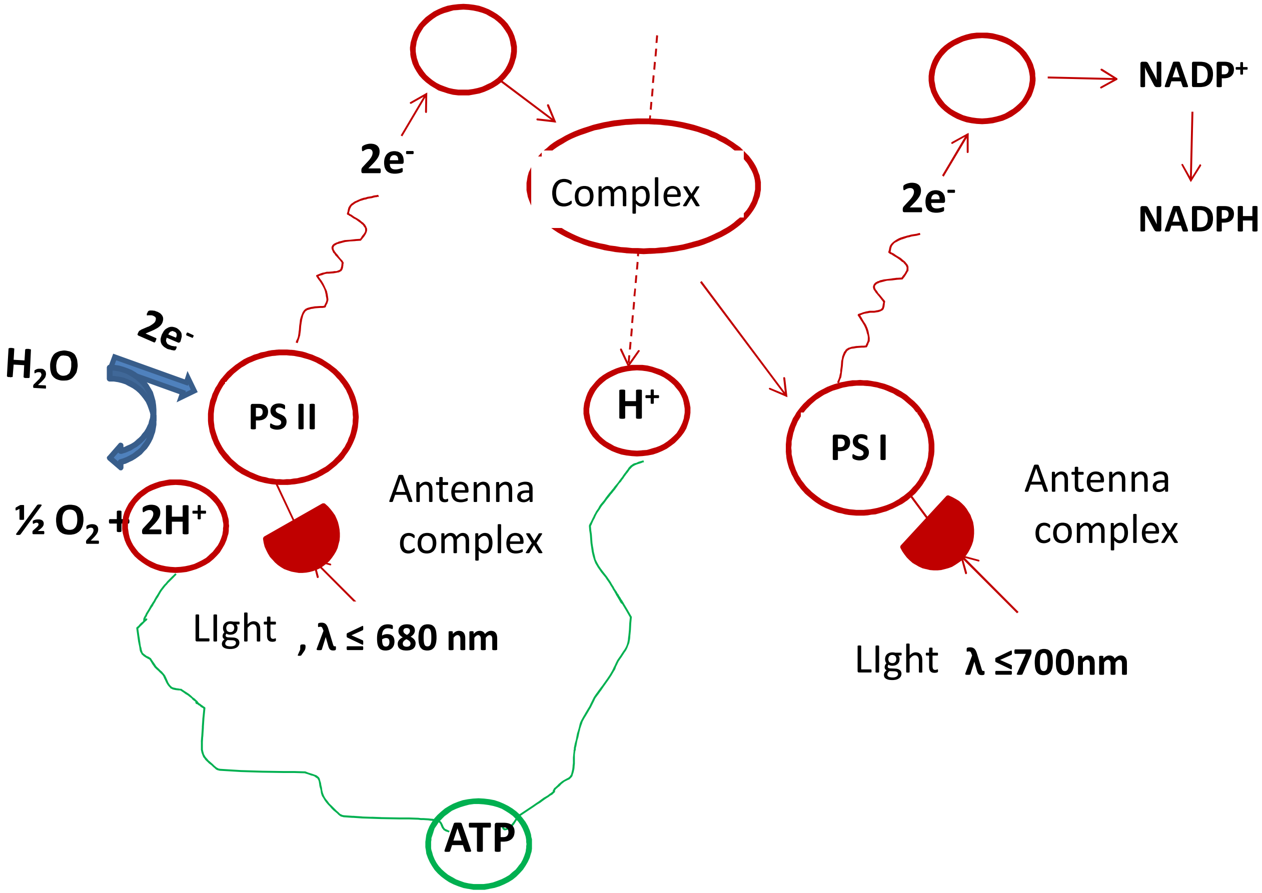


**Figure 5.** Transport of electrons during photosynthesis. Non-cyclic phosphorilation.

# 3. STAGES OF THE OXYGENIC PHOTOSYNTHESIS

## 3.1 LIGHT REACTIONS

**CONCLUSIONS**

- **Light reactions occur** through electron transport **in the thylakoid membranes of chloroplasts.**

- **Transport happens from $H_2O$,** a weak electron donor, to **$NADP^+$** a weak electron-acceptor.

- This electron transfer process will not happen in the absence of an energy donation.

- That is the reason why photosynthesis depends on light energy: to be able to take electrons from water and transfer them to reduce $NADP^+$ to NADPH .

- This process is called non-cyclic reaction.

## 3. STAGES OF THE OXYGENIC PHOTOSYNTHESIS

### 3.1 LIGHT REACTIONS

For each molecule of water broken by photolisis, we will obtain one ***NADPH* molecule and one *ATP* molecule.** This fact could be a problem because, as will see later on, we will be needing more ATP than NADPH during the light-independent reactions.

- This means that photosynthetic cellulae will be needing an, **alternative mechanism** to ***ATP without NADPH*** .

- **This alternative mechanism** is called **Cyclic phosphorilation** and it goes like this: electrons excited in PS I, instead of joining the electrion-carrying chain to *NADP*$^+$, join the chain in a different part that takes them back to PS I.

- This return produces enough energy to pump protons to obtain ATP. If we compare this process with the non-cyclic phosphorilation, in this case water and PS II have no part in the process, there is no oxygen release nor NADPH formation.

# 3. STAGES OF THE OXYGENIC PHOTOSYNTHESIS

## 3.1 LIGHT REACTIONS

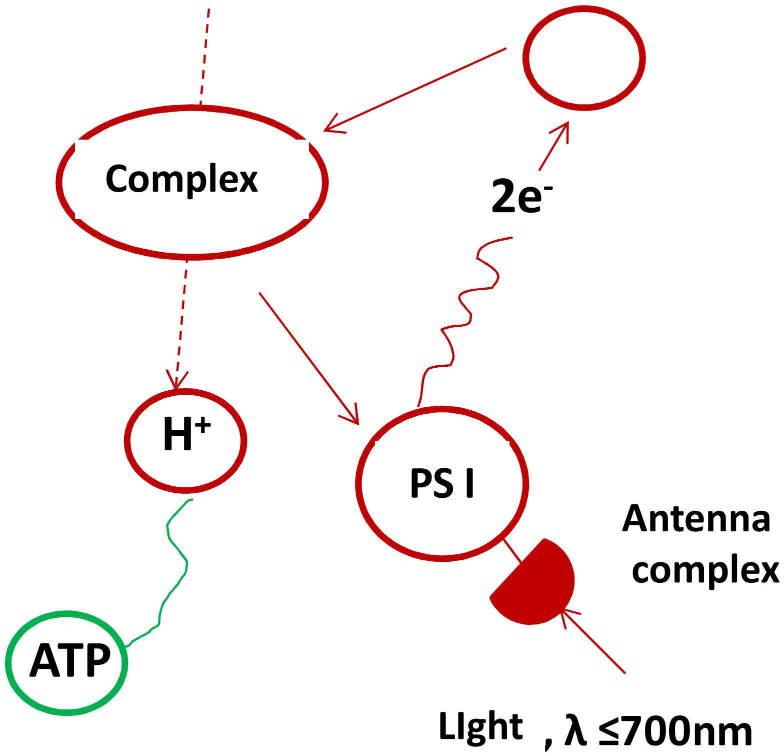


**Figure 6.** Transport of electrons during photosynthesis. Cyclic phosphorilation.

# 3. STAGES OF THE OXYGENIC PHOTOSYNTHESIS

## 3.2 LIGHT INDEPENDENT REACTIONS

During this phase, energy stoted in ***NADPH and ATP will be used to transform* carbon dioxide and mineral matter into organic material.**

While there is no need for light energy for this process, we do need products from the lighted phase to function.

The time amount available for this light independent reactions is limited and it will stop when the light-phase products are used-up.

The producs obtained in this phase will depend on the molecules that will be used to bond the carbon and the mineral matter.

Videos:
Spanish (http://www.youtube.com/watch?v=hN_xBspEjAw)
English (http://www.youtube.com/watch?v=hj_WKgnL6MI&list=LPIqE-v2NfJNc&index=1&feature=plcp)

# 3. STAGES OF THE OXYGENIC PHOTOSYNTHESIS

## 3.2 LIGHT INDEPENDENT REACTIONS

### *3.2.1. $CO_2$ fixation Calvin cycle*

- Photosynthetic binding of $CO_2$ → metabolic cycle: ***Calvin cycle***.
- In the Calvin cycle, inorganic carbon dioxide integrate into simple organic molecules to create biochemical compoundsin charge of biulding living organisms.
- It is a very complex process, so we will be looking at it in a very generic way:

  **1)** At first, $CO_2$ molecule will be fixed into a receptor molecule, producing **ribulose-1,5-bisphosphate** (RuBP) and 2 molecules of phosphoglyceric acid.

  **2)** phosphoglyceric acid will reduce (oxidising ATP and *NADPH-ren) to give glyceraldehyde 3-phosphate (also called triose phosphate).*

  **3) Part of this triose phosphate** will be used to regenerate RuBP using ATP and part will be used to obtain other different biomolecules.

# 3. STAGES OF THE OXYGENIC PHOTOSYNTHESIS

## 3.2 LIGHT INDEPENDENT REACTIONS

### *3.2.2. Nitrogen and Sulphur fixation*

**Carbon is not the only element fixed into** photosynthetic organisms. For instance, ***Nitrogen and Sulphur are also bonded to obtain biomolecules (i.e. aminoacids).***

These elements enter the system as nitrates and sulphates that can be found in soils.

Nitrates are reduced to nitrites and, at the end, to ammonia thanks to the reduction capabilities of the NADPH from light reactions.

Simmilarly, *sulphates get reduced to sulphites and, finally, to hydrogen sulphide that will end up asimmilated into aminoacids.*

# 3. STAGES OF THE OXYGENIC PHOTOSYNTHESIS

## 3.3 FACTORS THAT CAN INFLUENCE PHOTOSYNTHESIS

**Some environmental factos can have a big influence on photosynthetic intensity,** in orther words the speed to obtain organic matter from inorganic matter throught photosynthesis.

### *3.3.1. $CO_2$ concentration*

**Suposing constant lightning, <u>photosynthetic intensity will increase as carbon dioxide concentration increases.</u>** The hight the [$CO_2$] the fast will RuBP ficated the carbon throught the Calvin cycle.

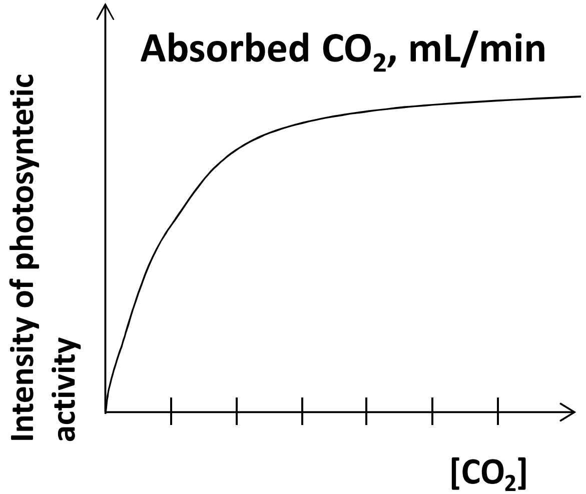


**Figure 7.** Changes in photosynthetic intensity with $CO_2$ concentration.

# 3. STAGES OF THE OXYGENIC PHOTOSYNTHESIS

## 3.3 FACTORS THAT CAN INFLUENCE PHOTOSYNTHESIS

### *3.3.2. Light intensity*

Over all, ***light intensity increases*** **Photosynthetic yield.**

**The more light-photons** arriving into PS I and II, **the more ATP and NADPH will be obatined from the light reactions** and **more $CO_2$ will be bonded during thelight independent reactions.**

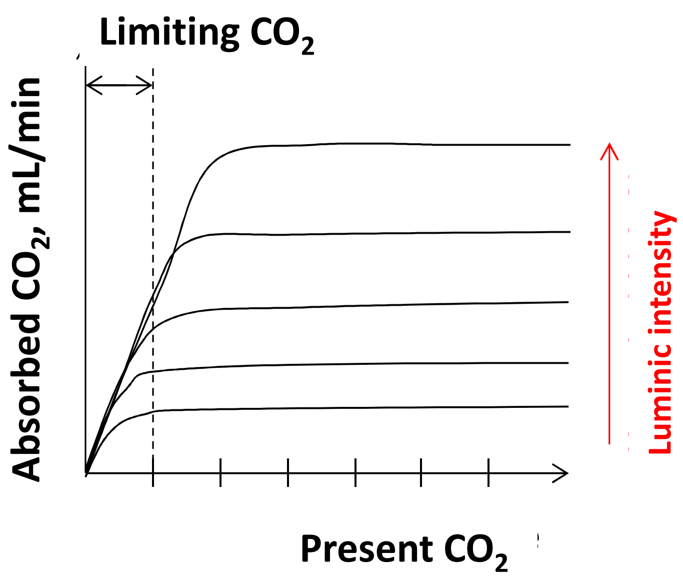


**Figure 8.** Correlation of absorbed $CO_2$ and light intensity.

# 3. STAGES OF THE OXYGENIC PHOTOSYNTHESIS

## 3.3 FACTORS THAT CAN INFLUENCE PHOTOSYNTHESIS

### *3.3.2. Light intensity*

- **If the light intentsity is too high**, it is possible that enzymes that take part in the process will **denaturalize or degrade.** If this happens, photosynthetic intentsity will lower.
- **If $CO_2$ concentration is too low, light intensity will have no effect on photosynthetic intensity.** (it does not matter how much ATP and NADPH is produced during the light reactions if there is not enough $CO_2$ to bond during the light-independent phase).
- If **$CO_2$ concentration is over certain level, light intentsity will be a limiting factor for the phoptosynthetic process.**

# 3. STAGES OF THE OXYGENIC PHOTOSYNTHESIS

## 3.3 FACTORS THAT CAN INFLUENCE PHOTOSYNTHESIS

### *3.3.3. Oxygen concentration*

- **$O_2$** is an hindrance in the photosynthetc process (it inhibits the reaction): the higher the $O_2$ concentration the lower the photosynthetic intensity.

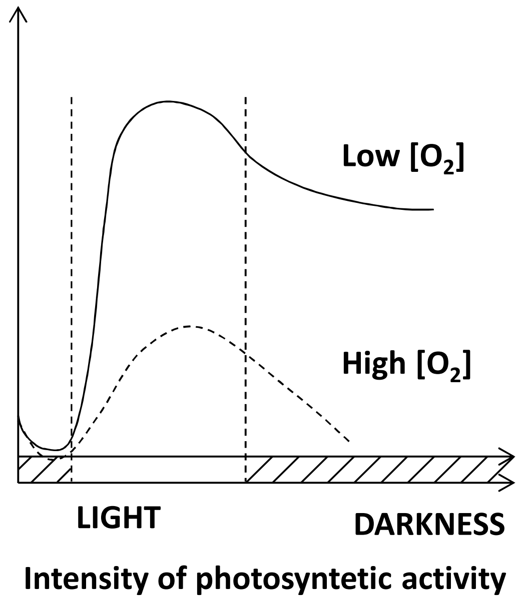


**Figure 9.** $O_2$ concentration vs. lhotosynthetic intensity

### *3.3.4. Temperature*

- Light reactions are temperature independent.
- In light-independent reactions, the reaction speed will increase with temperature (as far as it does not degrade the intervening enzymes).

## CHAPTER 1 – QUESTIONS

- Which process is necessary to obtain organic matter?
- Differences between oxygenic and anoxygenic photosynthesis
- Main contribution of the oxygenic photosynthesis
- What does it mean heterotrophe ? And autotrophe?
- Detailed reaction for OXYGENIC photosynthesis
- Function of photosyntehtic pigments. How de they capture light energy?
- Draw an schematic for Non-Cyclic Phosphorilation.
- Say what is the aim of the light-independent reactions and which factor can affect (influence) the process.
- Say how carbon dioxide concentration and light intensity affect photosynthesis intensity.