Topic 2.9 Photosynthesis

Essential idea: Photosynthesis uses the energy in sunlight to produce the chemical energy needed for life.

Understandings:

- 2.9.U1 Photosynthesis is the production of carbon compounds in cells using light energy.
- 2.9.U2 Visible light has a range of wavelengths with violet the shortest wavelength and red the longest.
- 2.9.U3 Chlorophyll absorbs red and blue light most effectively and reflects green light more than other colours.
- 2.9.U4 Oxygen is produced in photosynthesis from the photolysis of water.
- 2.9.U5 Energy is needed to produce carbohydrates and other carbon compounds from carbon dioxide.
- 2.9.U6 Temperature, light intensity and carbon dioxide concentration are possible limiting factors on the rate of photosynthesis.

Applications:

- 2.9.A1 Changes to the Earth's atmosphere, oceans and rock deposition due to photosynthesis.

Skills:

- 2.9.S1 Drawing an absorption spectrum for chlorophyll and an action spectrum for photosynthesis.
- 2.9.S2 Design of experiments to investigate the effect of limiting factors on photosynthesis.
- 2.9.S3 Separation of photosynthetic pigments by chromatograph. (Practical 4)

I. What is Photosynthesis?

A. Photosynthesis is the production of carbon compounds in cells using light energy-

1. Photosynthesis is a metabolic pathway. Carbon dioxide and along with water is used to produce carbohydrates. Oxygen is released as a waste gas.

$6\,CO_2$

Carbon is 'fixed' from carbon dioxide and used to produce to glucose.

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I. What is Photosynthesis?

$6CO_2 + 6H_2O$

Water is split: the hydrogen is used to help in the production of glucose, but the oxygen is excreted as a waste gas.

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I. What is Photosynthesis?

$6CO_2 + 6H_2O \xrightarrow{\text{sunlight}} C_6H_{12}O_6 + 6O_2$

Light energy is transferred to chemical energy stored in the glucose molecule through enzymes

Glucose is used in cellular respiration, stored as starch, or used to cell walls with cellulose

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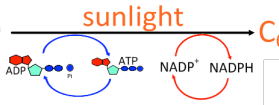
I. What is Photosynthesis?

$6CO_2 + 6H_2O \xrightarrow{\text{sunlight}} C_6H_{12}O_6 + 6O_2$



ATP and electron carriers also play a vital role in the formation of glucose

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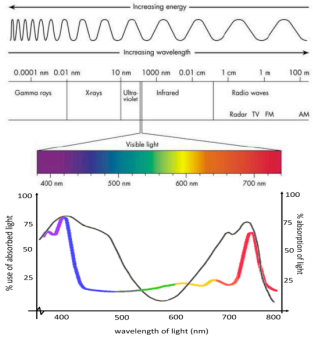
II. Wavelengths of Light

A. Visible light has a range of wavelengths with violet the shortest wavelength and red the longest-



Review:

- *All radiation has a frequency and a wavelength.*
- *High frequency radiation has many waves per unit time (x-rays and gamma rays) and are harmful because they can pass through living tissue and cause cell and DNA damage.*
- *Low frequency radiation does not carry enough energy for living organisms to perform work.*
- *Visible light makes up a small part of the electromagnetic spectrum, but some frequencies can be absorbed to do work.*

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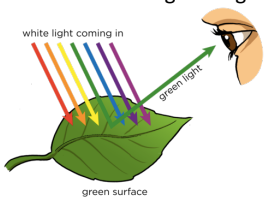
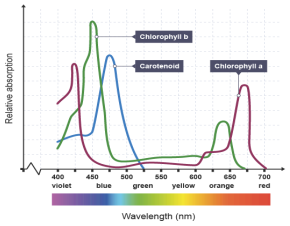
III. Light absorption by chlorophyll

A. Chlorophyll absorbs red and blue light most effectively and reflects green light more than other colors-



- *White light (visible light) contains all the colors.*
- *Plants contain green pigment called chlorophyll that mainly absorbs blue and red light, but also some other colors.*



- *Green light is not absorbed and either reflected or transmitted.*
- *Not all plants are the same color green, and use different pigments to absorb different wavelengths of light.*

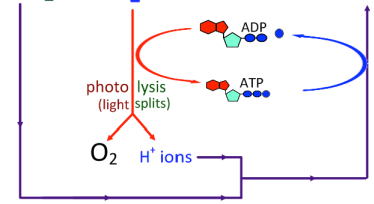
quizizz.com; umich.edu; bbc.co.uk

IV. Oxygen production in photosynthesis

A. Oxygen is produced in photosynthesis from photolysis of water-

1. One use of the energy absorbed by pigments in photosynthesis is photolysis (splitting of water molecules).

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



Most of the oxygen is excreted as a waste product.

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V. Effects of photosynthesis on the Earth

A. Changes to the Earth's atmosphere, oceans and rock deposition due to photosynthesis.

Primordial Earth had a reducing atmosphere that contained very low levels of oxygen gas, about 2%.

Cyanobacteria (prokaryotes) containing chlorophyll first performed photosynthesis about 2.5 billion years ago.

Oxygen levels remained at 2% until about 750 million years ago (mya). From 750 mya until the now there has been a significant rise to 20%.

Oxygen in the atmosphere lead to the production of oxidized compounds. Insoluble iron oxides were formed in the ocean and laid down in sediments and produced rocks with layers rich in iron ore called the banded iron formations.

Oxygen generation also allowed the formation of an ozone layer (O_3). Ozone shielded the Earth from damaging levels of UV radiation. This, in turn, lead to the evolution of a wider range of organisms.

NASA images by Reto Stöckli

VI. Production of carbohydrates

A. Energy is needed to produce carbohydrates and other carbon compounds from carbon dioxide-

1. Plants convert CO_2 and water to carbohydrates through:
   a. Light dependent reactions that use light energy to produce ATP, and protons and electrons through photolysis needed for electron carriers.
   b. Light independent reactions that use ATP, protons and electrons to fix CO_2 into glucose.

Photosynthesis is an endothermic reaction due to energy needing to be absorbed from the environment.

Glucose can be used by cell respiration or stored as starch.

Larger molecules tend to contains more bonds than smaller ones. Therefore more ATP is required to build the bonds and generate larger molecules. Consequently large molecules can act as energy storage.

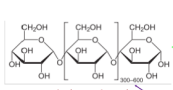
VI. Production of carbohydrates

Starch and cellulose are polysaccharide molecules found in plants.
Starch is a chemical store of energy. Cellulose builds up the plant cell wall.

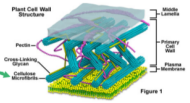
Revision:
What is the process through which monosaccharides are combined to make carbohydrates?

$C_6H_{12}O_6$ + $C_6H_{12}O_6$ + ... ⟶ $(C_6H_{10}O_5)_n$

glucose glucose polysaccharide (repeating units)



Starch (amylose) (repeating units)



Cell walls (cellulose)

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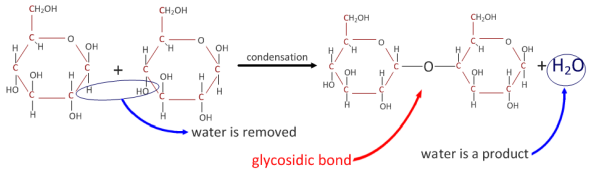
glucose glucose polysaccharide (repeating units)

It's condensation!



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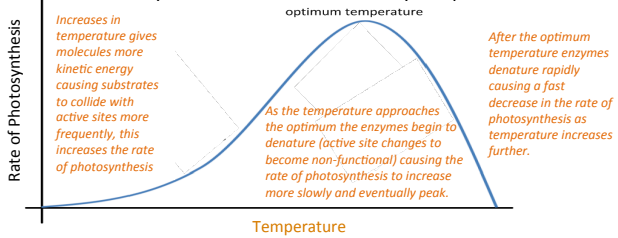
VII. Limiting factors

A. Temperature, light intensity and carbon dioxide concentration are possible limiting factors on the rate of photosynthesis-

1. Temperature can affect the rate of photosynthesis since it is a metabolic pathway hence the relationship is similar to how enzyme reactions are affected by temperature.



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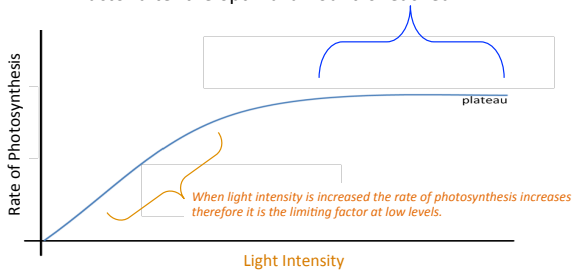
VII. Limiting factors

2. Light intensity can affect photosynthesis at low levels due to low chlorophyll activity. At high levels of light intensity further increases have no effect on the rate of photosynthesis. Therefore light intensity is not a limiting factor after the optimal amount is reached.



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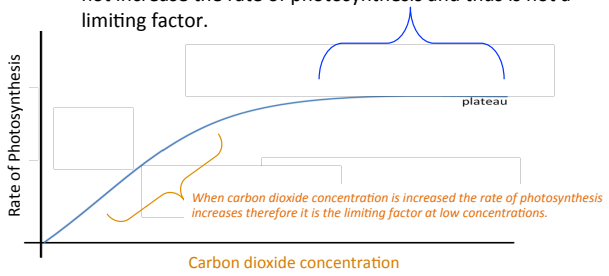
VII. Limiting factors

3. Carbon dioxide is a substrate for the metabolic pathway hence the relationship is similar to how enzyme reactions are limited by substrate concentration. After the optimal concentration is reached, increases in carbon dioxide do not increase the rate of photosynthesis and thus is not a limiting factor.



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