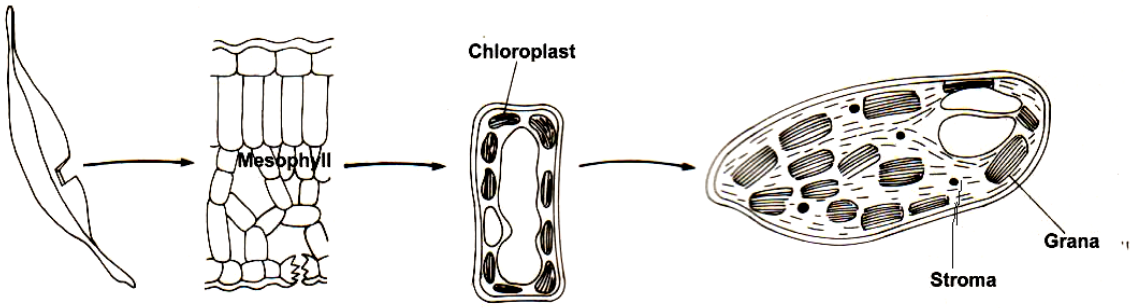
PHOTOSYNTHESIS AND RESPIRATION

Photosynthesis

Photosynthesis is not just a simple reaction occurring in the presence of light but a process involving a number of complex biochemical reactions.

The reaction occurs near the upper surface of the leaf in specialised photosynthetic cells (mesophyll) containing a high number of chloroplasts. Chloroplasts have two distinct regions; the grana where chlorophyll is found and the stroma.

This can be summarised by:



The process can be subdivided into a light-dependent stage, occurring in the grana (chlorophyll is required) and a light-independent stage occurring in the stroma. The appropriate enzymes for each stage are found in each section of the chloroplast.

The light dependent reaction does the following:

- "Splits" the water molecule.
- Adds hydrogen atoms to the coenzyme $NADP^+$ to convert it into NADPH which, is used in the next stage.
- Produces ATP molecules which are also used in the next stage.

A summary of this stage can be represented by the equation:

$$12H_2O + 12NADP^+ + 18ADP + 18P_i \rightarrow 6O_2 + 12NADPH + 12H^+ + 18ATP$$

The light-independent stage does the following:

- Carbon dioxide is converted into glucose.

  This is also known as carbon dioxide fixation.
- The ATP produced in the previous stage provides energy for the reaction.
- The NADPH molecules from the previous stage provide the hydrogen atoms for the glucose.

A summary of this stage can be represented by:

$$12NADPH + 12H^+ + 18ATP + 6CO_2 \rightarrow C_6H_{12}O_6 + 12NADP^+ + 18ADP + 18P_i + 6H_2O$$

**P_i=Inorganic phosphate which is part of the ATP molecule.*

Cancelling the common items on opposite sides of each equation can summarise the overall process and we come up with:

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

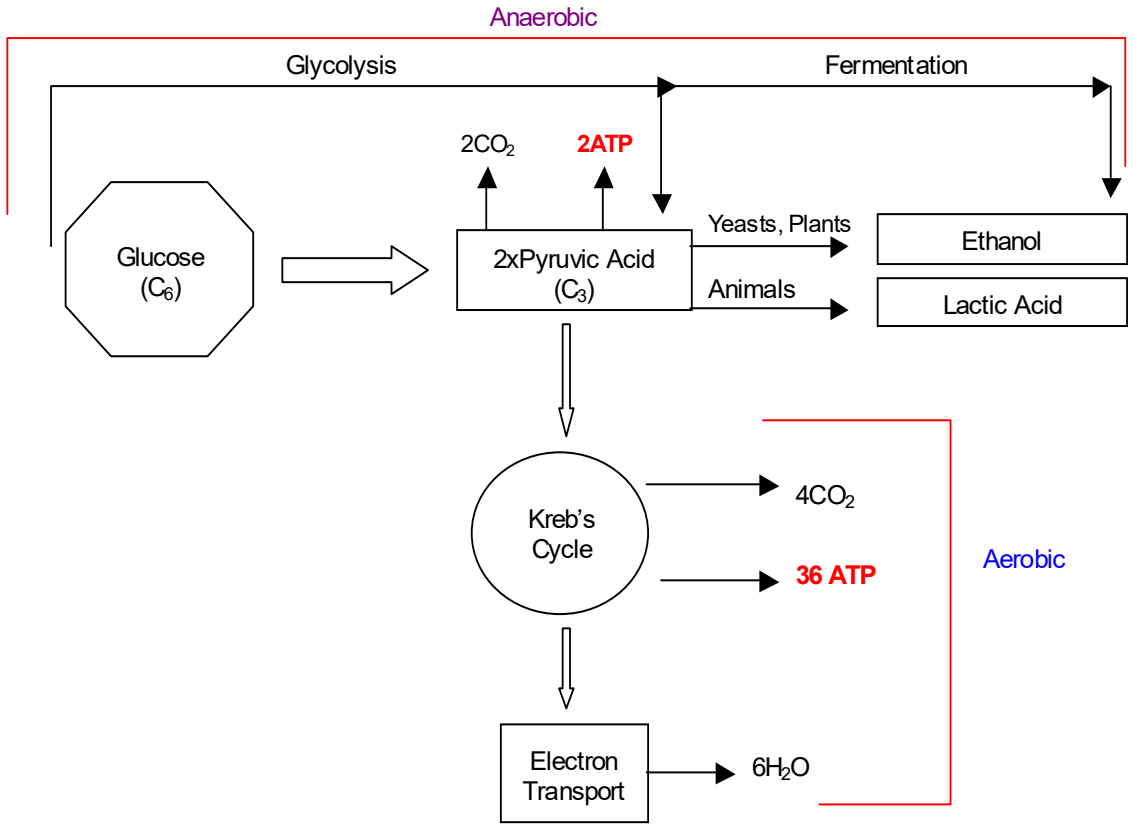
In the process described above, glucose is formed in the light-independent stage by the joining together of 2 intermediate substances containing 3 carbons. Plants using this process are called C3 plants. On dry, hot days these plants may run into problems because they have to close their stomata in order to prevent excessive water loss but, the amount of carbon dioxide runs low as it can't diffuse into the leaves with the stomata closed.

In tropical areas, a number of plants use a different intermediate substance to make glucose, a four-carbon compound (oxaloacetate). A different enzyme is involved in glucose synthesis and this allows the final stage of the reaction to occur even at low CO_2 concentration. Stomata can remain closed to prevent loss of water. These plants are known as C4 plants.

A third category of plants known as CAM plants (CAM=crassulacean acid metabolism). These plants need to keep their stomata closed during the day or they would dehydrate. The CAM strategy is to keep the stomata closed also at night and trap the carbon dioxide produced by aerobic respiration, which is used to make glucose. It may not be enough for normal functioning but it keeps the plant alive.

CELLULAR RESPIRATION

As for photosynthesis, cellular respiration is a process involving a series of complex biochemical reactions and a number of enzymes. The picture below summarises the process of cellular respiration:



GLYCOLYSIS

This occurs in the cytoplasm of cells, without oxygen but only produces 2 ATP molecules per molecule of glucose reacted. If anaerobic conditions persist, fermentation occurs, where pyruvic acid is converted into lactic acid in mammals or ethanol in plants or fungi.

KREB'S CYCLE

In the presence of oxygen inside mitochondria, pyruvic acid enters the cycle and undergoes a series of reactions resulting in the production of a considerable number of ATP molecules and carbon dioxide.

ELECTRON TRANSPORT

This completes the process and produces water.

The overall respiration process can be summarised as:

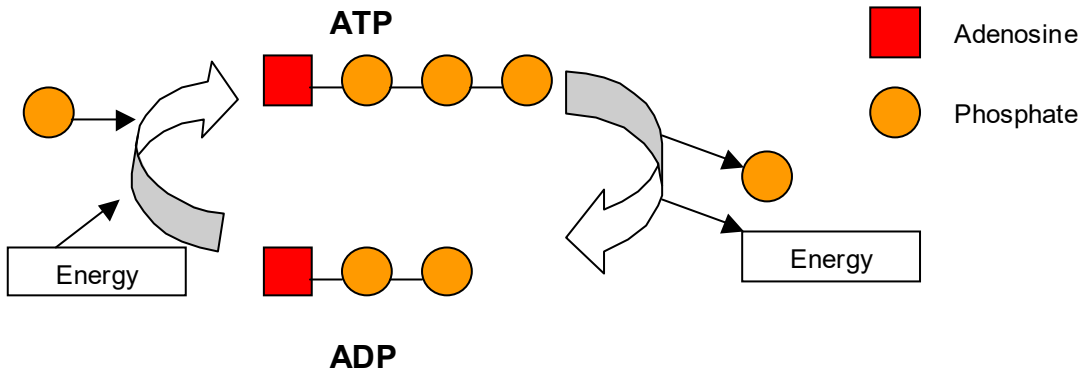
$$C_6H_{12}O_6 + 6O_2 \rightarrow 6H_2O + 6CO_2 + 36ATP$$

In chemical terms, 1 mole of glucose (i.e.: 180g) produces 2880 Kj of energy.

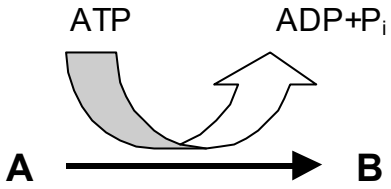
ADP/ATP CYCLE

Adenosine triphosphate (ATP) is a molecule which has energy stored in its chemical bonds. When a phosphate group breaks off, energy is released and when a phosphate group is added to adenosine diphosphate (ADP), energy is absorbed.

The cycle can be shown as:



ATP can be utilised to provide energy for a number of reactions. For example; for A to be converted into B, energy is required. The reaction can be written as follows:



The breakdown of ATP into ADP provides the energy required for the reaction.